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HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

UTILITY PATENT APPLICATION TRANSMITTAL *(Only for new nonprovisional applications under 37 CFR 1.53(b))*	Attorney Docket No.	3274.1003-004
	First Named Inventor	Melanie Holmes
	Express Mail Label No.	

Title of Invention	OPTICAL PROCESSING

Name of Assignee for Publication Purposes	Thomas Swan & Co. Ltd.	City and State for Publication Purposes	United Kingdom

APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: **Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450**

1. ☐ Fee Transmittal Form
2. ☒ Specification **Total Pages 104**
   Both the claims and the abstract must start on a new page
   (For information on the preferred arrangement, see MPEP 608.01(a))
3. ☒ Drawing(s) (35 U.S.C. 113) **Total Sheets 36**
   ☐ Fig. of the Drawings for Publication [ ]
   ☒ No Figure to be Published
4. ☐ Oath or Declaration **Total Pages [ ]**
   a. ☐ Newly executed (original or copy)
   b. ☐ Copy from a prior application (37 C.F.R. 1.63(d))
   (for continuation/divisional with Box 18 completed)
   i. ☐ DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. ☐ CD-ROM or CD-R in duplicate ☐ Text file attached herewith
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6. ☐ Nucleotide and/or Amino Acid Sequence Submission (if applicable, items a.-c. are required)
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   c. ☐ Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. ☐ Assignment Papers *(Do not submit when e-filing application)*
8. ☐ 37 CFR 3.73(b) Statement ☐ Power of Attorney
   (when there is an assignee)
9. ☐ English Translation Document *(if applicable)*
10. ☒ Information Disclosure Statement
    (Listing of References *(formerly PTO-1449)*)
    ☐ Copies of foreign patent docs., publications, and other info.
11. ☐ Preliminary Amendment
12. ☐ Return Receipt Postcard *(Check this box if going by express mail)*
13a. ☐ A Foreign Priority Claim under 35 U.S.C. § 119 or 365
    i. ☐ is made to [country], [app. #], filed [ ]
    ii. ☐ is presented in the attached
    ☐ Specification ☐ Preliminary Amendment
    ☐ Separate Sheet ☐ Declaration
13b. ☐ A Certified Copy of each Priority Document
    i. ☐ is enclosed
    ii. ☐ was filed in U.S. Application No. [ ]
14. ☐ Nonpublication Request under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
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16. ☐ Small Entity Statement(s)
17. ☐ Other: ______

18. **If a CONTINUING APPLICATION,** check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title:
☒ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: 11/978,258
Prior application information: Examiner: Loha Ben Group Art Unit: 2873
The entire disclosure of the prior application is considered a part of the disclosure of the accompanying application and is hereby incorporated by reference. ***(Add standard Related Applications section with incorporation by reference to specification or update same)***

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PATENT APPLICATION
Attorney's Docket No.: 3274.1003-004

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Melanie Holmes

Continuation Application of:

Application No.: 11/978,258

Filed: October 29, 2007

For: OPTICAL PROCESSING

Date: ____________________
EXPRESS MAIL LABEL NO. ____________________

REMARKS

Commissioner for Patents
P.O. Box 1450
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Sir:

The above-captioned application is a Continuation of application number 11/978,258 filed on October 29, 2007 to which priority is claimed under 35 U.S.C. § 120.

The specification of the present application is substantially the same as that of the parent application. The related applications paragraph has been revised to include a specific reference to the parent application.

All of the claims from the parent application have been omitted. A new claim set is being presented herein for examination.

Respectfully submitted,

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Attorney's Docket No.: 3274.1003-004

OPTICAL PROCESSING

RELATED APPLICATIONS

This application is a continuation of U.S. Application No. 11/978,258, filed October 29, 2007, which is a continuation of U.S. Application No. 11/515,389, filed September 1, 2006, which is a divisional of U.S. Application No. 10/487,810, which is the U.S. National Stage of International Application No. PCT/GB02/04011, filed September 2, 2002, and published in English. This application claims priority under 35 U.S.C. § 119 or 365 to Great Britain Application No. 0121308.1, filed September 3, 2001. The entire teachings of the above application(s) are incorporated herein by reference.

FIELD OF THE INVENTION

[0001] The present invention relates to an optical device and to a method of controlling an optical device.

[0002] More particularly but not exclusively the invention relates to the general field of controlling one or more light beams by the use of electronically controlled devices. The field of application is mainly envisaged as being to fields in which reconfiguration between inputs and outputs is likely, and stability of performance is a significant requirement.

BACKGROUND OF THE INVENTION

[0003] It has previously been proposed to use so-called spatial light modulators to control the routing of light beams within an optical system, for instance from selected ones of a number of input optical fibres to selected ones of output fibres.

[0004] Optical systems are subject to performance impairments resulting from aberrations, phase distortions and component misalignment. An example is a multiway fibre connector, which although conceptually simple can often be a critical source of system failure or insertion loss due to the very tight alignment tolerances for optical fibres, especially for single-mode optical fibres. Every time a fibre connector is connected, it may provide a different alignment error. Another example is an optical switch in which aberrations, phase distortions and component misalignments result in poor optical coupling efficiency into the intended output optical fibres. This in turn may lead to high insertion loss. The aberrated propagating waves may diffract into intensity fluctuations creating significant unwanted coupling of light into other output optical fibres, leading to levels of crosstalk that impede operation. In some cases, particularly where long path lengths are involved, the component misalignment may occur due to ageing or temperature effects.

[0005] Some prior systems seek to meet such problems by use of expensive components. For example in a communications context, known free-space wavelength multiplexers and demultiplexers use expensive thermally stable opto-mechanics to cope with the problems associated with long path lengths.

[0006] Certain optical systems have a requirement for reconfigurability. Such reconfigurable systems include optical switches, add/drop multiplexers and other optical routing systems where the mapping of signals from input ports to output ports is dynamic. In such systems the path-dependent losses, aberrations and phase distortions encountered by optical beams may vary from beam to beam according to the route taken by the beam through the system. Therefore the path-dependent loss, aberrations and phase distortions may vary for each input beam or as a function of the required output port.

[0007] The prior art does not adequately address this situation.

[0008] Other optical systems are static in terms of input/output configuration. In such systems, effects such as assembly errors, manufacturing tolerances in the optics and also changes in the system behaviour due to temperature and ageing, create the desirability for dynamic direction control, aberration correction, phase distortion compensation or misalignment compensation.

[0009] It should be noted that the features of dynamic direction control, phase distortion compensation and misalignment control are not restricted to systems using input beams coming from optical fibres. Such features may also be advantageous in a reconfigurable optical system. Another static system in which dynamic control of phase distortion, direction and (relative) misalignment would be advantageous is one in which the quality and/or position of the input beams is time-varying.

[0010] Often the input and output beams for optical systems contain a multiplex of many optical signals at different wavelengths, and these signals may need to be separated and adaptively and individually processed inside the system. Sometimes, although the net aim of a system is not to separate optical signals according to their wavelength and then treat them separately, to do so increases the wavelength range of the system as a whole. Where this separation is effected, it is often advantageous for the device used to route each channel to have a low insertion loss and to operate quickly.

[0011] It is an aim of some aspects of the present invention at least partly to mitigate difficulties of the prior art.

[0012] It is desirable for certain applications that a method or device for addressing these issues should be polarisation-independent, or have low polarisation-dependence.

[0013] SLMs have been proposed for use as adaptive optical components in the field of astronomical devices, for example as wavefront correctors. In this field of activity, the constraints are different to the present field-for example in communication and like devices, the need for consistent performance is paramount if data is to be passed without errors. Communication and like devices are desirably inexpensive, and desirably inhabit and successfully operate in environments that are not closely controlled. By contrast, astronomical devices may be used in conditions more akin to laboratory conditions, and cost constraints are less pressing. Astronomical devices are unlikely to need to select successive routings of light within a system, and variations in performance may be acceptable.

SUMMARY OF THE INVENTION

[0014] According to a first aspect of the invention, there is provided a method of operating an optical device comprising an SLM having a two-dimensional array of controllable phase-modulating elements, the method comprising

[0015] delineating groups of individual phase-modulating elements;

[0016] selecting, from stored control data, control data for each group of phase-modulating elements;

[0017] generating from the respective selected control data a respective hologram at each group of phase-modulating elements; and

[0018] varying the delineation of the groups and/or the selection of control data whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

[0019] In some embodiments, the variation of the delineation and/or control data selection is in response to a signal or signals indicating a non-optimal performance of the device. In other embodiments, the variation is performed during a set up or training phase of the device. In yet other embodiments, the variation is in response to an operating signal, for example a signal giving the result of sensing non-performance system parameters such as temperature.

[0020] An advantage of the method of this aspect of the invention is that stable operation can be achieved in the presence of effects such as ageing, temperature, component, change of path through the system and assembly tolerances.

[0021] Preferably, control of said light beams is selected from the group comprising: control of direction, control of power, focussing, aberration compensation, sampling and beam shaping.

[0022] Clearly in most situations more than one of these control types will be needed-for example in a routing device (such as a switch, filter or add/drop multiplexer) primary changes of direction are likely to be needed to cope with changes of routing as part of the main system but secondary correction will be needed to cope with effects such as temperature and ageing. Additionally such systems may also need to control power, and to allow sampling (both of which may in some cases be achieved by direction changes).

[0023] Advantageously, each phase modulating element is responsive to a respective applied voltage to provide a corresponding phase shift to emergent light, and the method further comprises;

[0024] controlling said phase-modulating elements of the spatial light modulator to provide respective actual holograms derived from the respective generated holograms, wherein the controlling step comprises;

[0025] resolving the respective generated holograms modulo 2pi.

[0026] The preferred SLM uses a liquid crystal material to provide phase shift and the liquid crystal material is not capable of large phase shifts beyond plus or minus 2π. Some liquid crystal materials can only provide a smaller range of phase shifts, and if such materials are used, the resolution of the generated hologram is correspondingly smaller.

[0027] Preferably the method comprises:

[0028] providing a discrete number of voltages available for application to each phase modulating element;

[0029] on the basis of the respective generated holograms, determining the desired level of phase modulation at a predetermined point on each phase modulating element and choosing for each phase modulating element the available voltage which corresponds most closely to the desired level.

[0030] Where a digital control device is used, the resolution of the digital signal does not provide a continuous spectrum of available voltages. One way of coping with this is to determine the desired modulation for each pixel and to choose the individual voltage which will provide the closest modulation to the desired level.

[0031] In another embodiment, the method comprises:

[0032] providing a discrete number of voltages available for application to each phase modulating element;

[0033] determining a subset of the available voltages which provides the best fit to the generated hologram.

[0034] Another technique is to look at the pixels of the group as a whole and to select from the available voltages those that give rise to the nearest phase modulation across the whole group.

[0035] Advantageously, the method further comprises the step of storing said control data wherein the step of storing said control data comprises calculating an initial hologram using a desired direction change of a beam of light, applying said initial hologram to a group of phase modulating elements, and correcting the initial hologram to obtain an improved result.

[0036] The method may further comprise the step of providing sensors for detecting temperature change, and performing said varying step in response to the outputs of those sensors.

[0037] The SLM may be integrated on a substrate and have an integral quarter-wave plate whereby it is substantially polarisation insensitive.

[0038] Preferably the phase-modulating elements are substantially reflective, whereby emergent beams are deflected from the specular reflection direction.

[0039] In some aspects, for at least one said group of pixels, the method comprises providing control data indicative of two holograms to be displayed by said group and generating a combined hologram before said resolving step.

[0040] According to a second aspect of the invention there is provided an optical device comprising an SLM and a control circuit, the SLM having a two-dimensional array of controllable phase-modulating elements and the control circuit having a store constructed and arranged to hold plural items of control data, the control circuit being constructed and arranged to delineate groups of individual phase-modulating elements, to select, from stored control data, control data for each group of phase-modulating elements, and to generate from the respective selected control data a respective hologram at each group of phase-modulating elements,

[0041] wherein the control circuit is further constructed and arranged, to vary the delineation of the groups and/or the selection of control data

[0042] whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

[0043] An advantage of the device of this aspect of the invention is that stable operation can be achieved in the presence of effects such as ageing, temperature, component and assembly tolerances. Embodiments of the device can handle many light beams simultaneously. Embodiments can be wholly reconfigurable, for example compensating differently for a number of routing configurations.

[0044] Preferably, the optical device has sensor devices arranged to detect light emergent from the SLM, the control circuit being responsive to signals from the sensors to vary said delineation and/or said selection.

[0045] In some embodiments, the optical device has temperature responsive devices constructed and arranged to feed signals indicative of device temperature to said control circuit, whereby said delineation and/or selection is varied.

[0046] In another aspect, the invention provides an optical routing device having at least first and second SLMs and a control circuit, the first SLM being disposed to receive respective light beams from an input fibre array, and the second SLM being disposed to receive emergent light from the first SLM and to provide light to an output fibre array, the first and second SLMs each having a respective two-dimensional array of controllable phase-modulating elements and the control circuit having a store constructed and arranged to hold plural items of control data, the control circuit being constructed and arranged to delineate groups of individual phase-modulating elements, to select, from stored control data, control data for each group of phase-modulating elements, and to generate from the respective selected control data a respective hologram at each group of phase-modulating elements,

[0047] wherein the control circuit is further constructed and arranged, to vary the delineation of the groups and/or the selection of control data

[0048] whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

[0049] In a further aspect, the invention provides a device for shaping one or more light beams in which the or each light beam is incident upon a respective group of pixels of a two-dimensional SLM, and the pixels of the or each respective group are controlled so that the corresponding beams emerging from the SLM are shaped as required.

[0050] According to a further aspect of the invention there is provided an optical device comprising one or more optical inputs at respective locations, a diffraction grating constructed and arranged to receive light from the or each optical input, a focussing device and a continuous array of phase modulating elements, the diffraction grating and the array of phase modulating elements being disposed in the focal plane of the focussing device whereby diverging light from a single point on the diffraction grating passes via the focussing device to form beams at the array of phase modulating elements, the device further comprising one or more optical output at respective locations spatially separate from the or each optical input, whereby the diffraction grating is constructed and arranged to output light to the or each optical output.

[0051] This device allows multiwavelength input light to be distributed in wavelength terms across different groups of phase-modulating elements. This allows different processing effects to be applied to any desired part or parts of the spectrum.

[0052] According to a still further aspect of the invention there is provided a method of filtering light comprising applying a beam of said light to a diffraction grating whereby emerging light from the grating is angularly dispersed by wavelength, forming respective beams from said emerging light by passing the emerging light to a focussing device having the grating at its focal plane, passing the respective beams to an SLM at the focal plane of the focussing device, the SLM having a two-dimensional array of controllable phase-modulating elements, selectively reflecting light from different locations of said SLM and passing said reflected light to said focussing element and then to said grating.

[0053] Preferably the method comprises delineating groups of individual phase-modulating elements to receive beams of light of differing wavelength;

[0054] selecting, from stored control data, control data for each group of phase-modulating elements;

[0055] generating from the respective selected control data a respective hologram at each group of phase-modulating elements; and

[0056] varying the delineation of the groups and/or the selection of control data.

[0057] According to a still further aspect of the invention there is provided an optical add/drop multiplexer having a reflective SLM having a two-dimensional array of controllable phase-modulating elements, a diffraction device and a focussing device wherein light beams from a common point on the diffraction device are mutually parallel when incident upon the SLM, and wherein the SLM displays respective holograms at locations of incidence of light to provide emergent beams whose direction deviates from the direction of specular reflection.

[0058] In a yet further aspect, the invention provides a test or monitoring device comprising an SLM having a two-dimensional array of pixels, and operable to cause incident light to emerge in a direction deviating from the specular direction, the device having light sensors at predetermined locations arranged to provide signals indicative of said emerging light.

[0059] The test or monitoring device may further comprise further sensors arranged to provide signals indicative of light emerging in the specular directions.

[0060] Yet a further aspect of the invention relates to a power control device for one or more beams of lights in which the said beams are incident on respective groups of pixels of a two-dimensional SLM, and holograms are applied to the respective group so that the emergent beams have power reduced by comparison to the respective incident beams.

[0061] The invention further relates to an optical routing module having at least one input and at least two outputs and operable to select between the outputs, the module comprising a two dimensional SLM having an array of pixels, with circuitry constructed and arranged to display holograms on the pixels to route beams of different frequency to respective outputs.

[0062] According to a later aspect of the invention there is provided an optoelectronic device comprising an integrated multiple phase spatial light modulator (SLM) having a plurality of pixels, wherein each pixel can phase modulate light by a phase shift having an upper and a lower limit, and wherein each pixel has an input and is responsive to a value at said input to provide a phase modulation determined by said value, and a controller for the SLM, wherein the controller has a control input receiving data indicative of a desired phase modulation characteristic across an array of said pixels for achieving a desired control of light incident on said array, the controller has outputs to each pixel, each output being capable of assuming only a discrete number of possible values, and the controller comprises a processor constructed and arranged to derive, from said desired phase modulation characteristic, a non-monotonic phase modulation not extending outside said upper and lower limits, and a switch constructed and arranged to select between the possible values to provide a respective one value at each output whereby the SLM provides said non-monotonic phase modulation.

[0063] Some or all of the circuitry may be on-chip leading to built-in intelligence. This leads to more compact and ultimately low-cost devices. In some embodiments, some or all on-chip circuitry may operate in parallel for each pixel which may provide huge time advantages; in any event the avoidance of the need to transfer data off chip and thereafter to read in to a computer allows configuration and reconfiguration to be faster.

[0064] According to another aspect of the invention there is provided a method of controlling a light beam using a spatial light modulator (SLM) having an array of pixels, the method comprising:

[0065] determining a desired phase modulation characteristic across a sub-array of said pixels for achieving the desired control of said beam;

[0066] controlling said pixels to provide a phase modulation derived from the desired phase modulation, wherein the controlling step comprises

[0067] providing a population of available phase modulation levels for each pixel, said population comprising a discrete number of said phase modulation levels;

[0068] on the basis of the desired phase modulation, a level selecting step of selecting for each pixel a respective one of said phase modulation levels; and

[0069] causing each said pixel to provide the respective one of said phase modulation levels.

[0070] The SLM may be a multiple phase liquid crystal over silicon spatial light modulator having plural pixels, of a type having an integrated wave plate and a reflective element, such that successive passes of a beam through the liquid crystal subject each orthogonally polarised component to a substantially similar electrically-set phase change.

[0071] If a non-integrated wave plate is used instead, a beam after reflection and passage through the external wave plate will not pass through the same zone of the SLM, unless it is following the input path, in which case the zero order component of said beam will re-enter the input fibre.

[0072] The use of the wave plate and the successive pass architecture allows the SLM to be substantially polarisation independent.

[0073] In one embodiment the desired phase modulation at least includes a linear component.

[0074] Linear phase modulation, or an approximation to linear phase modulation may be used to route a beam of light, i.e. to select a new direction of propagation for the beam. In many routing applications, two SLMs are used in series, and the displayed information on the one has the inverse effect to the information displayed on the other. Since the information represents phase change data, it may be regarded as a hologram. Hence an output SLM may display a hologram that is the inverse of that displayed on the input SLM. Routing may also be "one-to-many" (i.e. multicasting) or "one-to-all" (i.e. broadcasting) rather than the more usual one-to-one in many routing devices. This may be achieved by correct selection of the relevant holograms.

[0075] Preferably the linear modulation is resolved modulo 2pi to provide a periodic ramp.

[0076] In another embodiment the desired phase modulation includes a non-linear component.

[0077] Preferably the method further comprises selecting, from said array of pixels, a sub-array of pixels for incidence by said light beam.

[0078] The size of a selected sub-array may vary from switch to switch according to the physical size of the switch and of the pixels. However, a typical routing device may have pixel arrays of between 100*100 and 200*200, and other devices such as add/drop multiplexers may have arrays of between 10*10 and 50*50. Square arrays are not essential.

[0079] In one embodiment the level-selecting step comprises determining the desired level of phase modulation at a predetermined point on each pixel and choosing for each pixel, the available level which corresponds most closely to the desired level.

[0080] In another embodiment, the level-selecting step comprises determining a subset of the available levels, which provides the best fit to the desired characteristic.

[0081] The subset may comprise a subset of possible levels for each pixel.

[0082] Alternatively the subset may comprise a set of level distributions, each having a particular level for each pixel.

[0083] In one embodiment, the causing step includes providing a respective voltage to an electrode of each pixel, wherein said electrode extends across substantially the whole of the pixel.

[0084] Preferably again the level selecting step comprises selecting the level by a modulo 2pi comparison with the desired phase modulation. The actual phase excursion may be from A to $A+2\pi$ where A is an arbitrary angle.

[0085] Preferably the step of determining the desired phase modulation comprises calculating a direction change of a beam of light.

[0086] Conveniently, after the step of calculating a direction change, the step of determining the desired phase modulation further comprises correcting the phase modulation obtained from the calculating step to obtain an improved result.

[0087] Advantageously, the correction step is retroactive.

[0088] In another embodiment the step of determining the desired phase modulation is retroactive, whereby parameters of the phase modulation are varied in response to a sensed error to reduce the error.

[0089] A first class of embodiments relates to the simulation/synthesis of generally corrective elements. In some members of the first class, the method of the invention is performed to provide a device, referred to hereinafter as an accommodation element for altering the focus of the light beam.

[0090] An example of an accommodation element is a lens. An accommodation element may also be an anti-astigmatic device, for instance comprising the superposition of two cylindrical lenses at arbitrary orientations.

[0091] In other members of the first class, the method of the invention is performed to provide an aberration correction device for correcting greater than quadratic aberrations.

[0092] The sub-array selecting step may assign a sub-array of pixels to a beam based on the predicted path of the beam as it approaches the SLM just prior to incidence.

[0093] Advantageously, after the sub-array is assigned using the predicted path, it is determined whether the assignment is correct, and if not a different sub-array is assigned.

[0094] The assignment may need to be varied in the event of temperature, ageing or other physical changes. The sub-array selection is limited in resolution only by the pixel size. By contrast other array devices such as MEMS have fixed physical edges to their beam steering elements.

[0095] An element of this type may be used in a routing device to compensate for aberrations, phase distortions and component misalignment in the system. By providing sensing devices a controller may be used to retroactively control the element and the element may maintain an optimum performance of the system.

[0096] In one embodiment of this first class, the method includes both causing the SLM to route a beam and causing the SLM to emulate a corrective element to correct for errors, whereby the SLM receives a discrete approximation of the combination of both a linear phase modulation applied to it to route the beam and a non-linear phase modulation for said corrections.

[0097] Synthesising a lens using an SLM can be used to change the position of the beam focused spot and therefore correct for a position error or manufacturing tolerance in one or more other lenses or reflective (as opposed to transmissive) optical elements such as a curved mirror.

[0098] The method of the invention may be used to correct for aberrations such as field curvature in which the output 'plane' of the image(s) from an optical system is curved, rather than flat.

[0099] In another embodiment of the first class, intelligence may be integrated with sensors that detect the temperature changes and apply data from a look-up table to apply corrections.

[0100] In yet another embodiment of this class, misalignment and focus errors are detected by measuring the power coupled into strategically placed sensing devices, such as photodiode arrays, monitor fibres or a wavefront sensor. Compensating holograms are formed as a result of the discrete approximations of the non-linear modulation. Changes or adjustments may then be made to these holograms, for example by applying a stimulus and then correcting the holograms according to the sensed response until the system alignment is measured to be optimised.

[0101] In embodiments where the method provides routing functions by approximated linear modulation, adaptation of non-linear modulation due to changes in the path taken through the system desirably takes place on a timescale equivalent to that required to change the hologram routing, i.e. of the order of milliseconds.

[0102] A control algorithm may use one or more of several types of compensation.

[0103] In one embodiment a look-up table is used with pre-calculated 'expected' values of the compensation taking account of the different routes through the system.

[0104] In another embodiment the system is trained before first being operated, by repeated changes of, or adjustments to, the compensating holograms to learn how the system is misaligned.

[0105] A further embodiment employs intelligence attached to the monitor fibres for monitoring and calculation of how these compensating holograms should adapt with time to accommodate changes in the system alignment. This is achieved in some embodiments by integrating circuitry components into the silicon backplane of the SLM.

[0106] In many optical systems there is a need to control and adapt the power or shape of an optical beam as well as its direction or route through the optical system. In communications applications, power control is required for network management reasons. In general, optical systems require the levelling out or compensation for path and wavelength-dependent losses inside the optical system. It is usually desirable that power control should not introduce or accentuate other performance impairments.

[0107] Thus in a second class of embodiments, the modulation applied is modified for controlling the attenuation of an optical channel subjected to the SLM.

[0108] In one particular embodiment, the ideal value of phase modulation is calculated for every pixel, and then multiplied by a coefficient having a value between 0 and 1, selected according to the desired attenuation and the result is compared to the closest available phase level to provide the value applied to the pixels.

[0109] In another embodiment, the method further comprises selecting by a discrete approximation to a linear phase modulation, a routing hologram for display by the SLM whereby the beams may be correctly routed; selecting by a discrete approximation to a non-linear phase modulation, a further hologram for separating each beam into main and subsidiary beams, wherein the main beam is routed through the system and the or each subsidiary beam is diffracted out of the system; combining the routing and further holograms together to provide a resultant hologram; and causing the SLM to provide the resultant hologram.

[0110] The non-linear phase modulation may be oscillatory.

[0111] In yet another embodiment, the method further comprises selecting by a discrete approximation to a linear phase modulation, a routing hologram for display by the SLM whereby the beams may be correctly routed; selecting by a discrete approximation to a non-linear phase modulation, a further hologram for separating each beam into main and subsidiary beams, wherein the main beam is routed through the system and at least one subsidiary beam is incident on an output at an angle such that its contribution is insignificant; combining the routing and further holograms together to provide resultant hologram; and causing the SLM to display the resultant hologram.

[0112] The non-linear phase modulation may be oscillatory.

[0113] In a closely allied class of embodiments, light may be selectively routed to a sensor device for monitoring the light in the system. The technique used may be a power control technique in which light diverted from the beam transmitted through the system to reduce its magnitude is made incident on the sensor device.

[0114] In another class of embodiments, a non-linear phase modulation profile is selected to provide beam shaping, for example so as to reduce cross-talk effects due to width clipping. This may use a pseudo amplitude modulation technique.

[0115] In a further class of embodiments, the method uses a non-linear modulation profile chosen to provide wavelength dependent effects.

[0116] The light may be at a telecommunications wavelength, for example 850 nm, 1300 nm or in the range 1530 nm to 1620 nm.

BRIEF DESCRIPTION OF THE DRAWINGS

[0117] Exemplary embodiments of the invention will now be described with reference to the accompanying drawings in which:

[0118] FIG. 1 shows a cross-sectional view through an exemplary SLM suitable for use in the invention;

[0119] FIG. 2 shows a sketch of a routing device in which a routing SLM is used additionally to provide correction for performance impairment due to misalignment;

[0120] FIG. 3 shows a sketch of a routing device in which a routing SLM is used to route light beams and an additional SLM provides correction for performance impairment due to misalignment;

[0121] FIG. 4 shows a block diagram of an adaptive corrective SLM;

[0122] FIG. 5 shows an adaptive optical system using three SLMs;

[0123] FIG. 6 shows a partial block diagram of a routing device with a dual function SLM and control arrangements;

[0124] FIG. 7 shows a block diagram of an SLM for controlling the power transferred in an optical system;

[0125] FIG. 8a shows a diagram of phase change distribution applied by a hologram for minimum attenuation;

[0126] FIG. 8b shows a diagram of phase change distribution applied by a hologram enabling attenuation of the signal;

[0127] FIG. 9 shows a power control system;

[0128] FIG. 10 shows a phasor diagram showing the effect of non-linear oscillatory phase modulation applied to adjacent pixels;

[0129] FIG. 11 shows a schematic diagram of a part of an optical routing system illustrating the effects of clipping and cross talk;

[0130] FIG. 12 shows a partial block diagram of a system enabling beams of different wavelength from a composite input beam to be separately controlled before recombination; and

[0131] FIG. 13 shows a schematic diagram of an add/drop multiplexer using an SLM.

[0132] FIG. 14 is a diagram similar to FIG. 12 but showing a magnification stage for increasing the effective beam deflection angle;

[0133] FIG. 15 shows a vector diagram of the operation of an add/drop multiplexer;

[0134] FIG. 16 shows a block diagram showing how loop back may be effected;

[0135] FIG. 17 is a vector diagram illustrating the operation of part of FIG. 16;

[0136] FIG. 18 is a vector diagram of a multi-input/multi-output architecture;

[0137] FIG. 19 is a graph showing the relative transmission Tlo for in-band wavelengths as a function of the ratio of the wavelength offset u to centre of the wavelength channel separation;

[0138] FIG. 20 is a graph showing the relative transmission Thi inside adjacent channels;

[0139] FIG. 21 shows a logical diagram of the sorting function;

[0140] FIG. 22 shows a block diagram of an add/drop node using two routing modules;

[0141] FIG. 23 shows a block diagram of modules used to cross-connect two rings;

[0142] FIG. 24 shows a block diagram of routing modules connected to provide expansion;

[0143] FIG. 25 shows a block diagram of an optical cross-connect;

[0144] FIG. 26 shows a block diagram of an upgrades node having a cascaded module at an expansion output port;

[0145] FIG. 27 is a graph showing the effect of finite hologram size of the field of a beam incident on a hologram;

[0146] FIG. 28 shows a schematic layout of a wavelength filter device; and,

[0147] FIG. 29 shows a schematic layout of an add/drop device;

[0148] FIG. 30 shows a block diagram of an optical test set;

[0149] FIG. 31 is a diagram showing the effect of finite hologram size on a beam at a wavelength different to the centre wavelength associated with the hologram;

[0150] FIG. 32 shows the truncated beam shapes for wavelengths at various wavelength differences from the centre of the wavelength channel dropped in isolation;

[0151] FIG. 33 shows the overlap integrands of the beams of FIG. 32 with the fundamental mode of the fibre;

[0152] FIG. 34 shows beam output positions for different wavelengths with respect to two optical fibres; and

[0153] FIG. 35 shows the overlap integrand between the beams of FIG. 34 and the fundamental mode of one of the optical fibres.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0154] Many of the embodiments of the invention centre upon the realisation that the problems of the prior art can be solved by using a reflective SLM having a two-dimensional array of phase-modulating elements that is large in number, and applying a number of light beams to groups of those phase-modulating elements. A significant feature of these embodiments is the fact that the size, shape and position of those groups need not be fixed and can, if need be, be varied. The groups may display holograms which can be set up as required to deflect the light so as to provide a non-specular reflection at a controllable angle to the specular reflection direction. The holograms may additionally or alternatively provide shaping of the beam.

[0155] The SLM may thus simulate a set of highly flexible mirrors, one for each beam of light. The size, shape and position of each mirror can be changed, as can the deflection and the simulated degree of curvature.

[0156] Devices embodying the invention act on light beams incident on the device to provide emerging light beams which are controlled independently of one another. Possible types of control include control of direction, control of power, focussing, aberration compensation, sampling and beam shaping.

[0157] The structure and arrangement of polarisation-independent multiple phase liquid crystal over silicon spatial light modulators (SLMs) for routing light beams using holograms are discussed in our co-pending patent application PCT/GB00/03796. Such devices have an insertion loss penalty due to the dead-space between the pixels. As discussed in our co-pending patent application GB0107742.9, the insertion loss may be reduced significantly by using a reflecting layer inside the substrate positioned so as to reflect the light passing between the pixels back out again.

[0158] Referring to FIG. 1, an integrated SLM 200 for modulating light 201 of a selected wavelength, e.g. 1.5 μm, consists of a pixel electrode array 230 formed of reflective aluminium. The pixel electrode array 230, as will later be described acts as a mirror, and disposed on it is a quarter-wave plate 221. A liquid crystal layer 222 is disposed on the quarter-wave plate 221 via an alignment layer (not shown) as is known to those skilled in the art of liquid crystal structures. Over (as shown) the liquid crystal layer 222 are disposed in order a second alignment layer 223, a common ITO electrode layer 224 and an upper glass layer 225. The common electrode layer 224 defines an electrode plane. The pixel electrode array 230 is disposed parallel to the common electrode plane 224. It will be understood that alignment layers and other intermediate layers will be provided as usual. They are omitted in FIG. 1 for clarity.

[0159] The liquid crystal layer 222 has its material aligned such that under the action of a varying voltage between a pixel electrode 230 and the common electrode 224, the uniaxial axis changes its tilt direction in a plane normal to the electrode plane 224.

[0160] The quarter wave plate 221 is disposed such that light polarised in the plane of tilt of the director is reflected back by the mirror 230 through the SLM with its plane of polarisation perpendicular to the plane of tilt, and vice-versa.

[0161] Circuitry, not shown, connects to the pixel electrodes 230 so that different selected voltages are applied between respective pixel electrodes 230 and the common electrode layer 224.

[0162] Considering an arbitrary light beam 201 passing through a given pixel, to which a determined potential difference is applied, thus resulting in a selected phase modulation due to the liquid crystal layer over the pixel electrode 230. Consider first and second orthogonal polarisation components, of arbitrary amplitudes, having directions in the plane of tilt of the director and perpendicular to this plane, respectively. These directions bisect the angles between the fast and slow axes of the quarter-wave plate 221.

[0163] The first component experiences the selected phase change on the inward pass of the beam towards the aluminium layer 230, which acts as a mirror. The second component experiences a fixed, non-voltage dependent phase change.

[0164] However, the quarter-wave plate 221 in the path causes polarisation rotation of the first and second components by 90 degrees so that the second polarisation component of the light beam is presented to the liquid crystal for being subjected to the selected phase change on the outward pass of the beam away from the mirror layer 230. The first polarisation component experiences the fixed, non-voltage dependent phase change on the outward pass of the beam. Thus, both of the components experience the same overall phase change contribution after one complete pass through the device, the total contribution being the sum of the fixed, non-voltage dependent phase and the selected voltage dependent phase change.

[0165] It is not intended that any particular SLM structure is essential to the invention, the above being only exemplary and illustrative. The invention may be applied to other devices, provided they are capable of multiphase operation and are at least somewhat polarisation independent at the wavelengths of concern. Other SLMs are to be found in our co-pending applications WO01/25840, EP1050775 and EP1053501 as well as elsewhere in the art.

[0166] Where liquid crystal materials other than ferroelectric are used, current practice indicates that the use of an integral quarter wave plate contributes to the usability of multiphase, polarisation-independent SLMs.

[0167] A particularly advantageous SLM uses a liquid crystal layer configured as a pi cell.

[0168] Referring to FIG. 2, an integrated SLM 10 has processing circuitry 11 having a first control input 12 for routing first and second beams 1,2 from input fibres 3,4 to output fibres 5,6 in a routing device 15. The processing circuitry 11 includes a store holding control data which is processed to generate holograms which are applied to the SLM 10 for control of light incident upon the SLM 10. The control data are selected in dependence upon the data at the control input 12, and may be stored in a number of ways, including compressed formats. The processing circuitry 11, which may be at least in part on-chip, is also shown as having an additional input 16 for modifying the holograms. This input 16 may be a physical input, or may be a "soft" input-for example data in a particular time slot.

[0169] The first beam 1 is incident on, and processed by a first array, or block 13 of pixels, and the second beam 2 is incident on and processed by a second array, or block 14 of pixels. The two blocks of pixels 13,14 are shown as contiguous. In some embodiments they might however be separated from one another by pixels that allow for misalignment.

[0170] Where the SLM is used for routing the beams 1,2 of light, this is achieved by displaying a linearly changing phase ramp in at least one direction across the blocks or arrays 13,14. The processing circuitry 11 determines the parameters of the ramp depending on the required angle of deflection of the beam 1,2. Typically the processing circuitry 11 stores data in a look-up table, or has access to a store of such data, to enable the required ramp to be created in response to the input data or command at the first control input 12. The angle of deflection is probably a two dimensional angle where the plane common to the direction of the incident light and that of the reflected light is not orthogonal to the SLM.

[0171] Assigning x and y co-ordinates to the elements of the SLM, the required amount of angular shift from the specular reflection direction may be resolved into the x and y directions. Then, the required phase ramp for the components is calculated using standard diffraction theory, as a "desired phase characteristic".

[0172] This process is typically carried out in a training stage, to provide the stored data in the look-up table.

[0173] Having established a desired phase modulation characteristic across the array so as to achieve the desired control of said beam the processing circuitry 11 transforms this characteristic into one that can be displayed by the pixels 13,14 of the SLM 10. Firstly it should be borne in mind that the processing circuitry 11 controlling the pixels of an SLM 10 is normally digital. Thus there is only a discrete population of values of phase modulation for each pixel, depending on the number of bits used to represent those states.

[0174] To allow the pixels 13,14 of the SLM 11 to display a suitable phase profile, the processing circuitry 11 carries out a level selecting operation for each pixel. As will be appreciated, the ability of the SLM to phase modulate has limits due to the liquid crystal material, and hence a phase ramp that extends beyond these limits is not possible. To allow for the physical device to provide the effects of the ideal device (having a continuously variable limitless phase modulation ability), the desired phase ramp may be transformed into a non-monotonic variation having maxima and minima within the capability limits of the SLM 10. In one example of this operation, the desired phase modulation is expressed modulo 2pi across the array extent, and the value of the desired modulo-2pi modulation is established at the centre of each pixel. Then for each pixel, the available level nearest the desired modulation is ascertained and used to provide the actual pixel voltage. This voltage is applied to the pixel electrode for the pixel of concern.

[0175] For small pixels there may be edge effects due to fringing fields between the pixels and the correlations between the director directions in adjacent pixels. In such systems the available phase level nearest to the value of the desired modulo-2pi modulation at the centre of each pixel (as described above) should be used as a first approximation. A recursive algorithm is used to calculate the relevant system performance characteristic taking into account these 'edge' effects and to change the applied level in order to improve the system performance to the required level.

[0176] "Linear" means that the value of phase across an array of pixels varies linearly with distance from an arbitrary origin, and includes limited linear changes, where upon reaching a maximum phase change at the end of a linear portion, the phase change reverts to a minimum value before again rising linearly.

[0177] The additional input 16 causes the processing circuitry 11 to modify the holograms displayed by applying a discrete approximation of a non-linear phase modulation so that the SLM 10 synthesises a corrective optical element such as a lens or an aberration corrector. As will be later described, embodiments may also provide power control (attenuation), sampling and beam shaping by use of the non-linear phase modulation profile. "Non-linear" is intended to signify that the desired phase profile across an array of pixels varies with distance from an arbitrary origin in a curved and/or oscillatory or like manner that is not a linear function of distance. It is not intended that "non-linear" refer to sawtooth or like profiles formed by a succession of linear segments of the same slope mutually separated by "flyback" segments.

[0178] The hologram pattern associated with any general non-linear phase modulation exp $j\phi(u) = \exp j(\phi_0(u) + \phi_1(u) + \phi_3(u) \ldots)$ where j is the complex operator, can be considered as a product. In this product, the first hologram term in the product exp j $\phi_0(u)$implements the routing while the second hologram term exp j $\phi_1(u)$ implements a corrective function providing for example lens simulation and/or aberration correction. The third hologram term exp j $\phi_2(u)$ implements a signal processing function such as sampling and/or attenuation and/or beam shaping. The routing function is implemented as a linear phase modulation while the corrective function includes non-linear terms and the signal processing function includes non-linear oscillatory terms.

[0179] Different methods of implementing the combination of these three terms are possible. In one embodiment the total required phase modulation $\phi_0(u) + \phi_1(u) + \phi_2(u)$ including linear routing and corrective function and the signal processing function is resolved modulo 2 pi and approximated to the nearest available phase level before application by the pixels. In another embodiment the summation of the phase modulation required for the linear and corrective function $\phi_0(u) + \phi_1(u)$ is resolved modulo 2 pi and approximated to the nearest phase level in order to calculate a first phase distribution. A second phase distribution $\phi_2(u)$ is calculated to provide sampling and/or attenuation and/or beam shaping. The two phase distributions are then added, re-resolved modulo 2 pi and approximated to the nearest available phase level before application by the pixels. Other methods are also possible.

[0180] Mathematically the routing phase modulation is periodic due to the resolution modulo 2pi and by nature of its linearity.

[0181] Therefore the routing phase modulation results in a set of equally spaced diffraction orders. The greater the number of available phase levels the closer the actual phase modulation to the ideal value and the stronger the selected diffraction order used for routing.

[0182] By contrast, the corrective effects are realised by non-linear phase changes $\phi_1(u)$ that are therefore non-periodic when resolved modulo 2pi. This non-periodic phase modulation changes the distribution of the reflected beam about its centre, but not its direction. The combined effect of both linear (routing) and non-periodic phase modulation is to change both the direction and distribution of the beam, as may be shown using the convolution theorem.

[0183] The signal processing effects are usually realised by a method equivalent to 'multiplying' the initial routing and/or hologram exp $j(\phi_0(u)+\phi_1(u))$ by a further hologram exp j $\phi_2(u)$ in which $\phi_2(u)$ is non-linear and oscillatory. Therefore the set of diffraction orders associated with the further hologram creates a richer structure of subsidiary beams about the original routed beam, as may be shown using the convolution theorem.

[0184] While this explanation is for a one-dimensional phase modulator array the same principle may be applied in 2-D.

[0185] Hence in a reconfigurable optical system this non-linear phase modulation may be applied by the same spatial light modulator(s) that route the beam. It will be understood by those skilled in the art that the SLM may have only a single control input and the device may have processing circuitry for combining control data for routing and control data for corrective effects and signal processing effects to provide an output to control the SLM.

[0186] The data may be entered into the SLM bit-wise per pixel so that for each pixel a binary representation of the desired state is applied. Alternatively, the data may be entered in the form of coefficients of a polynomial selected to represent the phase modulation distribution of the pixel array of concern in the SLM. This requires calculating ability of circuitry of the SLM, but reduces the data transfer rates into the SLM. In an intermediate design the polynomial coefficients are received by a control board that itself sends bit-wise per pixel data to the SLM. On-chip circuitry may interpret data being entered so as to decompress that data.

[0187] The pixel array of concern could be all of the pixels associated with a particular beam or a subset of these pixels. The phase modulation distribution could be a combined phase modulation distribution for both routing and corrective effects or separate phase modulation distributions for each. Beam shaping, sampling and attenuation phase modulation distributions, as will be described later, can also be included. In some cases it may not be possible to represent the phase modulation distribution as a simple polynomial. This difficulty may be overcome by finding a simple polynomial giving a first approximation to the desired phase modulation distribution. The coefficients of this polynomial are sent to the SLM. A bit-wise correction is sent for each pixel requiring a correction, together with an address identifying the location of the pixel. When the applied distribution is periodic only the corrections for one period need be sent.

[0188] The processing circuitry 11 may be discrete from or integral with the SLM, or partly discrete and partly integral.

[0189] Referring to FIG. 3, a routing device 25 includes two SLMs 20,21 which display holograms for routing light 1,2 from an input fibre array 3,4 to an output fibre array 5,6. The two SLMs are reflective and define a zigzag path. The first SLM 20 hereinafter referred to as a "corrective SLM" not only carries out routing but also synthesises a corrective optical element. The second SLM 21 carries out only a routing function in this embodiment, although it could also carry out corrections or apply other effects if required. The second SLM 21 is hereinafter referred to as a "routing SLM". Although the corrective SLM 20 is shown disposed upstream of the routing SLM 21, it may alternatively be disposed downstream of the routing SLM 21, between two routing SLMs, or with systems using routing devices other than the routing SLM 21.

[0190] The routing SLM 21 has operating circuitry 23 receiving routing control data at a routing control input 24, and generating at the SLM 21 sets of holograms for routing the beams 1,2. The corrective SLM 20 has operating circuitry 26 receiving compensation or adaptation data at a control input 27 to cause the SLM 20 to display selected holograms. In this embodiment, the SLM 20 forms a reflective lens.

[0191] Synthesising a lens at the SLM 20 can be used to change the position of the beam focused spot and therefore correct for a position error or manufacturing tolerance in one or more other lenses or reflective (as opposed to transmissive) optical elements, such as a curved mirror. The synthesised lens can be spherical or aspheric or cylindrical or a superposition of such lenses. Synthesised cylindrical lenses may have arbitrary orientation between their two long axes and the lens focal lengths can both be positive, or both be negative, or one can be positive and the other negative.

[0192] To provide a desired phase modulation profile for a lens or curved mirror to compensate for an unwanted deviation from a required system characteristic, the system is modelled without the lens/mirror. Then a lens/mirror having the correction to cancel out the deviation is simulated, and the parameters of the lens/mirror are transformed so that when applied to an SLM the same effect is achieved.

[0193] In one application what is required is to adjust the position and width of the beam waist, of a Gaussian-type beam at some particular point in the optical system, in order to compensate for temperature changes or changes in routing configuration. Hence two properties of the beam must be adjusted and so it is necessary to change two properties of the optical system. In a conventional static optical system both a lens focal length and the position of the lens are selected to achieve the required beam transformation. In the dynamic systems under consideration it is rarely possible deliberately to adjust the position of the optical components. A single variable focus action at a fixed position changes both the position and the width of the beam waist and only in special circumstances will both properties be adjusted to the required value.

[0194] One method to overcome this problem is to apply both corrective phase and corrective 'pseudo-amplitude' modulation (to be described later) with a single SLM. However the amplitude modulation reduces the beam power which may be undesirable in some applications. A further and preferred method is to apply corrective phase modulation with two separate SLMs.

[0195] For example consider coupling from one input fibre (or input beam) through a routing system into the selected output fibre (or output beam). Inside the routing system there are at least two SLMs carrying out a corrective function. They may also be routing and carrying out other functions (to be described in this application). In between a given pair of SLMs carrying out focus correction there is an intermediate optical system.

[0196] At the first SLM carrying out a corrective function there may be calculated and/or measured the incident amplitude and phase distribution of the input beam that had propagated from the input fibre or beam. At the second SLM carrying out a corrective function there may be calculated and/or measured the ideal amplitude and phase distribution that the output beam would adopt if coupling perfectly into the output fibre or beam. This can be achieved by backlaunching from the output fibre or beam or by a simulation of a backlaunch. The required focus correction functions of these two SLMs is to transform the incident amplitude and phase distribution arriving at the first SLM to the ideal amplitude and phase distribution at the second SLM to achieve perfect (or the desired) coupling efficiency into the output fibre or output beam.

[0197] The corrective phase modulation to be applied at the first SLM should be calculated, so as to achieve the ideal amplitude distribution at the second SLM as the beam arrives at the second SLM after passing from the first SLM and through the intermediate system. This calculation should take into account propagation through the intermediate system between the first and second SLMs. Hence the function of the first SLM is to correct the beam so as to achieve the ideal amplitude distribution for the output beam. The beam phase distribution should also be calculated as it arrives at the second SLM. The corrective phase distribution to be applied at the second SLM should be calculated so as to transform the phase distribution of the beam incident upon it from the intermediate system to the ideal phase distribution required for the output beam at the second SLM.

[0198] Two variables available at the SLM to effect corrections from an optimal or other desired level of performance are firstly the blocks of pixels that are delineated for the incident light beam, and secondly the hologram that is displayed on the block(s) of concern.

[0199] Starting with the delineation of blocks, it should be borne in mind that the point of arrival of light on the SLM can only be predicted to a certain accuracy and that the point may vary according to physical changes in the system, for example due to temperature effects or ageing. Thus, the device allows for assessment of the results achieved by the current assignment, and comparison of those results with a specified performance. In response to the comparison results, the delineation may be varied so as to improve the results.

[0200] In one embodiment a training phase, uses for example a hill climbing approach to control and optimise the position of the centre of the block. Then if the "in-use" results deviate by more than a specified amount from the best value, the delineation of the block is varied. This process reassignment may step the assigned block one pixel at a time in different directions to establish whether an improved result is achieved, and if so continuing to step to endeavour to reach an optimum performance. The variation may be needed where temperature effects cause positional drift between components of the device. It is important to realise that unlike MEMS systems and the like, all the pixels are potentially available for all the beams. Also the size, shape and location of a delineated block is not fixed.

[0201] Equally the size and shape of a block may be varied if required. Such changes may be necessary under a variety of situations, especially where a hologram change is needed. If for example a hologram requiring a larger number of pixels becomes necessary for one beam, the size of the block to display that hologram can be altered. Such changes must of course usually be a compromise due to the presence of other blocks (possibly contiguous with the present block) for displaying holograms for other beams of light.

[0202] Monitoring techniques for determining whether the currently assigned block is appropriate include the techniques described later herein as "taking moments".

[0203] Turning to variation of the hologram that is displayed on the block of concern, one option to take into account for example physical changes in the system, such as movement out of alignment, is to change one normal linear-type routing hologram for another, or to adjust the present hologram in direct response to the sensed change. Thus if, due for example to temperature effects, a target location for a beam moves, it may be necessary to change the deflection currently being produced at a pixel block. This change or adjustment may be made in response to sensed information at the target location, and may again be carried out "on-line" by varying the hologram step by step. However, it may be possible to obtain an actual measure of the amount and direction of change needed, and in this case either a new hologram can be read in to the SLM or a suitable variation of the existing hologram carried out.

[0204] As well as, or instead of, linear changes to linear routing holograms, corrective changes may be needed, for example to refocus a beam or to correct for phase distortion and non-focus aberrations.

[0205] Having corrected the beam focus other aberrations may remain in the system. Such aberrations distort the phase distributions of the beams. These aberrations will also change with routing configuration as the beams are passing through different lenses and/or different positions on the same lenses. Similarly the aberrations will change with temperature. To obtain stable and acceptable performance of a reconfigurable optical system, the aberrations can be corrected dynamically.

[0206] To provide a desired phase modulation profile for these aberrations the system may be modelled or measured to calculate the phase distortion across the SLM, compared to the ideal phase distribution. The ideal phase distribution may again be found by modelling the system 'backwards' from the desired output beam, or by backlaunching and measurement, while the actual phase distribution may be found by modelling the system forwards from the input beam or measurement. The calculations will include the effects of reflection from the SLM itself. The corrective function of the SLM is to transform between the actual and ideal phase distortion. The phase distortion is defined as the phase difference between the actual phase distribution and the ideal phase distribution. The desired corrective profile is the conjugate phase of the phase distortion.

[0207] Alternatively, these corrective functions can be shared by two SLMS, which allows an extra degree of freedom in how the beam propagates inside the intermediate system between the two SLMs.

[0208] Further, given a real system a sampling method (as will be described later) may be used to direct a fraction of the beam towards a wavefront sensor that may assess the beam. So far the process is deterministic. Then the changes are applied to the real system, and perturbations on the parameters are applied while monitoring the sensor and/or the input/output state, so as to determine whether an optimum configuration is achieved. If not, the parameters are changed until a best case is achieved. Any known optimising technique may be used. It is preferred to provide a reasonable starting point by deterministic means, as otherwise local non-optimum performance maxima may be used instead of the true optimum.

[0209] The method or device of the invention may be used to correct for aberrations such as field curvature in which the output 'plane' of the image(s) from an optical system is curved, rather than flat.

[0210] Equally, even if in use the SLM forms a corrective element by having non-linear phase modulation applied across it, if it is operated in separate training and use phases, it may be desirable while training for the SLM to route as well. In this case the SLM scans the processed beam over a detector or routes the beam, for example using one or more dummy holograms, into a monitor fibre.

[0211] Referring now to FIG. 4, the corrective SLM 20, used purely for synthesising a corrective element, has operating circuitry 125, and further comprises processing circuitry 122 and temperature sensors 123. In this embodiment the operating circuitry, temperature sensors and processing circuitry are integrated on the same structure as the rest of the SLM, but this is not critical to the invention. Associated with the processing circuitry is a store 124 into which is programmed a lookup table. The sensors detect temperature changes in the system as a whole and in the SLM, and in response to changes access the look up table via the processing circuitry 122 to apply corrections to the operating circuitry. These corrections affect the holograms displayed on the blocks 13, 14 of pixels. The sensors may also be capable of correction for temperature gradients.

[0212] This technique may also be applied to an SLM used for routing.

[0213] Referring now to FIG. 5, an optical system 35 has a corrective SLM 30 with operating circuitry 31, and processing circuitry 32. The system includes further devices, here second and third SLMs 33 and 34, disposed downstream of the corrective SLM 30. The second SLM 33 is intended to route light to particular pixel groups 15, 16 of the third SLM 34. The third SLM 34 has monitor sensors 37 for sensing light at predetermined locations. In one embodiment these sensors 37 are formed by making the reflective layer partially transmissive, and creating a sensing structure underneath. In another, the pixel electrode of selected pixels is replaced by a silicon photodetector or germanium sensor structure.

[0214] In either case, circuitry may be integrated into the silicon backplane to process the output of the sensors 37, for example to compare the outputs of adjacent sensors 37, or to threshold one sensor against neighbouring sensor outputs. Where possible, processing circuitry is on chip, as it is possible to reduce the time taken after light has been received to respond to it in this way. This is because there is no need to read information off-chip for processing, and also because calculations may be able to be performed in parallel.

[0215] Provided the routing-together with any compensation effects from the corrective SLM 30-is true, the sensors 37 will receive only a minimal amount of light. However where misalignment or focus errors are present, the extent of such errors is detected by measuring the power coupled into the monitor sensors. To that end, the sensors 37 provide data, possibly after some on-chip processing, to the processing circuitry 32. The processing circuitry 32 contains a control algorithm to enable it to control the operating circuitry 31 to make changes of, or adjustments to, the compensating holograms displayed on the corrective SLM 30 until the system alignment is measured to be optimised. In some embodiments, changes to the sub-arrays to which beam affecting holograms are applied may be made in response to the sensor output data.

[0216] In another embodiment a determined number of dummy ports are provided. For example for a connector two or more such ports are provided and for routing devices three or more dummy ports are provided. These are used for continuous misalignment monitoring and compensation, and also for system training at the start.

[0217] Although some embodiments can operate on a trial and error basis, or can be adapted "on the fly", a preferred optical system uses a training stage during which it causes to be stored in the look-up table data enabling operation under each of the conditions to be encountered in use.

[0218] In one embodiment, in the training stage, a set of initial starting values is read in for application to the SLM 30 as hologram data, then light is applied at a fibre and the result of varying the hologram is noted. The variations may include both a change of pixels to which the hologram is applied, and a change of the hologram. Where more than one fibre is provided, light is applied to each other fibre in turn, and similar results obtained. Then other environmental changes are applied and their effects noted, e.g. at the sensors 37, and the correction for input data either calculated or sought by varying the presently-applied data using optimisation techniques to seek best or acceptable performance.

[0219] Then, in use, the system may be operated on a deterministic basis-i.e. after ascertaining what effect is sought, for example responding to a temperature change or providing a change in routing, the change to the applied data for operating the device can be accessed without the need for experiment.

[0220] A preferred embodiment operates in the deterministic way, but uses one or more reference beams of light passed through the device using the SLM 30. In that way the effect of deviations due to the device itself can be isolated. Also it can be confirmed that changes are being correctly made to take into account environmental and other variations.

[0221] The device may also have further monitor sensors placed to receive the zero-order reflections from the SLM(s) to enable an assessment to be made of the input conditions. For example, where an input channel fails, this can be determined by observing the content of the specular reflection from the light beam representing that channel. Where there are two SLMs as in some routing systems, the specular reflections from each SLM may be sensed and compared.

[0222] Referring now to FIG. 6, a dual-function SLM 40 provides both routing and correction. The SLM 40 has operating circuitry 41 and processing circuitry 42. The operating circuitry 41 receives routing data at a first control input 44 for causing the processing circuitry 42 to generate the holograms on the SLM 40 to achieve the desired routing. The processing circuitry 42 also receives routing data on an input 45, and controls the operating circuitry 41 using an algorithm enabling adaptation due to changes in the path taken through the system to take place on a timescale equivalent to that required to change the hologram display, i.e. of the order of milliseconds.

[0223] The control algorithms for this embodiment may use one or more of several types of compensation.

[0224] In one embodiment a look-up table is stored in a memory 43, the look-up table storing pre-calculated and stored values of the compensation for each different route through the system.

[0225] In another embodiment the system is trained before first being operated, using changes of, or to the compensating holograms to learn how changing the compensating holograms affects the system performance, the resulting data being held in the memory 43.

[0226] In a further embodiment, the processing circuitry 42 employs intelligence responsive to signals from monitor sensors 47,48 for monitoring and calculation of how these compensating holograms should adapt with time to accommodate changes in the system alignment. This is achieved in some embodiments by integrating circuitry components into the silicon backplane of the SLM, or by discrete components such as germanium detectors where the wavelengths are beyond those attainable by silicon devices. In some embodiments sensors 47 are provided for sensing light at areas of the SLM, and in others the sensors 48 may instead or also be remote from the SLM 40 to sense the effects of changes on the holograms at the SLM 40.

[0227] Referring now to FIG. 7, an optical system 80 includes an SLM 81 for routing beams 1,2 of light from input fibres 3,4 to output fibres 5,6 by means of holograms displayed on pixel groups 13,14 of the SLM. The holograms are generated by processing circuitry 82 which responds to a control input 83 to apply voltages to an array of pixellated elements of the SLM, each of which is applied substantially uniformly across the pixel of concern. This result is a discrete approximation of a linear phase modulation to route the beams.

[0228] The processing circuitry 82 calculates the ideal linear phase ramp to route the beams, on the basis of the routing control input 83 and resolves this phase modulo 2Pi. The processing circuitry at each of the pixels then selects the closest available phase level to the ideal value. For example if it is desired to route into the m'th diffraction order with a grating period Ω the ideal phase at position u on the SLM 81 is $2pi.mu/\Omega$. Therefore, approximately, the phase goes linearly from zero up to 2pi over a distance

Ω/m after which it falls back to zero, see FIG. 8a.

[0229] Control of the power in individual wavelength channels is a common requirement in communication systems. Typical situations are the need to avoid receiver saturation, to maintain stable performance of the optical amplifiers or to suppress non-linear effects in the transmission systems that might otherwise change the information content of the signals. Power control may be combined with sampling or monitoring channels to allow adjustment of the power levels to a common power level (channel equalisation) or to some desired wavelength characteristic.

[0230] Deliberate changes to the value of 'Ω' can be used to reduce the coupling efficiency into the output in order to provide a desired attenuation. This is suitable for applying a low attenuation. However, it is not suitable for a high attenuation as, in that event, the beam may then be deflected towards another output fibre, increasing the crosstalk. If there is only one output fibre this method may be used regardless of the level of attenuation.

[0231] To provide a selected desired attenuation of the optical channel in the system, processing circuitry 85 responds to an attenuation control input 84 to modify the operation of the operating circuitry 83 whereby the operating circuitry selects a linear phase modulation such that by the end of each periodic phase ramp the phase has reached less than 2pi, see FIG. 8b.

[0232] This may be achieved by calculating the ideal value of phase for every pixel, and then multiplying this ideal value by a coefficient r between 0 and 1, determined on the basis of the desired attenuation. The coefficient is applied to every pixel of the array in order to get a reduced level per pixel, and then the available phase level nearest to the reduced level is selected.

[0233] The method of this embodiment reduces the power in this diffraction order by making the linear phase modulation incomplete, such that by the end of each periodic phase ramp the phase has only reached 2pi.r. It has however been found that the method of this embodiment may not provide sufficient resolution of attenuation. It also increases the strength of the unwanted diffraction orders likely to cause crosstalk. When combined with deliberate changes in the length of the ideal phase ramp the resolution of attenuation may be improved. Again if there is only a single output fibre the crosstalk is less important.

[0234] Resolution may also be improved by having a more complex incomplete linear phase modulation. However, the unwanted diffraction orders may still remain too strong for use in a wavelength-routed network. Hence to control the power by adapting the routing hologram may have undesirable performance implications in many applications, as crosstalk worsens with increase of attenuation. The problem can be overcome by use of a complex iterative design. This could be used to suppress the higher orders but makes the routing control more expensive.

[0235] Referring now to FIG. 9, a system 99 includes an SLM 90 controlled by applying a discrete approximation of a linear phase modulation to route beams 1,2 from input fibres 3,4 to output fibres 5,6 as previously described with respect to FIG. 7. Thus operating circuitry 91 selects a routing hologram for display by the SLM, in accordance with a routing input 92, whereby the beams may be correctly routed, using a look up table or as otherwise known. A memory holds sets of data each allowing the creation of a respective power controlling hologram. Processing circuitry 93 runs an algorithm which chooses a desired power controlling hologram corresponding to a value set at a power control input 94. The power controlling hologram is selected to separate each beam into respective main 1a, 2a and subsidiary 1b, 2b beams, such that the main beams 1a, 2a are routed through the system and the or each subsidiary beam(s) 1b, 2b is/are diffracted out of the system, for example to a non-reflective absorber 97.

[0236] The processing circuitry 93 applies the power controlling hologram data to a second input 95 of the operating circuitry 91 which acts on the routing hologram data so as to combine the routing and power controlling holograms together to provide a resultant hologram. The operating circuitry then selects voltages to apply to the SLM 90 so that the SLM displays the resultant hologram.

[0237] Thus power in a routing context is controlled by combining the routing hologram with another hologram that has the effect of separating the beam into a main beam and a set of one or more subsidiary beams of these the main beam is allowed to propagate through the system as required while the other(s) are diffracted out of the system.

[0238] For example consider a hologram that applies phases of $+\phi$ and $-\phi$ on adjacent pixels. In terms of real and imaginary parts this hologram has the same real part, cos ϕ, on every pixel, see FIG. 10, while the imaginary part oscillates between +- sin ϕ. It can be shown using Fourier theory that the net effect is to multiply the amplitude of the original routed beam by a factor cos ϕ, and to divert the unwanted power into a set of weak beams at angles that are integer multiples of $\pm\lambda/2p$ with respect to the original routed beam, where λ is the operating wavelength and p is the pixel pitch.

[0239] The system is designed from a spatial viewpoint such that light propagating at such angles falls outside the region of the output fibres 5,6 of FIG. 9. An alternative design directs the unwanted light into output fibres 5,6 at such a large angle of incidence that the coupling into the fundamental mode is very weak, and has no substantial effect. In this case the unwanted power is coupling into the higher-order modes of the fibre and so will be attenuated rapidly. A fibre spool or some other technique providing mode stripping is then used on the output fibre before the first splice to any other fibre.

[0240] In either case, the effective attenuation of the beam is $10 \log_{10} \cos^2\phi$. Hence, in this way, polarisation-independent phase modulation may be used to create an effect equivalent to polarisation-independent amplitude modulation. This is termed herein "pseudo amplitude modulation". In this particular case the pseudo-amplitude modulation applied at every pixel is cos ϕ.

[0241] It will be clear to those skilled in the art that use of alternate pixels as the period of alternation is not essential, and may in some cases be undesirable. This is because of edge effects in the pixels.

[0242] The period and pattern of alternation can be varied so as to adjust the deflection angle of the 'unwanted power'. This light directed away from the output fibres can be collected and used as a monitor signal. Hence the pseudo-amplitude modulation can be used to sample the beam incident on an SLM as previously discussed. This sampling hologram can be combined with a routing and/or power control and/or corrective SLM.

In the latter case the sampled beam can be directed towards a wavefront sensor and then used to assess the quality of the beam correction. While the pseudo-amplitude modulation as described above is applied to the whole beam, it could be applied selectively to one or more parts of the beam.

[0243] A further modification to this pseudo-amplitude modulation is to multiply it by a further phase modulating hologram such as to achieve a net effect equivalent to a complex modulation.

[0244] It is often important that the sampling hologram takes a true sample of the output beam. Therefore in some cases the sampling hologram should be applied after the combination of all other desired effects including resolution modulo 2pi and approximation to the nearest available phase level. In this case the overall actual phase modulation distribution is achieved by a method equivalent to forming the product of the sampling hologram and the overall hologram calculated before sampling.

[0245] Similar pseudo-amplitude modulation techniques may be extended to suppress the crosstalk created by clipping of the beam tails at the edges of each hologram and to tailor the coupling efficiency vs. transverse offset characteristic of the output fibres. Since the transverse position at the output fibre is wavelength dependent, this tailoring of the coupling efficiency vs. offset can be used to tailor the wavelength response of the system. This is important in the context of wavelength division multiplexing (WDM) systems where the system wavelength can be expected to lie anywhere in the range of the available optical amplifiers. The output angle for beam steering using an SLM and periodic linear phase modulation is proportional to the wavelength while the focal length of corrective lenses is also wavelength-dependent. Therefore a hologram configured to give the optimum coupling efficiency at one wavelength will produce an output beam with transverse and/or longitudinal offset at another wavelength. These effects result in wavelength-dependent losses in systems required to route many wavelength channels as an ensemble. Hence a method designed to flatten or compensate for such wavelength-dependent losses is useful and important.

[0246] Among the envisaged applications are the flattening of the overall wavelength response and the compensation for gain ripple in optical amplifiers, especially Erbiumdoped fibre optic amplifiers (EDFA).

[0247] An SLM device may also be used to adapt the shape, e.g. the mode field shape, of a beam in order to suppress crosstalk.

[0248] Beam shaping is a type of apodisation. It is advantageously used to reduce crosstalk created at a device by clipping of the energy tails of the light beams. Such clipping leads to ripples in the far field. These ripples cause the beam to spread over a wider region than is desired. In telecommunications routing this can lead to crosstalk. Other applications may also benefit from apodisation of a clipped laser beam, such as laser machining, for example, where it is desired to process a particular area of a material without other areas being affected and laser scalpels for use in surgery.

[0249] Clipping occurs because the energy of the beam spreads over an infinite extent (although the amplitude of the beam tails tends to zero), while any device upon which the beam is incident has a finite width. Clipping manifests itself as a discontinuity in the beam amplitude at the edges of the device.

[0250] Referring to FIG. 11, two SLMs 100,101 are used for beam steering or routing of beams 1,2 from input fibres 3,4 to output fibres 5,6, as described in PCT GB00/03796. Each SLM 100,101 is divided into a number of blocks of pixels 103a, 104a; 103b, 104b. Each block 103a, 104a is associated with a particular input fibre 3,4- i.e. the fibre of concern points to the subject block. Each block displays a hologram that applies routing. As previously discussed herein the holograms may also or alternatively provide focus compensation, aberration correction and/or power control and/or sampling, as required.

[0251] The blocks 103a, 104a at the input SLM 100 each receive a beam from an associated input fibre 3,4 while the blocks 103b, 104b at the output SLM 101 each direct a beam towards an associated output fibre 5,6. Each block 103a, 103b has a finite width and height. As known to those skilled in the art and as previously noted, the beam width is infinite, therefore the block clips the beam from or to the associated fibre and this creates undesired ripples in the far field.

[0252] The ripples due to clipping of the beam 1 are figuratively shown as including a beam 106 which, it will be seen, is incident on the wrong output hologram, displayed on block 104b at the output SLM 101. "Wrong" signifies holograms other than that to which the beam of concern is being routed, for example holograms displayed by blocks around the block to which the beam should be routed. Some of these ripples will then be coupled into "wrong" output fibres 5,6-i.e. those to which the beam is not deliberately being routed-leading to crosstalk. It will be clear to those skilled in the art that these effects will be present on blocks other than those adjacent to the "correct" blocks, as the field of beam 1 is infinite in extent.

[0253] In any physical system the effect of the ripples created by clipping at the output SLM 101 depends on the optical architecture.

[0254] In practice the non-ideal transfer function of the optics (due to finite lens apertures and aberrations) means that a sharp change in the amplitude spreads out and causes crosstalk in adjacent output fibres. In effect the optics applies a limit to the range of spatial frequencies that can be transmitted. This frequency limit causes crosstalk.

[0255] The wider the device, compared to the beam spot size at the device, the weaker the ripples in the far field and the lower the crosstalk. In general a parameter C is defined such that the required width of SLM per beam is given by $H=C.\omega$, where ω is the beam spot size at the SLM. The value of C depends on the beam shape, the optical architecture and the allowable crosstalk. Typically for a Gaussian beam, with no beam shaping and aiming for crosstalk levels around -40 dB, C would be selected to have a value greater than or equal to three. Looking at this system from the spatial frequency viewpoint, the field incident on the SLM contains (for perfect optics) all the spatial frequencies in the input beam. The finite device width cuts off the higher spatial frequencies, so, again, the optics applies a limit to the range of spatial frequencies that can be transmitted and this frequency limit causes crosstalk.

[0256] Beam shaping can be used to decrease the crosstalk for a given value of C, and also allow the use of a lower value of C. Calculations for N*N switches have shown that decreasing the value of C leads to more compact optical switches and increases the wavelength range per port. Hence beam shaping can be employed to provide more compact optical switches and/or an increased wavelength range per port.

[0257] The idea behind using beam shaping or 'apodisation' to reduce crosstalk is based on an analogy with digital transmission systems. In these systems a sequence of pulses is transmitted through a channel possessing a limited bandwidth. The frequency response of the channel distorts the edges of pulses being transmitted so that the edges may interfere with one another at the digital receiver leading to crosstalk. The channel frequency response can, however, be shaped so as to minimise such crosstalk effects. Filters with responses that have odd-symmetry can be used to make the edges go through a zero at the time instants when pulses are detected.

[0258] Therefore beam-shaping with odd symmetry can be used to make the crosstalk go through a zero at the positions of the output fibres. Such a method is likely to be very sensitive to position tolerances.

[0259] Another method used in digital systems is to shape the frequency cut-off so that it goes smoothly to zero. In the present context the ideal case of 'smoothly' is that the channel frequency response and all derivatives of the frequency response become zero. In practice it is not possible to make all derivatives go to zero but a system may be designed in which the amplitude and all derivatives up to and including the k'th derivative become zero at the ends of the frequency range. The higher the value of k, the quicker the tails of the pulse decay. Therefore the beam shaping should go as smoothly as possible to zero.

[0260] To investigate the effects of beam shaping the amplitude modulation was treated as continuous. The system studied was a single lens 2f system where 2f is the length of the system between fibres and SLM, assuming f is the focal length with fibres in one focal plane, and an SLM in the other focal plane. The input fibre beam was treated as a Gaussian. Various amplitude modulation shapes were applied at the SLM and the coupling efficiency into the output fibre was calculated. In this architecture and from Abbe theory, the incident field at the SLM is proportional to the Fourier Transform of the field leaving the input fibre. In particular, different spatial frequencies in the fibre mode land on different parts of the SLM. Clipping removes the spatial frequencies outside the area of the hologram. Beam shaping at the SLM has the effect of modifying the relative amplitude of the remaining spatial frequencies.

[0261] Residual ripples may still remain due to the discontinuity in the beam derivative but the ripples will be reduced in amplitude and decay more quickly. Further reduction in the ripple amplitude and increase in the rate of decay may be achieved by shaping the beam such that both the amplitude and the first k derivatives go to zero at the edges.

[0262] Mathematical analysis of the effect has also been carried out. The results are as follows:

[0263] The n^{th} time derivative of a function can be expressed in terms of its Fourier Transform as shown in equation (1):

$$\frac{d^n g(t)}{dt^n} = \int_{-\infty}^{\infty} (i2\pi f)^n G(f) \exp i2\pi ft \, df \qquad (1)$$

[0264] Hence, by inversion, the frequency dependence of the Fourier Transform (FT) may be expressed as an FT of any one of the function's derivatives as shown in equation (2):

$$G(f) = \frac{1}{(i2\pi f)^n} \int_{-\infty}^{\infty} \frac{d^n g(t)}{dt^n} \exp - i2\pi ft \, dt \qquad (2)$$

[0265] Choosing the zeroth derivative provides the expression in equation (3):

$$G(f) = \int_{-\infty}^{\infty} g(t) \exp - i2\pi ft \, dt \qquad (3)$$

[0266] To apply the analysis to free-space beam-steering:

[0267] let x and y be the position co-ordinates at the fibre output from a switch, and u and v be the position co-ordinates at the SLM. Assume the SLM to be in one focal plane of a lens of focal length f, and the fibre array to be in the other focal plane:

$$E_{FIB}(x,y) = \frac{i}{f\lambda} \exp(-i\frac{2\pi}{\lambda}(2f + nt)) \iint E_{SLM}(u,v) \exp i\frac{2\pi f}{\lambda}(xu + yv) du dv \qquad (4)$$

[0268] such that the output field (see equation (4)) is a 2-D Fourier Transform of the field at the SLM, E_{SLM}. In this result t is the lens thickness and N its refractive index, while λ is the optical wavelength.

[0269] For the present purposes the 1-D equivalent is considered (relation 5):

$$E_{FIB}(x) = \frac{i}{f\lambda}\exp(-i\frac{2\pi}{\lambda}(2f+nt))\int E_{SLM}(u)\exp i\frac{2\pi f}{\lambda}(xu)du \qquad (5)$$

[0270] Comparing with (3) it is clear that the position co-ordinate at the SLM (u) is equivalent to the time domain and the position co-ordinate at the output (x) is equivalent to the frequency domain. Hence from (2) the output field may be expressed in terms of a derivative of the field at the SLM, as shown in equation (6):

$$E_{FIB}(x) = \frac{i}{f\lambda}\exp(-i\frac{2\pi}{\lambda}(2f+nt))\left(\frac{i}{2\pi x}\right)^n \int \frac{d^n E_{SLM}(u)}{du^n}\exp i\frac{2\pi f}{\lambda}(xu)du \qquad (6)$$

[0271] Let the k^{th} derivative of $E_{SLM}(u)$ be non-zero and smoothly varying over the range [-H/2, H/2], but zero outside this range, such that the derivative changes discontinuously at u = ±H/2:

$$\begin{aligned}\frac{d^k E_{SLM}(u)}{du^k} &= 0 && \forall u : u < -\tfrac{H}{2} \\ &= g^H && u = -\tfrac{H}{2} \\ &= s(u) + g^H && -\tfrac{H}{2} < u < \tfrac{H}{2} \\ &= g^H && u = +\tfrac{H}{2} \\ &= 0 && u > \tfrac{H}{2}\end{aligned} \qquad (7)$$

[0272] This representation assumes E_{SLM} to be even in u. Physically this situation represents a beam that is perfectly aligned with respect to the centre of a hologram of width H.

[0273] This derivative may be expressed as the sum of a rect function and a smoothly varying function, s(u), that is zero at and outside |u|=H/2:

$$\frac{d^k E_{SLM}(u)}{du^k} \equiv g_H rect\left(\frac{u}{H/2}\right) + s(u) \qquad (8)$$

[0274] For example consider a clipped (and unapodised) Gaussian beam; the zeroth derivative (k=0) may be expressed as:

$$\begin{aligned} s(u) &= \exp-\left(\frac{u}{\omega_{HOL}}\right)^2 - \exp-\left(\frac{H}{2\omega_{HOL}}\right)^2 \quad \forall|u| < \frac{H}{2} \\ &= 0 \quad \forall|u| \geq \frac{H}{2} \end{aligned} \qquad (9)$$

$$g_H = \exp-\left(\frac{H}{2\omega_{HOL}}\right)^2 \qquad (10)$$

[0275] Now returning to the general case (equation(8)) the k+1[th] derivative is calculated:

$$\frac{d^{k+1}E_{SLM}(u)}{du^{k+1}} \equiv g_H\left\{\delta\left(u+\frac{H}{2}\right)-\delta\left(u-\frac{H}{2}\right)\right\}+\frac{ds(u)}{du} \qquad (11)$$

[0276] It is now convenient to calculate the output field. Set $n=k+1$ in (6) to obtain:

$$E_{FIB}(x) \propto \frac{1}{(i2\pi x)^{k+1}}\left\{\begin{aligned} & g_H \int_{-\infty}^{\infty}(\delta(t+H/2)+\delta(t-H/2))\exp-i2\pi xu\,du \\ & + \int_{-\infty}^{\infty}\frac{ds(u)}{du}\exp-i2\pi xu\,du \end{aligned}\right\} \qquad (12)$$

[0277] which becomes equation (13):

$$E_{FIB}(x) \propto \frac{1}{(i2\pi x)^{k+1}}\left\{2ig_H\sin(\pi xH)+\int_{-\frac{H}{2}}^{\frac{H}{2}}\frac{ds(u)}{du}\exp-i2\pi xu\,du\right\} \qquad (13)$$

[0278] As the position is increased, the exponential term in the 2[nd] integral of (13) oscillates more and more rapidly. Eventually the spatial frequency is so high that the derivative of s(u) can be considered to be constant, or nearly constant, over the spatial period. In which case the integral is zero, or nearly zero, when evaluated over each period of the oscillation. Therefore at high frequencies the whole of the second integral must approach zero.

[0279] It is assumed that the behaviour is dominated by the first integral. The first integral shows that if the amplitude changes discontinuously (k=0, i.e. an unapodised hologram), the spectrum (E_{FIB}) decays as 1/x. Now, if the amplitude and the first derivative are continuous, it is the second derivative that changes discontinuously, and so k=2 and the spectrum (E_{FIB}) decays as $1/x^3$. Numerical simulations have been carried out to confirm this behaviour.

[0280] A particularly advantageous shape is one in which the shaped beam has odd symmetry about points midway between the centre and the edges such that the beam amplitude and all of its derivatives go to zero at the beam edges.

[0281] The beam shaping may be effected to remove only a small amount of power from the central portion of the beam, to maintain acceptable system efficiency. A method for shaping a beam to achieve suppression of the ripples is now described.

[0282] Defining the middle of the beam as f(u), then f(u) can describe the original beam in its central portion, or what is left in the original beam after it has already been partially shaped, using, for example, pseudo-amplitude. To avoid ripples in the far field the edges of the beam go to zero at u = ±H/2, where H is the width of the hologram.

[0283] Hence, at the right-hand edge, describe the beam as in equation (14):

$$f_R(u) = f(0) - f(u-H/2) \qquad (14)$$

[0284] (The left-hand edge is considered later).

[0285] To get matching of the amplitude half-way between the middle and the edge it is required that

$$f(H/4)=f_R(H/4) \qquad (15)$$

[0286] From which there is obtained

$$f(H/4) + f(-H/4) = f(0) \qquad (16)$$

[0287] Now consider the derivatives at the joining point. The n[th] derivative of the right-hand edge function is given by equation (17):

$$\left.\frac{d^n f_{RH}}{du^n}\right|_{u=U} = -\left.\frac{d^n f}{du^n}\right|_{u=U-H/2} \qquad (17)$$

[0288] Hence at the joining point condition (18) is valid:

$$\left.\frac{d^n f_{RHEDGE}}{du^n}\right|_{u=H/4} = \left.\frac{d^n f}{du^n}\right|_{u=-H/4} \qquad (18)$$

[0289] In order to avoid the creation of high frequency effects (crosstalk tails) by the joining point all derivatives are desirably continuous here. Hence it is required that condition (19) should be true:

$$\left.\frac{d^n f}{du^n}\right|_{u=H/4} = -\left.\frac{d^n f}{du^n}\right|_{u=-H/4} \qquad (19)$$

[0290] To find out whether this is possible, expand the function f in a Taylor series about x=0 to obtain equation (20)

$$f = f(0) + a_1 u + a_2 u^2 + a_3 u^3 + a_4 u^4 + a_5 u^5 + a_6 u^6 + ... \qquad (20)$$

[0291] The first derivative is given by equation (21):

$$\frac{df}{du} = a_1 + 2a_2 u + 3a_3 u^2 + 4a_4 u^3 + ... \qquad (21)$$

[0292] The required condition (19) for the first derivative (n=1) can be obtained provided f is even in x, so that all the odd coefficients {a1, a3. . . } in (20) and (21) are zero. This makes the first derivative continuous at the joining point. Furthermore if *f* is an even function then *f(H/4)=f(–H/4)* in which case (16) becomes:

$$f(H/4) = \tfrac{1}{2} f(0) \qquad (22)$$

[0293] Given that f is now an even function, the second derivative of f is given by equation (23):

$$\frac{d^2 f}{du^2} = 2a_2 + 12a_4 u^2 + \ldots\ldots \qquad (23)$$

[0294] Returning to the required condition in (19) it is clear that it cannot be satisfied for n=2. Hence the second derivative is discontinuous at the joining point u=H/4.

[0295] The left-hand edge is given by equation (24)

$$f_{LH}(u) = f(0) - f(u+H/2) \qquad (24)$$

[0296] Given that f is even, the overall function has odd symmetry in each half plane x = ± H/4.

[0297] To work out what happens at x = ± H/2, expand f_{RH} and f_{LH} in Taylor series, as shown in equations 25 and 26:

$$f_{RH} = a_2\left(u - \tfrac{H}{2}\right)^2 + a_4\left(u - \tfrac{H}{2}\right)^4 + a_6\left(u - \tfrac{H}{2}\right)^6 + \ldots\ldots\ldots \qquad (25)$$

$$f_{LH} = a_2\left(u + \tfrac{H}{2}\right)^2 + a_4\left(u + \tfrac{H}{2}\right)^4 + a_6\left(u + \tfrac{H}{2}\right)^6 + \ldots\ldots\ldots \qquad (26)$$

[0298] The function and its first derivative are both zero at u= ½H, but the second derivative has the value $2a_2$. Outside of the range [−½H, ½H] the beam drops to zero. Hence the second derivative is discontinuous at both u=±½H and u=±H/4, and the far field must therefore decay as the cube of the distance measured in the far field.

[0299] From the analysis, the required properties of f(u) for a hologram of width H are that firstly it should be even in u, and that secondly its amplitude at the position u=H/4 should be half the amplitude at u=0. After apodisation has been applied the shape of the beam in the region between u=H/4 and u=H/2 should be given by $f_{RH}(u)=f(0)-f(u-H/2)$ while in the region between u=-H/2 and u=-H/4 the shape of the beam should be given by fLH(u)=f(0)-f(u+H/2). In practice the shaping may not increase the local beam amplitude. Hence the hologram width and/or the shape of the central portion may have to be adjusted to avoid the requirement for 'amplifying' shaping.

[0300] As an example these conditions are satisfied by a Gaussian distribution given by equation (27):

$$f(u) = \exp -\left(\frac{u\sqrt{\ln(2)}}{H/4}\right)^2 - \qquad (27)$$

[0301] If the original beam satisfies the first two conditions it can be apodised without removing power from the central region. Otherwise shaping can be applied to the central region so that these two conditions are satisfied.

[0302] In some systems there may be a requirement to adapt the width of the beam in the far field: either to narrow the beam or to broaden the beam. This may be useful for laser processing of materials as well as for routing. It is advantageous that the method to change the width does not introduce side lobes. A particular application that would benefit is laser drilling of holes. The SLM could be used to narrow the drilling beam as well as to change its focus so that the drilled hole remains of uniform diameter (or has reduced diameter variation) as the hole is progressively bored.

[0303] In order to broaden the far field, the near field (at the SLM) needs to be made narrower. This may be implemented by applying shaping to the central portion of the beam so that its full width half maximum (FWHM) points become closer together and so that the beam shape has even symmetry about its centre. Preferably the amplitude at the very peak is not reduced so as not to lose too much power. The distance between the two FWHM points defines the effective half-width of the hologram. Further shaping should be applied to the left-hand and right-hand edges of this effective hologram, so that the beam shape has the required properties as described previously. Outside of the width of the effective hologram the beam shape should have zero amplitude.

[0304] To narrow the far field, the near field (at the SLM) needs to be made broader. This may be implemented by applying shaping to the central portion of the beam, so that the FWHM points become further apart, and so that the beam shape has even symmetry about its centre. Typically this will require reduction of the amplitude around its peak. The extent of this reduction is governed by the need to be able to apply shaping to the right and left hand edges of the hologram with the constraint that the shaping may only decrease the amplitude (and not increase it).

[0305] Amplitude-modulating SLMs can be used to implement the shaping but they are polarisation-dependent.

[0306] Another pseudo-amplitude modulation can be created to implement the beam shaping by using a phase-modulating SLM, which may be made polarisation-independent. This may be achieved by recognising that a phase modulation exp j ϕ (u), where j is the complex operator, is equivalent to a phase modulation cos ϕ (u)+j sin ϕ (u). Now choose ϕ (u) such that the modulus of ϕ (u) is varying slowly but the sign is oscillating.

[0307] Hence the real part of the modulation, cos ϕ (u), will be slowly varying and can act as the amplitude modulator to create the beam shape, while the imaginary part of the modulation, $\pm$ sin ϕ(u), will be oscillating rapidly with an equivalent period of two or more pixels. Hence the energy stripped off by the effective amplitude modulator will be diffracted into a set of beams that are beam-steered out of the system at large angles.

[0308] In a preferred embodiment, the system is designed such that light travelling at such angles will either not reach the output plane or will land outside the region defined by the output ports. Therefore the beam component shaped by sin ϕ (u) is rejected by the optical system, while the beam component shaped by cos ϕ (u) is accepted by the system and couples into one or more output ports, as required. While this explanation is for a one-dimensional phase modulator array the same principle is applicable in 2-D. If ϕ (u) varies from 0 at the centre of the beam to $\pi/2$ at the edges then the amplitude of the beam shaped by cos ϕ (u) varies from 1 at the centre of the beam to 0 at the edges, thus removing the amplitude discontinuity that creates rippling tails in the far field. This can be achieved with minimal change to the insertion loss of the beam as it passes through the system. Indeed, often the insertion loss due to clipping is due to interference from the amplitude discontinuity, rather than the loss of energy from the beam tails.

[0309] The beam-shaping hologram is non-periodic but oscillatory and may be applied as a combination with other routing and/or lens synthesis and/or aberration correcting and/or power control and/or sampling holograms.

[0310] Further advantages of the beam shaping are that it reduces the required value of C for a given required crosstalk, allowing more compact optical switches. Another advantage is that the crosstalk decays much more rapidly with distance away from the target output fibre. Hence, essentially, the output fibres receive crosstalk only from their nearest neighbour fibres.

[0311] Therefore in a large optical switch used as a shared N*N switch for a range of wavelengths, it should be possible to arrange the wavelength channel allocation such that no output fibre collects crosstalk from a channel at the same system wavelength as the channel it is supposed to be collecting. This would reduce significantly the homodyne beat noise accumulation in networks using such switches, and, conversely, allow an increase in the allowed crosstalk in each switch as heterodyne crosstalk has much less of an impact at the receiver, and can also be filtered out if necessary.

[0312] The crosstalk suppression method uses beam shaping to suppress ripples in the beam tails. The same method can be adapted to change the beam shape around the beam centre. For the case when the output beam is an image of the beam at the SLM the beam shaping is working directly on an image of the output beam. The fraction of the initial beam that is shaped by the slowly varying function cos ϕ (u) can have the correct symmetry to couple efficiently into the fundamental mode of the output fibre. The fraction of the initial beam that is shaped by the rapidly varying function $\pm$ sin ϕ(u) has the wrong symmetry to couple into the fundamental mode and can be adjusted to be at least partially orthogonal to the fundamental mode.

[0313] Effectively, it is the fraction of the beam shaped by cos ϕ (u) that dominates the coupling efficiency into the fundamental mode. Therefore the dependence of the coupling efficiency vs. transverse offset is dominated by the overlap integral between the cos ϕ (u) shaped beam and the fibre fundamental mode.

[0314] When the incident beam is the same shape as the fundamental mode and for small transverse offsets the coupling efficiency decreases approximately parabolically with transverse offset. In many beam-steering systems using phase-modulating SLMs the transverse offset at the output fibre increases linearly with the wavelength difference from the design wavelength. Consequently the system coupling efficiency decreases approximately parabolically with wavelength difference from the design wavelength. Beam shaping can be used to adjust the shape of the incident beam and optimised to flatten the dependence on transverse offset and hence to flatten the wavelength response. Alternatively a more complex wavelength dependence could be synthesised to compensate for other wavelength-dependent effects.

[0315] Beam shaping may also be used during system assembly, training or operation in order to measure mathematical moments of a light beam. A description of the method and theory will be followed by a description of some example applications.

[0316] The method requires a first stage during which corrective phase modulation is applied by the SLM such that the phase profile of the beam leaving the SLM has no non-linear component. This may be confirmed with a collimeter or wavefront sensor or some other suitable device. In a first embodiment the phase profile has no linear component applied to deflect the beam such that the beam is reflected in a specular direction. An optical receiver is placed to receive the reflected beam. The power reflected exactly into the specular direction is proportional to the square of an integral A(n) given in equation (28) where f(n,u,v) is the complex amplitude of the beam leaving the SLM at co-ordinates u,v during the n^{th} stage of the method.

$$A(n) = \iint f(n,u,v)\,du\,dv \qquad (28)$$

[0317] The optical power received by the photodiode during the n^{th} stage of the method is given by equation (29)

$$P(n) = K(A(n))^2 \qquad (29)$$

[0318] where K is a constant of proportionality.

[0319] If received by an optical fibre the received power will be modified according to the fibre misalignment and mode field distribution, leading to possible ambiguities in the method. Hence it is preferred instead to receive the beam by a photodiode. During the first stage of the method the net phase modulation applied by the SLM is such that the beam is of uniform phase. Let b(u, v) be the beam amplitude distribution. Therefore during this first stage the integral A is equal to the zeroth moment, a0, of the beam amplitude distribution, as shown in equation (30), and f(n,u,v) is equal to

$$A(1) = a0 = \iint b(u,v)\,du\,dv \qquad (30)$$

[0320] Therefore the power, P(1), measured by the photodiode during this first stage is given by equation (31).

$$P(1) = Ka_0^{\,2} \qquad (31)$$

[0321] In order to characterise a two-dimensional beam, moments of the beam distribution may be taken in two orthogonal directions, in this case the u and v directions. Consider the pixel block of concern to be broken up into a set of columns. To each column in the block a particular effective amplitude modulation may be applied using the pseudo-amplitude method or some other method. For example consider the pixel column with a centre at co-ordinate u*. By applying an alternating phase modulation of +ϕ (u*) and -ϕ (u*) to adjacent pixels in the same column the effective amplitude modulation applied to the particular column is cos(ϕ (u*)).

[0322] In order to calculate the first moment in the u direction, during the second stage of the method the values of cos(ϕ (u*)) are chosen such as to approximate to a linear distribution, as described in equation (32)

$$\cos(\phi(u^*)) \approx mu^* + c \qquad (32)$$

[0323] Therefore the power P(2) measured during the second stage of the process is given by (33).

$$P(2) \approx K\left(m^2 a_{1U}^{\,2} + 2mca_{1U}a_0 + c^2 a_0^{\,2}\right) \qquad (33)$$

[0324] where a_{1U} is the first moment of the beam distribution in the u direction, as given by (34).

[0325] $$a1u = \iint ub(u,v)\,du\,dv \qquad (34)$$

[0326] The ratio of the powers measured during the two stages is then given by equation (35)

$$\frac{P(2)}{P(0)} \approx m^2 \left(\frac{a_{1U}}{a_0} \right)^2 + 2mc\frac{a_{1U}}{a_0} + c^2 \tag{35}$$

[0327] Given the measured power ratio and the values of m and c as chosen to satisfy the constraints of the method, the quadratic equation given in (35) may be solved to calculate the ratio of the first order moment in the u direction to the zeroth order moment.

[0328] The constraints on m and c are such that the actual values of the alternating phase of each column need to be chosen from the available set and such that the total phase excursion across the expected area of the beam remains within the range $[0,\pi]$ or $[-\pi,0]$ so that the cos(ϕ (u*)) term may decrease (or increase) monotonically. In practise a photodiode of finite size will receive power diffracted from the SLM within an angular distribution about the specular direction. A further constraint on the gradient 'm' in equation (32) is such that the side lobes created by the linear amplitude modulation fall outside the area of the photodiode.

[0329] Similar methods may be used to take approximate higher-order moments in the u direction, and also first and higher-order moments in the v direction. In the latter case to each row in the block a particular effective amplitude modulation is applied, e.g. by setting adjacent pixels in the row to alternating phases of +ϕ (v*) and -ϕ (v*), where v* is the position co-ordinate of the row. The second-order moments may also be calculated and used to estimate the beam spot size at the hologram. This estimate can be used as part of the control algorithm for focus adjustment.

[0330] In a second embodiment a further linear phase modulation is applied to the hologram during each stage so as to deflect the beam to be measured while taking the moments towards a particular photodiode.

[0331] Consider a Gaussian type beam b(u,v) centred at position co-ordinates (u0,v0).

The even symmetry of the beam about axes parallel to the u and v directions and through the centre lead to the identities given by equations (36) and (37).

$$\iint (u - u0) b(u,v)\, du\, dv = 0 \qquad (36)$$

$$\iint (v - v0) b(u,v)\, du\, dv = 0 \qquad (37)$$

[0332] Hence approximate values of the first order moments measured as described previously, or by some other method, may be used to deduce approximate positions for the beam centres, as shown by equations (38) and (39).

$$u_0 \approx \frac{a_{1U}}{a_0} \qquad (38)$$

$$v_0 \approx \frac{a_{1V}}{a_0} \qquad (39)$$

[0333] In the next stage of the measurement the pixel block initially assigned to the beam is re-assigned such that it is centred within half a pixel in each of the u and v directions from the approximate centre of the beam, as just calculated.

[0334] Let the new centre of the pixel block be at (u1,v1). A new hologram should be calculated such that the beam leaving the SLM acts as the product of a beam of uniform phase distribution and an effective amplitude distribution given by equation (40)

$$\cos(\phi(u^*)) \approx m(u^* - u1) \qquad (40)$$

[0335] The principle is that if the beam centre lies exactly at u1 the measured power exactly in the specular direction will be zero. Taking into account the finite area of the photodiode the measured power cannot be zero but will be minimised when u1 is within half a pixel pitch of the beam centre.

[0336] This new hologram should be applied to the pixel block and the power measured. At this point the method can proceed in two ways.

[0337] In one embodiment a further estimate of the beam centre can be calculated, as described previously, a new centre position u1 calculated, the hologram recalculated according to equation (40) and the power measured again. This process can be repeated until the value of u1 appears to have converged.

[0338] In a second embodiment the centre of the pixel block, u1 can be re-assigned, the hologram recalculated according to (40) and the power measured again. At the current pixel block centre, u1, for which the beam centre is within half a pixel of u1, the measured power should be at a minimum value.

[0339] A further embodiment is to use a suitable combination of these two alternative methods.

[0340] The centre of the pixel block in the v direction can be measured using similar methods.

[0341] The size of the pixel block used should be chosen so as to cover the expected area of the beam. Outside of this area the phase can be modulated on a checkerboard of, for example, +-pi/2, so that the effective amplitude modulation is zero and the light from these regions is diffracted far away from the photodiode.

[0342] It can be shown that equations (36) and (37) are also satisfied if the beam waist is not coincident with the SLM, that is the beam is defocused. Although the method as described above will not be calculating the proper moments of the beam, it can be shown that the position of the beam centre may still be identified using the methods described.

[0343] The beam shaping method may be extended to control and adapt the amplitude of the beam steered through the system. If $\phi(u)$ varies from ψ at the centre of the beam to $\pi/2$ at the edges then the real part of the pseudo-amplitude modulation can be considered as cos ψ multiplied by an ideal beam-shaping function that causes insignificant insertion loss. In which case there is an associated additional insertion loss given by approximately $10\log_{10}(\cos^2 \psi)$. By varying the value of ψ the beam power can be varied. Therefore the same device can be used to achieve power control, otherwise known as channel equalisation, as well as changing the routing or direction of a beam. Deliberate changes in the beam shaping function can be used to increase the number of 'grey levels' possible for the beam attenuation, i.e. to provide an increased resolution. As for the beam shaping, the rejected power is diffracted out of the system. Therefore this attenuation method does not increase crosstalk.

[0344] Another technique for controlling beam power without increasing crosstalk is to deflect the unwanted energy in a direction orthogonal to the fibres susceptible to crosstalk.

[0345] This may be combined with yet another technique, namely distorting the beam phase in such a way that much of the energy couples in to the higher-order modes of the fibre, rather than the fundamental mode that carries the signal. The beam phase distortion may alternatively be used alone.

[0346] In an embodiment, these methods are achieved by dividing the area of the SLM on which the beam is incident into a set of 'power controlling' stripes. The long side of the stripes are at least substantially in the plane in which the input and output-beam are travelling. By varying the relative phase in the stripes the coupling efficiency into the fundamental mode of the output fibre is changed, and hence the throughput efficiency of the optical system is set. This method can be applied to a pixellated device that is also routing or otherwise adapting a beam. In this case each 'stripe' would contain between one and many of the pixels already in use.

[0347] Alternatively the long side of the power controlling stripes could be in one plane in one electrode, with the long side of the routing pixels in an orthogonal direction in the other electrode, of which either the stripe electrodes, or the pixellated electrodes, or both, are transparent.

[0348] Alternatively the device acts solely as a beam power controller, or channel equaliser. In this case each stripe could be a single pixel. The set of stripes for each beam defines a block. Many blocks could be placed side by side to form a row of blocks, with each block in the row providing channel equalisation for a different beam. Many rows could also be provided so as to provide channel equalisation for signals coming in on different input fibres.

[0349] If a pair of confocal focusing elements is disposed between the output fibre and SLM then the output fibre receives an image of the field at the SLM. In this case the attenuation at the output fibre is governed by the orthogonality between the image and the fundamental mode of the fibre. Assuming, and without loss of generality, that a perfect image is formed such that sharp phase discontinuities are preserved, it may be shown that the coupling efficiency into the fundamental mode is proportional to the square of a sum of weighted integrals. The weight is the modulation exp $j\phi$ applied by a stripe, and the associated integral is over the area onto which that stripe is imaged. The integrand is positive and depends on the square of the local electric field associated with the fundamental mode. Each integral is represented as a phasor, with a length depending on how much of the fundamental mode power passes through the region onto which the stripe is imaged, and a phasor angle depending on the phase modulation. The net coupling efficiency is given by the magnitude of the vector summation of the individual phasors associated with each stripe. For simple devices it may be advantageous to use as few stripes as possible as this reduces any losses due to dead space between the stripes and reduces the control complexity. With only two stripes of approximately equal area (and hence two phasors of approximately equal length) the possible vector sums lie on a semicircle and hence the number of possible grey levels is equal to the number of phase levels between 0 and π, which may not be sufficient. Transverse offset of the output fibre with respect to the centre of the image has the effect of making the two phasors unequal and hence complete extinction is not possible. These problems may be overcome by using three or more stripes per hologram. For example with three stripes the loci of vector sums lie on circles centred about the semicircle taking just two of the stripes into consideration. Hence many more values are possible. Increasing the number of stripes increases the number of grey levels and the depth of attenuation.

[0350] A fibre spool is used on the output fibre before any splices are encountered. It will clear to those skilled in the art that other mode stripping devices or techniques could be used instead.

[0351] This system can also be adaptive: given knowledge of the applied phase by each stripe and enough measurements of the coupling efficiency, the lengths of the different phasors associated with each stripe can be calculated. Given these lengths the performance can be predicted for any other applied phases. Hence suitable algorithms can be included in the SLM or interface to train and adapt the device performance to cater for transverse offset of the output fibre and other misalignments.

[0352] Sharp edges or phase discontinuities in this image will be eroded by the optical modulation transfer function (MTF) but, nevertheless, where a sufficient number of stripes is provided it is possible to vary the phase modulation of each and achieve a wide range of attenuation.

[0353] Ultimately what limits the depth of attenuation is the residual zero-order due to, for example, an imperfect quarter-wave plate or Fresnel reflections from different surfaces inside the SLM such that the reflected light has not yet been phase-modulated. An example reflection is from the interface between the cover glass and transparent electrode. Such residual zero orders will couple into the output fibre independently of the phase modulation. In many cases the residual zero order will have a different polarisation state to the beam that has been properly processed by the phase modulation, so even adapting the phase modulation will not recover the depth of attenuation.

[0354] In such cases it is advantageous to apply some routing to the output fibre, such that the zero order is offset from the output fibre and the intended output beam is steered into a diffraction order of the routing hologram. For a many-pixellated SLM this may be achieved using the standard routing algorithm described earlier. For a simple SLM with few pixels, e.g. the one with the stripes in the plane of the input and output fibres, these stripes can be subdivided in an orthogonal direction, that is to create a 2-D array of pixels. This however increases the device complexity.

[0355] An alternative simple device is to combine it with a tip-tilt beam-steering element, as described in Optics Letters, Vol. 19, No 15, Aug. 1, 1994 "Liquid Crystal Prisms For Tip-Tilt Adaptive Optics" G D Love et al. In this case the top 'common electrode' is divided into a set of top electrodes, one for each device, where each device is assumed to receive a separate beam or set of beams. Each top electrode has different voltages applied on two opposite sides. The shape of the top electrode is such that the voltage between the electrodes varies nonlinearly in such a way as to compensate for the non-linearity of the phase vs. applied volts characteristic of the liquid crystal. Hence with all the stripe electrodes at the same voltage the device provides a linear phase ramp acting like a prism and deflecting the phase-modulated beam in a pre-defined direction, such that the residual zero order falls elsewhere, as required. Changing the stripe electrode voltage causes phase changes in the imaged beam but does not prevent the deflection. Small adjustments in the phase ramp can be used to compensate for component misalignments and/or curvature of the SLM substrate and/or wavelength difference from the design wavelength for the tip-tilt device. Such small adjustments in the phase ramp can also be used to achieve fine control over the attenuation. Hence such a device would be useful whether or not the required attenuation is sufficiently strong for the residual zero order to become a problem. Alternatively the top electrode can be divided into two or more areas, with the shape of each so as to compensate for the phase vs. volts non-linearity. Varying the voltage on the ends of each electrode can be used to offset the phase modulation of each stripe in order to create the desired attenuation. In this case the aluminium electrode would be common to the device, removing dead-space effects.

[0356] In another embodiment of the tip-tilt device, the top electrode is common to all devices and a shaped transparent electrode is provided, e.g. by deposition, on top of the quarter-wave plate, with connections to the SLM circuitry to either side of the device. In this case the aluminium may act only as a mirror and not as an electrode. Again the shaped transparent electrode may be subdivided into two or more areas to provide the attenuation. This embodiment avoids dead-space effects and also a voltage drop across the quarter-wave plate.

[0357] In a further embodiment, such a tip-tilt device has a shaped transparent electrode on both cover glass and quarter-wave plate. The planes of tip-tilt for the two devices may be orthogonal or parallel. With two parallel tip-tilt electrodes the device may act as a power-controlling two-way switch, and also, as will be described later, can be used in a multi-channel add/drop multiplexer. With two orthogonal tip-tilt electrodes the device can beam steer in 2-dimensions such as to correct for positional errors. Either of the two tip-tilt electrodes can be subdivided so as to provide attenuation.

[0358] One advantageous SLM is that described in our co-pending patent application EP1053501.

[0359] If there is a single focusing element between the output fibre and SLM then the field at the output fibre is the Fourier Transform of the field leaving the SLM. In this case three classes of phase modulation can be used to change the coupling efficiency into the output fibre. The first two classes assume a many-pixellated SLM while the third class assumes a few-pixel SLM with or without tip-tilt features as described earlier. In the third class the tip-tilt feature may be used to compensate for transverse positional errors in the input and output fibre.

[0360] The different classes of phase modulation result in a variable coupling efficiency at the output fibres using the following methods:

[0361] As noted above, the first class uses a many-pixellated SLM. A periodic phase modulation is applied that creates a set of closely spaced diffraction orders at the output fibre. The spacing is comparable to the fibre mode spot size such that there is significant interference between the tails of adjacent diffraction orders. The phases of these diffraction orders are chosen such that the resulting superposition is rapidly alternating in phase and therefore couples into the higher-order fibre modes. Varying the strength, phase and position of each diffraction order changes the attenuation. If the long sides of the stripes used to create this alternating output field are in the plane of the input and output fibres, then diffraction orders landing outside the target optical fibre fall along a line orthogonal to the output fibre array, and therefore do not cause crosstalk.

[0362] In the second class, again using a many-pixellated SLM, a non-periodic smoothly varying non-linear phase modulation is applied at the SLM, in this case the SLM acts as a diffractive lens such that the beam is defocused and couples into higher-order modes.

[0363] In the third class, which uses a simple SLM with few pixels, the pixels are used to apply phase distortion across the beam incident on the SLM. Such phase modulation can be considered to be equivalent to the first class but with a long period. The phase distortion at the SLM results in amplitude and phase distortion in the reflected beam and hence reduces the coupling efficiency into the output fibre.

[0364] Again, all three methods require use of a mode stripper on the output fibre. Again suitable algorithms can be included in the SLM or interface to train the system.

[0365] Another embodiment, not illustrated, uses a graded-index (GRIN) lens secured to one face of an SLM, and having input and output fibres directed on or attached to the opposite face. The SLM may provide selective attenuation, and/or may selectively route between respective input fibres and selected output fibres. A requirement for stable performance is fundamental for optical devices used in communications and like fields. One of the dominant manufacturing costs for such optical devices is device packaging. The GRIN lens architecture results in a compact packaged device resilient to vibrations. However, the architecture can have problems with spherical aberration and problems in achieving the required alignment accuracy. In particular there is often a requirement for precise transverse positioning of the fibres. Also due to manufacturing tolerances in the GRIN lens the focused spot in the reflected beam can be offset significantly in the longitudinal direction from the end face of the output fibre, resulting in an insertion loss penalty. This problem gets worse the longer the GRIN lens. Applying selected non-linear phase modulation to the SLM may compensate for problems such as focus errors, length errors, longitudinal positional errors and spherical aberration. Applying selected linear phase modulation to the SLM and/or using tip-tilt electrodes may compensate for problems such as transverse positional errors.

[0366] Optical systems using SLMs may individually process the channels from an ensemble of channels on different wavelengths, entering the system as a multiplex of signals in a common beam. Given a continuous array of pixels the SLM may also process noise between the channels. Hence the optical system acts as a multiwavelength optical processor. The processing may include measurement of the characteristics of the signals and accompanying noise as well as routing, filtering and attenuation.

[0367] In a first application, the SLMs carry out attenuation, known in this context as channel equalisation. A second application is a channel controller. A third application is an optical monitor. A fourth application is an optical test set. A fifth application is add/drop multiplexing. Further applications are reconfigurable wavelength demultiplexers and finally modular routing nodes. In all of these applications the SLMs may carry out routing and/or power control and/or beam shaping and/or sampling and/or corrective functions as described earlier. The system to be described is not restricted to this set of seven applications but is a general multi-wavelength system architecture for distributing the wavelength spectrum from one or more inputs across an array of devices and recombining the processed spectrum onto one or more selected outputs.

[0368] The inputs and outputs may be to and from optical networking equipment such as transmission systems, transmitter line cards and receiver line cards. Alternatively the inputs may be from one or more local optical sources used as part of a test set: either via an intermediate optical fibre or emitting directly into the optical system. The outputs may be to one or more local photo detectors for use in testing and monitoring. Applications outside the field of communications are also possible such as spectroscopy.

[0369] Such multi-wavelength architectures can be adaptations of optical architectures used for wavelength de-multiplexing. Wavelength demultiplexers typically have a single input port and many output ports. These can use one or more blazed diffraction gratings: either in free-space or in integrated form such as an AWG (Arrayed Waveguide Grating). These devices are reciprocal and hence work in reverse. Hence if a signal of the appropriate wavelength is injected into the output port it will emerge from the input port. The output port usually consists of an optical waveguide or fibre with an accepting end that receives a focused beam from the optical system and a delivery end providing an external connection. Now consider replacing the acceptance end of the output waveguide/fibre with a reflective SLM: all of the processed signals reflected straight back will couple into the input fibre and emerge from the input port. These signals can be separated from the input signal with a circulator. Alternatively the system is adapted so that the reflected signals emerge and are collected together into a different fibre.

[0370] Free-space optical systems performing wavelength de-multiplexing can use diffraction gratings made by ruling, or from a master, or made holographically, or by etching. Usually these work in reflection but some can work in transmission. One or two gratings can be used in the system. The optics used to focus the beams can be based on refractive elements such as lenses or reflective elements such as mirrors or a combination of the two.

[0371] Referring to FIG. 12, a channel equaliser 350 has a single grating 300 used with a refractive focusing element 310 and an SLM 320. To make the diagram clearer, the grating 300 is drawn as working in transmission. Other embodiments use two gratings and/or reflective focusing elements and/or gratings that work in reflection, such as blazed gratings.

[0372] A first input beam 301 from an input port 304 contains an ensemble of channels at different wavelengths entering the equaliser on the same input port 304. As a result of the grating 300 the beam 301 is split into separate beams 301a, 301b, 301c for each wavelength channel, each travelling in a different direction governed by the grating equation. The grating 300 is positioned in the input focal plane of a main routing lens 310 with a reflective SLM 320 at the output focal plane of the routing lens 310. If desired, there may also be a field-flattening lens just in front of the SLM 320.

[0373] If lens 310 were an ideal lens, rays passing through the same point on the focal plane of the lens, regardless of direction provided they are incident on the lens, emerge mutually parallel from the lens. As lens 310 is not a real lens, this is no longer strictly true: however well-known lens design techniques can be applied to make it true over the required spatial window.

[0374] Hence, the beams 301a, 301b, 301c that were incident upon the lens 310 from the same point on the focal plane, but at different angular orientations, emerge mutually parallel from the routing lens 310, but spatially separate. Thus, the lens refracts each beam to a different transverse position 320a, 320b, 320c on the SLM 320. At each position the SLM 320 displays a pixellated hologram and/or has a tip-tilt device for processing the relevant wavelength component of the beam. In the preferred embodiment, the SIM 320 is a continuous pixel array of phase-modulating elements and is polarisation independent. The width of each hologram or tip/tilt device compared to the spot size of the incident beam incident is sufficient to avoid clipping effects. Instead, or additionally, beam shaping may be used. The device may be controlled to deflect or attenuate the beam as described earlier, and provides output processed beams 302a, 302b, 302c. Beams 302a and 302b have moderate channel equalisation applied by a power control hologram and routing towards the output port 305 applied by a routing hologram. As explained previously it is advantageous to use a routing hologram as it deflects the beams from their specular output direction and hence increases the available depth of attenuation. Beam 302c has strong attenuation applied in order to "block" the channel: this is achieved by selecting holograms that direct the light well away from the output port 305 towards, for example, an optical absorber 306. The processed beams are reflected back from the SLM 320 towards the main lens 310 and then refracted back by the main lens towards the diffraction grating 300. Assuming the SLM 320 is flat, all beams subjected to the same deflection at the SLM 320 and entering the system in the same common input beam emerge mutually parallel from the diffraction grating. Curvature of the SLM 320 is compensated by small changes in the deflection angle achieved due to the holograms displayed on the SLM 320. As the light beams 302a, 302b emerge parallel from the SLM 320 they are refracted by the lens 310 to beams 303a, 303b propagating towards a common point in the grating 300, which (having the same grating equation across the whole area of concern) diffracts the beams to provide a single output beam 302. Note that due to the action of the lens, beam 303a is parallel (but in the opposite direction) to beam 301a and beam 303b is parallel (but in the opposite direction) to beam 301b. Therefore all beams subjected to the same eventual output angle from the SLM 320 are collected into the same output port 305. Hence a system may be constructed with a single input port 304 and a single output port 305 that produces independent attenuation or level equalisation for each wavelength channel. Note that to obtain the same deflection angle for all wavelength channels, as required, the effective length of the hologram phase ramp, Ω/m, where m is the mode number of the excited diffraction order and Ω is the hologram period, should be adjusted in proportion to the channel wavelength. That is the wavelength dependence of the beam deflection should be suppressed.

[0375] As described later the channel equalisation can be uniform across each channel so as to provide the required compensation as measured at the centre of each channel. Alternatively the channel equalisation can vary across each channel, so as to compensate for effects such as amplifier gain tilt that become important at higher bit rates such as 40 Gb/s. Channels may be blocked as described earlier so as to apply policing to remote transmitters that renege on their access agreements or whose lasing wavelength has drifted too far. Furthermore the noise between selected channels may be partially or completely filtered out, as described later. Hence in a second application the multiwavelength optical processor acts as a channel controller.

[0376] Although such processing can be applied using conventional optics the multiwavelength optical processor has a number of advantages. Compared to a series of reconfigurable optical filters the multiwavelength processor has the advantage that the channels are processed by independent blocks of pixels. Hence reconfiguration of the processing applied to one or more selected channels does not cause transient effects on the other channels. Compared to a parallel optical architecture that separates the channels onto individual waveguides/fibres before delivery to a processing device (and hence avoids the transient effects) the multiwavelength optical processor has a number of advantages. Firstly it can process the whole spectrum entering the processor (subject to the grating spectral response). Secondly the filter passband width is reconfigurable and can be as much as the entire spectrum, reducing concatenation effects that occur when filtering apart sets of channels routed in the same direction. Thirdly the filter centre frequencies are reconfigurable. Further advantages are discussed later in this application.

[0377] By having a choice of two or more deflection angles at the SLM every input channel may be routed independently to one of two or more output ports. There may also be two or more input ports. It may be shown that for one or more parallel input beams, the action of the grating and main routing lens is such that all channels at the same wavelength but from different input ports are incident at the same transverse position at the SLM. Again this is because "parallel rays converge to the same point". Hence these channels at the same wavelength are incident on the same channel processing hologram and/or tip-tilt device. As every wavelength channel is incident on a different device, the device response may be optimised for that particular wavelength. For example if a pixellated SLM is used the deflection angle is proportional to the wavelength. Hence small adjustments in the phase ramp can be used to adjust the deflection angle to suit the wavelength to be routed. All channels incident on a particular transverse position on the SLM must be reflected from that same position. As this position is in the focal plane of the lens beams from said position will emerge parallel from the lens and travelling towards the grating. After the grating the beams will be diffracted (according to their wavelength). It may be shown that all beams entering the system in a parallel direction will emerge from the system in exactly the opposite direction. It may also be shown that all beams subject to the same output angle from the SLM will emerge coincident from the system and may therefore be collected into the same port.

[0378] Analysis of the beams at the diffraction grating in this architecture shows that the spot size required for a given wavelength channel separation and beam clipping factor C at the hologram depends on the grating dispersion but does not depend on the routing lens focal length nor the number of output ports. The beam centres must be far enough apart to provide adequate crosstalk suppression. Hence the greater the number of output beams the further the beam must be steered by the SLM and lens. As an example consider just routing in 1-D, into the m'th diffraction order with a hologram period , Ω and a routing lens of focal length f. The output beam at the diffraction grating will be offset from its zero order reflection by a distance given approximately by $f.m.\lambda/\Omega$, where λ is the optical wavelength and Ω/m is the effective length of the phase ramp on the hologram (as explained previously). To increase this offset distance the length of the phase ramp can be reduced, which tends to require smaller pixels, or the lens focal length can be increased. In practice there is a lower limit to the pixel size set by the dead space losses and the size of the pixel drive circuits, while increasing the lens focal length makes the overall system longer. This can be a particular problem when there are many output ports, even when close-packing 2-D geometries are used for the output beams.

[0379] Referring to FIG. 14, another method is to put a demagnification stage between the SLM 400 and a routing lens 404. This is positioned so that the SLM 400 is in the object plane of the demagnification stage while the image plane of the demagnification stage 402 is where the SLM would otherwise be, that is in the focal plane of the routing lens 404. What appears in this image plane is a demagnified image of the SLM 400, which therefore acts like a virtual SLM 402 with pixels smaller than those of the real

SLM 400 and hence a shorter effective phase ramp length. As an example consider the two lens confocal magnification stage shown in FIG. 14. In FIG. 14 f1 is the focal length of the first lens 401 and f2 is the focal length of the second lens 403 (closer to the virtual SLM). The demagnification is f2/f1 while the beam-steering deflection angle is magnified by f1/f2.

[0380] While this method for increasing the effective beam deflection angle has been described and illustrated in the context of one particular routing architecture it could also be applied to other optical architectures using SLMs to process an optical beam, for routing and other applications. The operating principle is that the virtual SLM 402 has an effective pixel size and hence an effective phase distribution that is smaller in spatial extent than that of the real SLM 400, by an amount equal to the demagnification ratio of the optics. The off-axis aberrations that occur in demagnification stages can be compensated using any of the methods described in this application or known to those skilled in the art.

[0381] In an alternative embodiment the input beam or input beams contain bands of channels, each incident on their own device. In this and the previous embodiment for the channel equaliser the beam deflection or channel equalisation may vary discontinuously with wavelength.

[0382] In a third embodiment the input beam could contain one or more signals spread almost continuously across the wavelength range. The light at a particular wavelength will be incident over a small transverse region of the SLM, with, typically a Gaussian type spatial distribution of energy against position. The position of the peak in the spatial distribution is wavelength dependent and may be calculated from the grating and lens properties. For such a system the beam deflection or channel equalisation varies continuously with wavelength. The pixellated SLM is divided into blocks, each characterised by a 'central wavelength', defined by the wavelength whose spatial peak lands in the middle of the block. A particular channel equalisation or beam deflection is applied uniformly across this block. Light of a wavelength with a spatial peak landing in between the centres of two blocks will see a system response averaged across the two blocks. As the spatial peak moves towards the centre of one block the system response will become closer to that of the central wavelength for the block. Hence a continuous wavelength response is obtained. The block size is selected with respect to the spatial width of each beam in order to optimise the system response. This method is particularly attractive for increasing the wavelength range of a 1 to N switch.

[0383] To achieve this aim the multi-wavelength architecture described earlier, should be configured so as to allow reconfigurable routing from a single input port to one of a set of multiple output ports. The length of the phase ramp used to route the beam to each output port should vary slowly across the SLM such that the wavelength variation in the deflection angle is minimised, or certainly reduced considerably compared to the case for which the phase ramp length is uniform across the SLM. Hence the transverse position of each output beam will vary considerably less with wavelength, with a consequent reduction in the wavelength dependence of the coupling efficiency at the system output. Alternatively, the length of the phase ramp can be varied spatially so as to obtain some desired wavelength dependence in the coupling efficiency.

[0384] The efficiency of a blazed diffraction grating is usually different for light polarised parallel or perpendicular to the grating fringes. In the multi-wavelength systems described above the effect of the quarter-wave plate inside the SLM is such that light initially polarised parallel to the grating fringes before the first reflection from the blazed grating is polarised perpendicular to the grating fringes on the second reflection from the blazed grating. Similarly the light initially polarised perpendicular to the grating fringes before the first reflection from the blazed grating is polarised parallel to the grating fringes on the second reflection from the blazed grating. Hence, in this architecture, the quarter-wave plate substantially removes the polarisation dependence of the double pass from the blazed grating, as well as that of the phase modulation. As is clear to those skilled in the art, this polarisation independence requires the fast and slow axes of the integrated quarter-wave plate to have a particular orientation with respect to the grating fringes. This required orientation is such that the integrated quarter-wave plate exchanges the polarisation components originally parallel and perpendicular to the grating fringes.

[0385] Referring to FIG. 28 a wavelength routing and selection device 600is shown.

This device has a multiwavelength input 601 from an input port 611, and provides three outputs 602, 603, 604 at output ports 612-614.

[0386] The device 600, similar to the device of FIG. 12, has a grating 620, a lens 621 and an SLM 622, with the disposition of the devices being such that the grating 620 and SLM 622 are in respective focal planes of the lens 621. Again the grating is shown as transmissive, although a reflective grating 620, such as a blazed grating, would be possible. Equally, the SLM 622 is shown as reflective and instead a transmissive SLM 622 could be used where appropriate.

[0387] The grating 620 splits the incoming beam 601 to provide three single wavelength emergent beams 605, 606, 607 each angularly offset by a different amount, and incident on the lens 621. The lens refracts the beams so that they emerge from the lens mutually parallel as beams 615,616, 617. Each of the beams 615,616,617 is incident upon a respective group of pixels 623,624,625 on the SLM 622. The groups of pixels display respective holograms which each provide a different deviation from the specular direction to provide reflected beams 635, 636 and 637. The beams 635, 636, 637 are incident upon the lens 621 and routed back to the grating 620.

[0388] In the embodiment shown, the beams 605 and 606 are finally routed together to output port 614 and the beam 607 is routed to output port 612. No light is routed to port 613.

[0389] However it will be understood that by careful selection of the holograms, the light can be routed and combined as required. It would be possible to route light of a selected frequency right out of the system if needed so as to extinguish or "block" that wavelength channel. It is also envisaged that holograms be provided which provide only a reduced amount of light to a given output port, the remaining light being "grounded", and that holograms may be provided to multicast particular frequencies into two or more output ports.

[0390] Although the number of output ports shown is three, additional output ports can be included: with appropriate lens design the insertion loss varies weakly with the number of output ports. Although the output ports are shown in the same plane as the input it will be clear to those skilled in the art that a 2-D distribution of output ports is possible.

[0391] Hence the device 600 provides the functions of wavelength demultiplexing, routing, multiplexing, channel equalisation and channel blocking in a single subsystem or module. These operations are carried out independently and in parallel on all channels. Reconfiguration of one channel may be performed without significant long-term or transient effects on other channels, as occurs in serial filter architectures. With most conventional optics (including parallel architectures) separate modules would be required for demultiplexing, routing, multiplexing and the power control functions. This adds the overheads of fibre interconnection between each module, separate power supplies, and a yield that decreases with the number of modules. The device 600 has no internal fibre connections, and a single active element requiring power-the SLM. Each active processing operation (routing, power control, monitoring etc) requires an associated hologram pattern to be applied by the controller but may be carried out by the same SLM, hence the yield does not decrease with increased functionality. Although integrated optical circuits can be made that combine different functions, in general they require a separate device inside the optical chip to perform each function. Again the power (dissipation) and the yield worsen with increased functionality.

[0392] Further applications of the multiwavelength optical processor are as an optical performance monitor, and as a programmable multifunction optical test set. In both applications the SLM may perform two or more different but concurrent monitoring or testing functions on two or more portions of the wavelength spectrum. This may be achieved by applying routing holograms to the pixel block associated with said portions of the wavelength spectrum that connect optically a selected input fibre or input optical source to a selected output fibre or output detector. The routing hologram applied to each portion of the spectrum may be reconfigured as required in order to perform different testing or monitoring functions on said portion of the spectrum. To each output photo detector or to each input optical source is applied control circuitry for carrying out the required tests.

[0393] Considering firstly the performance monitor, the method described later to measure the centre wavelength of a channel may be applied to a selected channel in order to monitor the lasing wavelength. Earlier in this application there is a description of how to measure the second order moments of a beam. Consider orthogonal axes u and v at the SLM. Choose the orientation of these axes such that all wavelength channels entering the system and incident on the grating in the defined parallel direction have the centres of their associated beams along a line of constant v. Hence the position along the u axis increases with wavelength. The second order moment in the v direction is related to the spot size of a monochromatic beam. The second order moment in the u direction is related to this spot size and also the wavelength distribution of the energy in each channel. Hence by measuring second order moments, as described previously, an estimate of the channel bandwidth may be obtained. The noise power between a selected pair of channels may be measured by routing that part of the spectrum between the channels towards a photo detector. Similarly the power of a selected channel may be measured by routing towards a photo detector. One or more photo detectors may be assigned to each type of measurement is allowing many parallel tests to proceed independently on different portions of the spectrum. Alternatively the control circuitry associated with each photo detector output may be designed to be able to perform two or more of the required monitor functions.

[0394] Hence the multiwavelength optical processor acts as an optical spectrum analyser with integrated parallel data processing. Conventional methods for achieving this use either a grating that is rotated mechanically to measure different portions of the spectrum with a photo detector in a fixed position, or a fixed grating with a linear photodiode array. In both cases data acquisition hardware and software and data processing are used to extract the required information from the measured spectrum. Both systems are expensive and require stabilisation against the effects of thermal expansion. The multiwavelength optical processor has no moving parts, can use as few as a single photodiode, and can adapt the holograms to compensate for temperature changes, ageing, aberrations as described previously in this application. The multiwavelength processor also carries out the data processing to measure centre wavelength and channel bandwidth in the optical domain. When used in a communications network the optical performance monitor would pass the processed data from the measurements to a channel controller, such as the one described previously, and also to a network management system. The signal for monitoring would be tapped out from a monitor port at the channel controller or from a routing system or from elsewhere in the network. The monitor processing could be implemented with the same or a different SLM to the channel controller. Monitor processing can also be implemented with the same or different SLMs used to route beams in the add drop routers and routing modules described later in this application. The control electronics for the monitor processing can be integrated with the control electronics for the pixel array.

[0395] With reference to FIG. 30, the programmable multifunction optical test set 900 has a multiwavelength optical processor 928 with one or more inputs 901, 902 from optical sources, 903, 904 each with control circuitry 905, 906 for performing one or more tests of optical performance. The channel equalisation and blocking functions described earlier may be used to adapt the spectrum of the selected source to suit a particular test. The channel filtering functions described later may be used to synthesise a comb or some other complex wavelength spectrum from a selected broadband optical source. A further input 907 from an optical source 910 may be used to exchange data and control information from control and communications software 929 with the same 900 or one or more other optical test sets, allowing remote operation over the fibre under test, or some other fibre. One or more outputs ports 911, 912 from the multiwavelength optical processor are connected to a set of optical fibre transmission systems (or other devices) 913, 914 to be tested. Routing holograms are applied to the pixels associated with the selected parts of the spectrum to direct said parts of the spectrum or said data and control information to the selected output port. A further or the same multiwavelength optical processor has input ports 917, 918 connected to the set of optical fibre transmission systems (or other devices) 915, 916 under test and output ports 919, 920 connected to a set of one or more photo detectors, 921, 922 each with associated control circuitry 925, 926 for carrying out testing functions. A further photo detector 924 connected to a further output port 923 is used to receive data and control information from one or more other test sets. Routing holograms are applied to direct the signals from the selected input port to the required photo detector. The optical monitor functions described above can be applied to the signals. The frequency shaping of the source or spectrum can take place at the transmitting test set or the receiving test set. The control electronics for the test set 927 and control and communications software 929 can be integrated with the control electronics for the pixel array.

[0396] Conventionally, different optical sources would be used to perform different types of test on the wavelength and transmission properties of fibres or devices under test; a separate optical switch would be used to poll the devices under test, and an external communications link would be used for communication of data and control information with a remote test set. However, the multiwavelength optical processor may be used to provide a multifunction programmable optical test set that is capable of remote operation. The test set may include as few as a single source and a single photo detector and performs a wide range of tests on fibres or devices selected from a group of fibres or devices attached to the test ports of the multiwavelength processor.

[0397] A multiwavelength system with two inputs and two outputs can work as an add/drop multiplexer. Add-drop multiplexers are usually used in ring topologies, with the 'main' traffic travelling between the ring nodes, and 'local' traffic being added and dropped at each node. Considering each node, one input (main in) is for the ensemble of channels that has travelled from the 'previous' routing node. The second input (add) is for the ensemble of channels to be added into the ring network at the add/drop node. One output (main out) is for the ensemble of channels travelling to the 'next' routing node while the second output (drop) is for the ensemble of channels to be dropped out of the ring network at the node. If a particular incoming wavelength channel is not to be 'dropped' at the node, then the channel-dedicated device at the SLM should be configured to route the incoming wavelength from the main input to the main output. However, if a particular incoming wavelength channel is to be dropped, then the channel-dedicated device at the SLM should be configured to route the incoming wavelength from the main input to the drop output. In this case the main output now has available capacity for an added channel at that same wavelength. Therefore the channel-dedicated device at the SLM should also be configured to route the incoming wavelength from the add input to the main output.

[0398] The multiwavelength optical processor described in this application distributes wavelength channels across and collects the wavelength channels from a single SLM, allowing the SLM to provide a set of one or more processing operations to each of the channels. However, in most conventional reconfigurable add drop multiplexers, the routing has to be carried out in two successive stages. Usually a first 1*2 switching stage either drops the channel or routes the channel through, while a second 2*1 switching stage either receives the through channel from the first stage or receives an added channel. Fortunately, careful choice of the deflection angles applied by the SLM, and the sharing of the same hologram by input signals at the same wavelength, allows add drop routing to be carried out in a single stage. Hence add drop routing may be conveniently applied in an independent and reconfigurable manner to every wavelength channel in the multiwavelength optical processor.

[0399] An explanatory diagram is shown in FIG. 13a.

[0400] Referring now to FIG. 13a, an SLM 141, used in the context of the multi-wavelength architecture, has a pixel block 140 and/or tip-tilt device upon which a main input beam 130 is incident, at an angle m1 to the normal 142. The main beam has a zero order or specular reflection 130a. Holograms are made available that will cause deflections at $+\theta_1$ to the specular direction and $-\theta_2$ to the specular direction. Due to the display of a first hologram on the pixel block 140, the main output is deflected by $+\theta_1$ from the specular direction to a main output beam 132. An add input 131 is incident at an angle a1 on the block 140, and produces a zero order reflection 131a. The device also has a drop output beam direction 133.

[0401] When the hologram applying the deflection of $+\theta_1$is displayed, light at the relevant wavelength entering in the add direction 131 is not steered into either of the main output beam direction 132 or the drop output beam direction 133. Effectively it is 'grounded'. This feature may be used to help to stop crosstalk passing between and around rings.

[0402] When the hologram applying the alternative deflection of $+\theta_2$ is applied, the add input is routed to the main output beam direction 132 while the main input is routed to the drop output beam direction 133.

[0403] In the interests of clarity, a simplified diagram may be used to explain an add-drop using 1-D routing. This is shown in FIG. 13b in which the point 134 represents the output position of the specular reflection from the add input while the point 135 represents the output position of the specular reflection from the main input. When a first routing hologram is applied the main output beam is deflected by an angle of $+\theta_1$ and therefore the output position of the main beam is deflected by an offset of $f.\theta_1$, compared to the output position 135 of its specular reflection. Here f is the focal length of the routing lens. In FIG. 13b this deflection is represented as a vector 136a and the output beam is routed to the main output 137. The beam from the add input is subject to the same angular deflection with respect to its specular reflection and is thus deflected by a vector of equal length and the same direction 136b with no output port to receive it this beam is "grounded". When a second routing hologram is applied the main output beam is deflected in the opposite direction by a vector 138a to arrive at a drop output 139. The beam from the add input is deflected by an identical vector 138b to arrive at the main output 137.

[0404] The example in FIG. 13a assumes 1-D routing due to the hologram. Given an ability to route in 2-D, either with two orthogonal tip-tilt electrodes or a 2-D pixel array (as described previously) the arrangement of the four ports can be generalised, as shown in FIG. 15. The use of 2-D routing allows closer packing of the input and output beams reducing off-axis aberrations. In FIG. 15 the output positions are shown in 2-D. The point 151 represents the output position of the zero order (specular) reflection from the add input while the point 152 represents the output position of the zero-order reflection from the main input. The hologram deflections are represented as vectors 155a, 155b, 156a and 156b. Vector 155b has the same length and direction as vector 155a and vector 156b has the same length and direction as vector 156a. When a first routing hologram is applied the add input beam is deflected from its specular output position 151 by the vector 155b to the main output 154 while the main input is deflected from its specular output position 152 by the identical vector 155a to the drop output 153. When the alternate routing hologram is applied the main input is deflected from its specular output position 152 by the vector 156a to the main output 154 while the add input is again 'grounded' due to deflection by the identical vector 156b.

[0405] In this general configuration there are six variables. These are the output positions of the main output and drop output, the positions of the zero order reflections from the main input and add input, and the two hologram deflections. Of these six variables only three are mutually independent.

[0406] For example, selection of the input position for the main input with respect to the routing lens axis defines the output position of the zero order reflection, 152. If this is followed by selection of the output positions for the main and drop outputs with respect to the routing lens axis then all three independent variables have been defined. Hence the required hologram deflections are determined as is the input position for the add input with respect to the routing lens axis (which then defines 151).

[0407] FIGS. 13a, 13b and 15 show the hologram deflections required to provide add-drop routing: FIGS. 13a and 13b assume 1-D routing while FIG. 15 assumes 2-D routing. A multiwavelength add-drop architecture using such hologram deflections is shown in FIG. 29. Compared to other methods for achieving add-drop functionality, the advantages are as described previously for FIG. 28.

[0408] Turning now to FIG. 29, an add/drop multiplexer device 700 has two input ports 701, 702 and two output ports 703,704. The first input port 701 is for an input beam 711 termed "add" and the second input port 702 is for a second input beam 712 termed "main in" having two frequencies in this embodiment. The first output port 703 is for a first output beam 713 termed "drop" and the second output port 704 is for a second output beam 714 termed "main out"

[0409] The input beams 711, 712 are incident upon a grating 720 that deflects the beams according to wavelength to provide emergent beams 731, 732 and 733. The emergent beams 731, 732 and 733 are incident upon a lens 722 having its focal plane at the grating 720, and the beams emerge from the lens respectively as beams 741, 742, and 743 to be incident upon an SLM 722 in the other focal plane of the lens 721. As the beams 741, 742 do not originate on the grating 720 from the same location, they are not mutually parallel when emerging from the lens 721. The beam 743 is from a point on the grating 720 common to the origin on the grating 720 of beam742, and hence these beams are mutually parallel. Although the grating is drawn as transmissive and the SLM as reflective, these types are arbitrary.

[0410] The first beam 731 and the third beam 733 are at the same wavelength, hence they emerge parallel from the grating 720 and are refracted by the lens 721 propagating as beams 741 and 743 respectively to a first group or block of pixels 723 on the SLM 722. This pixel block 723 applies the required hologram pattern that routes a channel entering the add port 701 to the main output 704, and also routes a channel entering the main input 702 to the drop port 703. Hence the first group of pixels 723 deflects the first beam 741 to provide first reflected beam 751, and deflects the third beam 743 to provide third reflected beam 753.

[0411] The second beam 732 is at a different wavelength to the first and third beams 731 and 733 and therefore emerges at a different angle from the grating 720. This third beam is refracted by the lens 721 and propagates as beam 742 to a second group of pixels or pixel block 724 on the SLM 722. This second group of pixels applies the hologram pattern that routes a channel entering the main input port 702 to the main output port 704 and "grounds" a channel entering the add port 701. The second group of pixels 724 deflects the second beam 742 to provide the second reflected beam 752. The holograms on the first and second groups of pixels are selected, (examples were described for FIGS. 13a, 13b and 15), so that the first and second reflected beams 751,752 are mutually parallel; the third beam 753 is routed in a different direction. The consequence of this is that the first and second beams 751,752, after passing again through the lens 721 become incident at a common point 726 on the grating 720, and emerge as main out beam 714. The third beam 753 is incident upon a different point on the grating 720 and emerges into as the drop beam 713.

[0412] In most cases ring networks are bi-directional, with separate add/drop nodes for each direction of travel. In some networks a loopback function is required. This allows isolation of one segment of the ring in case of link failure, for example. It also allows the transmission systems for both directions of a link between two nodes to be tested from a single node. This latter function is useful to confirm that a failed link has been repaired. Loop back requires the main input on each add/drop node to be routed to the main output on the other add/drop node, as shown in FIG. 16.

[0413] The figure shows a first module 161a and a second module 161b. The first module 161a has a main input 162a, an add input 166a, a loop back input 165a, a main output 163a, a drop output 167a and a loop back output 164a. The second module 161b has a main input 162b, an add input 166b, a loop back input 165b, a main output 163b, a drop output 167b and a loop back output 164b.

[0414] The node is divided into two sides: a west side 168 and an east side 169. Loop back may be required for one or for both sides of the node. Channels coming from the ring enter the first module 161a on a main input 162a and enter the second module 161b on a main input 162b. In normal operation through channels will be routed from the main input 162a to the main output 163a and from the main input 162b to the main output 163b.

[0415] In loop back operation for the west side 168 the through channels entering the input 162a on the first module 161a are routed to the loop back output 164a. This output 164a is connected to the loop back input 165b of the second module 161b. In loop back operation for the west side all channels entering the input 165b are routed to the main output 163b of the second module 161b.

[0416] In loop back operation for the east side 169 the through channels entering the second module 161b on the main input 162b are routed to the loop back output 164b. This output 164b is connected to the loop back input 165a of the first module 161a. In loop back operation for the east side 169 all channels entering the input 165a are routed to the main output 163a of the first module 161a.

[0417] The function can be implemented in the four port add drop node (explained in FIGS. 13, 13a, 15 and 29) by selecting a further hologram deflection 179a and 179b, as shown in FIG. 17. In the four port architecture both sides of the node loop back at the same time. This is due to the sharing of the same hologram by input signals at the same wavelength. In FIG. 17 the vector 179a deflects the main input from its specular output position 172 to the loop back output 176. The identical vector 179b is applied by the shared hologram to the loop back input such that it is deflected from its specular output position 173 by the identical vector 179b to the main output 175. The other vectors 177a, 177b, 178a and 178b are used for normal add-drop operation: 174 is the drop output and 171 is the specular output position for the add input.

[0418] When such a hologram is applied the main input is routed to the loopback output and the loop back input is routed to the main output. The two add/drop nodes are then connected as in FIG. 16.

[0419] The loop back function can be implemented in other add drop architectures (described later) by reserving drop ports for loop back out and add ports for loop back in. In these other architectures the loop back may be applied to just one side of the node, as well as to both sides.

[0420] The method used to provide loop back ports may also be applied to the multiport add drop (FIG. 18). This method may be used to provide cross connection ports to exchange channels between adjacent add drop nodes.

[0421] It is also possible to devise holograms for multicast, i.e. forwarding an incident light beam to each of several outputs. Such a hologram can be applied to route the main input to two outputs, with vectors 177a and 178a (in FIG. 17). In this case the device is performing a drop and continue function. This is required to provide a duplicated path at nodes connecting two touching ring networks.

[0422] Alternatively, or additionally, additional inputs and outputs can be provided so as to have a separate input for each added channel and a separate output for each dropped channel. This saves the expense and space taken up by additional filtering and/or wavelength multiplexing components that would otherwise be used to combine all added channels onto a common add port, and to separate all dropped channels to individual receivers. An example layout is shown in FIG. 18. In such an implementation care must be taken that sufficient distance is provided between the zero order reflections from each input, and the output positions for each output, so as to control the crosstalk. In FIG. 18 deflection v2 is used to deflect channels entering the main input from the specular output position m0 to the main output position m2. Deflections v4 to v7 are used to route from the four add inputs (with specular output positions a1, a2, a3 and a4) to the main output m2. Identical deflections v4 to v7 are applied by the shared holograms to deflect the main input from its specular output position m0 to the four drop outputs d1 to d4. For example if wavelength channels$\lambda 5$ and $\lambda 7$ enter on add input 2 which has its zero order (specular) reflection at a2, the holograms associated with these wavelength channels are configured to produce deflection v5. Hence these two channels will exit from the main output m2. Any channels entering the main input on these two wavelengths will experience the same hologram deflection, and will then exit from output d2.

[0423] In one implementation of the multiwavelength architecture the optics between any input fibre and the corresponding input beam that arrives at the diffraction grating, is such that the beam spot that arrives at the SLM is an image of the beam spot that leaves the input fibre. Similarly the optics between any output beam and the corresponding output fibre is such that the beam spot that arrives at the output fibre is an image of the beam spot that leaves the SLM. An example embodiment that would achieve this behaviour is to have an individual collimating lens associated with and aligned to every optical fibre.

[0424] Referring to FIG. 27, it is assumed that two adjacent channels are being routed in a different direction to the channel under consideration. Thus the beam under consideration has a first hologram 500, and the two adjacent beams have contiguous holograms 501 and 502 respectively. The beam under consideration has an intensity distribution shown as 510. Hence the energy incident from the beam under consideration on the two adjacent holograms, shown as 511 and 512, is lost. Given a perfect optical system what arrives at the selected output fibre is a demagnified image of the truncated beam. Due to the way that the optical system works, the centre line of the beam incident at the output fibre will be lined up with the centre of the output fibre (indeed the beam deflection angle at the SLM should be adjusted so this is the case).

[0425] To each wavelength channel there is assigned a block of pixels applying the same routing hologram. Preferably this block of pixels should be chosen such that an input light beam exactly at the centre wavelength for the channel arrives at the SLM such that the centre of the beam is within a half pixel's width of the centre of the assigned pixel block. In the presence of thermal expansion of the optomechanical assembly the centre of said beam may arrive at a different point on the pixel block resulting in partial loss of signal as more of the beam tails are lost. This problem can be avoided either by expensive thermally stable optomechanics or by dynamic reassignment of pixels to the blocks associated with each channel. For this to be achievable the pixel array should be continuous. This continuity of the pixel array is advantageous for thermal stability whether or not the imaging criterion used to calculate the filter response is satisfied.

[0426] The way that the architecture behaves is that for all parallel beams incident on the grating, the position at which the beam at a particular wavelength reaches the SLM is independent of the input port. Hence a reference signal of known wavelength will be incident at the same particular point on the SLM, whether it comes in with any of the signals to be routed, or on a separate input. The method to measure the position of the beam centre can be used on one or a pair of such reference signals. Given this information, an interpolation method can be used to measure the wavelength of some other signal entering the system on one of its input ports, given the measurement of the position of the centre of the beam associated with said other signal. This information can be used to monitor the behaviour of the original transmitter lasers, and also to inform the controller for the routing system.

[0427] Furthermore, given the position of said reference beams as they reach the SLM, and also the centre wavelength(s) of (an)other signal(s) entering the system, the position of the beam(s) at said centre wavelength(s) upon the SLM may also be calculated. This information can be used to control the adjustment of the pixel blocks and/or holograms used to route and control said other signal(s). Conversely the position of said reference beams may be used to select a pixel block that provides a given required centre wavelength for a filter. Hence reconfigurable assignment of pixel blocks may be used to tune the centre wavelength of one or more filter pass bands.

[0428] For the purpose of calculating the wavelength filtering response it is assumed that the centre of the beam at the centre wavelength of the channel (shown as 500 in FIG. 27) arrives exactly at the centre of the associated pixel block. With reference to

FIG. 31, as the wavelength is increased above the centre wavelength of the channel the centre line 946 of the beam 940 lands at a distance 941 away from the centre 945 of the pixel block or hologram 942. As a result of the offset 941 due to wavelength difference, the beam loses more energy 943 to the adjacent hologram 944. Assuming perfect imaging, what arrives at the output fibre is a demagnified image of this truncated beam.

[0429] An important difference for the multi-wavelength architecture, compared to conventional wavelength demultiplexers, is that a wavelength difference from the centre of a wavelength channel does not (to first order) result in an offset error of the beam at the output. This is because of the way the second pass from the grating 'undoes' the dispersion of the (fixed) diffraction grating, as was shown, for example, in FIG. 12. Hence the original centre line of the truncated beam should be aligned with the peak of the fundamental mode in the output fibre, or, equivalently, aligned with the optical axis of the output fibre. Standard methods for the calculation of coupling efficiency into single-mode fibres have been used to calculate the filter characteristics. Example results are in FIGS. 19 and 20.

[0430] FIG. 19 shows the relative transmission Tlo for in-band wavelengths as a function of the ratio of the wavelength offset u to centre of the wavelength channel separation. Each curve in the Figure is for a different value of the hologram clipping factor (CR) in the range 2 to 4: this factor is defined as the ratio of the hologram width to the beam spot size at the hologram.

[0431] FIG. 20 shows the relative transmission Thi inside the adjacent channel, with u=1 at the centre of the adjacent channel while u-0.5 is at the boundary with the adjacent channel. Again, each curve in the Figure is for a different value of the hologram clipping factor (CR) in the range 2 to 4. FIGS. 19 and 20 also show that a change in the width of the pixel block assigned to the filter passband (that is a change in CR) will change the passband width and extinction rate at the edges of the passband. Hence reconfigurable assignment of pixel blocks may be used to tune the shape and width of the filter pass bands.

[0432] Independently of the clipping factor, the suppression at the edges of the wavelength channel is 6 dB and the full width half maximum (FWHM) filter bandwidth is approximately 80% of the channel separation. Comparison of the different curves in FIG. 19 shows that the flatter the filter passband the steeper the skirts at the edges, leading to greater extinction of the adjacent channel, as shown in FIG. 20.

[0433] This behaviour is advantageous as it avoids the usual tradeoff between adjacent channel extinction and centre flatness. Good centre flatness means that the filters concatenate better, so more routing nodes using such filters can be traversed by a signal before the signal spectrum and hence fidelity starts to deteriorate. Good adjacent channel extinction is also important as it prevents excessive accumulation of crosstalk corrupting the signal.

[0434] For example, in a known conventional wavelength demultiplexer the filter pass bands are Gaussian and the 1 dB and 3 dB filter bandwidths are inversely proportional to the square root of the adjacent channel extinction (in dB), such that the greater the extinction, the narrower the filter passband. For the same FWHM filter bandwidth of 80% a Gaussian filter would have an adjacent channel extinction weaker than 20 dB, leading to crosstalk problems. However for the SLM multi-wavelength architecture the adjacent channel extinction is better than 30 dB, avoiding such problems in most known networks.

[0435] As is well-known to those skilled in the art, an arbitrary beam incident on an optical fibre couples partially into the fundamental mode of the fibre with the rest of the beam energy coupling into a superposition of the higher order modes of the fibre. The higher order modes may be stripped out with a fibre mode stripper. The coupling efficiency into the fundamental mode is given by the modulus squared of the ratio of an overlap integral divided by a normalisation integral. The overlap integrand is the product of the incident field and the fundamental mode. The normalisation integrand is the product of the fundamental mode with itself.

[0436] FIGS. 33 and 34 are included with the aim of explaining the behaviour of the 'imaging filter' as described above. FIG. 32 shows the truncated incident beam profiles 960-964 as the wavelength is increased from the centre of the channel under consideration, 960, to the centre of the adjacent channel, 964. Truncated beams 961, 962 and 963 are for wavelength differences of a quarter, a half and three-quarters, respectively, of the channel separation. In the diagram the truncated beam profiles are offset vertically for clarity. The beam profiles are aligned horizontally as they would be physically at the output fibre; the original centre of each truncated beam is aligned with the centre of the fibre fundamental mode. This is because, as explained above, a wavelength difference from the centre of a wavelength channel does not (to first order) result in an offset error at the output. Beam 965 is the fundamental mode of the fibre. FIG. 33 shows the overlap integrands 970-974 of the truncated incident beams with the fundamental mode of the fibre, as the wavelength is increased from the centre of the channel under consideration, 970, to the centre of the adjacent channel, 974. The normalisation integrand, 975, is also shown. The results in the figures show that the overlap integrand 974 has almost vanished explaining why the adjacent channel extinction is very strong. Overlap integrands 971 and 972 are for wavelength differences of a quarter and a half, respectively, of the channel separation.

* These results explain why the overlap integrand decreases slowly with wavelength difference in this range leading to a flat passband centre. In particular for the halfway case, 972, the overlap integral is exactly half of the normalisation integral (from integrating 975). Hence the amplitude transmission coefficient at this wavelength difference is a half with a power extinction of 6 dB, as was shown in FIG. 19. Therefore two factors are responsible for the excellent filter characteristics. The first factor is that the field incident on the fibre is an image of the field reflected from the SLM. The second factor is that the second pass from the grating undoes the dispersion applied by the first pass from the grating, such that whatever the wavelength offset inside the collected channel, (to first order), the peak of the reflected truncated beam is aligned with the peak of the fundamental mode of the fibre.

[0437] By way of comparison, FIGS. 34 and 35 illustrate the filtering process for a conventional wavelength demultiplexer. In FIG. 34 the centre of a first beam 984 is aligned with the optical axis 980 of the centre of a first optical fibre or optical waveguide 981. Hence the first beam 984 is at the centre wavelength of the channel collected by the first optical fibre 981. A second optical fibre 9B3, adjacent to the first fibre 981, has an optical axis 982. A second beam 988 is aligned with the optical axis

982 of this second optical fibre. Hence the second beam is at the centre wavelength of the channel collected by the second optical fibre, that is at the centre of the adjacent optical channel to that collected by the first fibre. Beams 985 to 987 are at wavelength differences from the first beam 984 of a quarter, a half, and three-quarters, respectively, of the wavelength separation between the two adjacent channels. The coupling efficiency of each of the beams 985 to 988 into the first optical fibre 981 again depends on the overlap integral of the respective beam with the fundamental mode of the fibre 981. This is mathematically identical to the overlap integral of the respective beam with the first beam 984.

[0438] FIG. 35 shows the overlap integrands 994 to 998 plotted against a vertical axis 990. The spatial width and shape of each curve is identical, as may be shown analytically. Hence the overlap integrand is proportional to the amplitude of the curve, as may be read from the axis 990. Curve 994 is the overlap integrand at the centre of the channel, and is the product of the distribution 984 of FIG. 34 with itself. This curve has an amplitude of 1.0 and hence maximal coupling efficiency. Curves 995 to 997 are the overlap integrands at wavelength differences from the channel centre of a quarter, a half, and three-quarters, respectively, of the wavelength separation between the two adjacent channels. Curve 998 is the overlap integrand at the centre of the adjacent wavelength channel. The coupling efficiency is given by the square of the amplitude of the overlap integrand. The results in FIG. 35 show that the coupling efficiency for the conventional wavelength demultiplexer decreases more quickly around the centre of the filter passband than for the 'imaging' filter discussed in this application. The results also show that the adjacent channel extinction is weaker for the conventional demultiplexer.

[0439] FIGS. 34 and 35 also explain why there is a performance tradeoff for the conventional multiplexer between filter passband flatness and adjacent channel extinction: to increase the width of the filter passband the beams 9B5-986 must be incident closer to the first optical fibre 981. Necessarily the beams 987-988 will also be closer to the first optical fibre, reducing the extinction of the adjacent channel, and requiring the second optical fibre 983 to be moved closer to the first fibre 981.

[0440] FIGS. 32 and 33 explain why the imaging filter behaves in a different way, such that a broader filter passband is associated with a greater extinction of the adjacent channel. Beam 960 in FIG. 32 shows the truncated reflected beam at the centre of the filter passband. The first and second amplitude discontinuities 966a, 966b are due to the two edges of the hologram. An increase in the hologram width relative to the spot size moves these two discontinuities outwards. The significant amplitude discontinuity in the middle beam 962 is exactly at the centre of said beam, whatever the hologram width. This is because said middle beam is associated with a wavelength halfway between the centres of adjacent channels. Hence the coupling efficiency for this halfway point is 6 dB, independently of the hologram width. The significant amplitude discontinuity in the quarterway beam, 961, is exactly halfway between the first amplitude discontinuity, 966a of the centre beam 960 and the significant amplitude discontinuity in the halfway beam, 962. As the first discontinuity 966a moves outwards due to an increased hologram width (in the direction of arrow 967) the significant discontinuity in the quarterway beam must move in the same direction, increasing the overlap integral and improving the filter passband centre flatness. Similarly as the second discontinuity 966b moves outwards (in the direction of arrow 968) the significant discontinuities in the three-quarter way beam 963 and adjacent beam 964 must move in the direction of arrow 968, decreasing the overlap integral and improving the adjacent channel extinction. This explanation reinforces the argument that the two factors described above (imaging and the second 'undoing' pass from the grating) are responsible for the excellent filter characteristics. This explanation also explains how the selection of the width of the block of pixels assigned to a channel may control the filter passband characteristics.

[0441] Analytically it can be shown that the filter response for dropping or adding an isolated channel is purely real. Hence there are no phase distortions with this type of dropping filter. This is advantageous because in many 'flat-top' filters the phase distortions associated with the steep skirts may distort the pulses, particularly in higher bit-rate transmission systems for which the signal bandwidth is broader.

[0442] In these calculations it was assumed that the blocks of pixels assigned to each wavelength channel are contiguous. That is there are no 'guard bands' of pixels between each block. Further analysis showed that introducing such guard bands has the effect of decreasing the channel bandwidth for a given channel separation. Hence, preferably the pixel blocks assigned to each wavelength channel should be contiguous. Alternatively guard bands can be used to route in a third direction to deliberately narrow a channel bandwidth, if required.

[0443] While the above discussion is for the case of an isolated channel, in which both adjacent channels are routed in a different direction to the channel under consideration, there are also filtering effects that can occur when one or both adjacent channels are routed in the same direction. These effects are caused by 'stitching errors' at the adjacent edges of a pair of holograms routing in the same direction. For example a stitching error of pi causes (in theory) complete extinction of a light beam at a wavelength exactly halfway between the centres of two adjacent channels, while for an absence of stitching error at either side of a hologram, the transmission is uniform right across the entire channel. Intermediate stitching errors cause intermediate extinction. This acts as an additional programmable filtering mechanism and can be used to advantage to partially or completely filter out amplifier noise between selected channels, if required. Alternatively when maximally flat passbands are required the stitching error should be minimised.

[0444] As described previously, all channels entering the architecture at the same wavelength are incident on the same hologram. This is because the input beams are arranged to be parallel as they arrive at the diffraction grating, such that all channels at the same wavelength emerge parallel from the diffraction grating. As the diffraction grating is at the focal plane of the lens the beams therefore converge towards the same point in the other focal plane of the routing lens (or equivalent mirror) at which point the SLM is placed.

[0445] Hence for the four port and multiport add/drop devices the channels entering on the main beam (from the main input fibre) share a hologram with those channels at the same wavelength entering on an add port. When configured with one particular routing hologram the channel entering the main input is routed to the (selected) drop port while the channel entering the add port is routed to the main output. Therefore any channel equalisation applied to an added channel will also be unavoidably applied to the dropped channel. Hence it is not possible to carry out independent channel equalisation on added and dropped channels.

[0446] This problem does not occur, however, for the devices with a single input and/or with a single output. This is because in these devices there is no sharing of individual holograms between channels entering or leaving on different ports. Nor does the problem occur for the devices with multiple inputs and multiple outputs, for channels routed from the main input to the main output.

[0447] Another configuration of the multi-wavelength architecture is to have a single input port and a separate output port for every wavelength channel and SLM devices for each channel capable of providing a set of many deflections. When configured so that a single channel leaves on each output port, the device acts as a reconfigurable demultiplexer such that the assignment of a particular wavelength to each output port can be changed dynamically.

[0448] Conventional wavelength demultiplexers are not reconfigurable and are therefore less flexible as a routing component. They also have a Gaussian filtering characteristic, which is inferior to the filter characteristic of the SLM multiwavelength optical processor, as described earlier. A further advantage of the invention, compared to a conventional free-space wavelength demultiplexer, is that the channel filter bandwidth is independent of the physical separation between the output fibres and also independent of the spot size of the output fibre. In contrast, for the conventional demultiplexer, the channel bandwidth is proportional to the ratio of the output waveguide spot size to the physical separation of the output waveguides. Consequently, and in order to obtain sufficient channel bandwidth, microlens arrays are required to increase the effective spot size or waveguide concentrators are used to decrease the waveguide separation.

[0449] When used in reverse the device acts as a reconfigurable multiplexer, allowing the use of, for example, tuneable lasers at each input. In contrast, for a conventional wavelength multiplexer, fixed-tuned lasers must be used at each input.

[0450] A system with a single input port and many output ports can act as a module to form part of a modular routing node. If the system has M output ports and a single input port, then each routing device produces M different deflections, with small adjustments to compensate for wavelength differences and alignment tolerances. All devices (i.e. holograms) producing the same eventual deflection will cause the associated wavelength channel to be routed out of the same output port. Hence such a system can send none, one or many (up to the number of channels entering the input port) channels out from the same output port. The logical function of the module is to sort the incoming channels on the input port according to their required output port, as also illustrated in FIG. 21. Considering firstly the case of the routing architecture shown in FIG. 12. As there is a single input port, every wavelength channel has its own hologram. Hence independent channel equalisation may be applied for all the signals flowing through the module.

[0451] One application of these modules is to use two of them to make an add/drop node, as shown in FIG. 22. FIG. 22 shows a first routing module 660 having one input 661 from a previous node, a through output 662 and three drop outputs 663-5, as well as two spare outputs 666,667. A second routing module 670 has a first input 671 connected to the through output 662 of the first module, three add inputs 672-4 and two spare inputs 675,676. The second module 670 has an output 677 to the next node. The second (output) module can be physically identical to the first (input) module but it is used 'in reverse'.

[0452] The first module routes all the through traffic out on a common through port 662 while providing multiple drop ports: one for each dropped channel. Any single wavelength or any set of wavelengths can be sent to any drop port. Hence each of the drop ports may connect to a local optoelectronic receiver in a local electronic switch, or to a remote customer requiring one or more channels for remote demultiplexing. The reconfigurability of the wavelength assignment means that the module acts like a wavelength demultiplexer combined with a matrix switching function, so may reduce the switching demands placed on the electronics servicing the drop ports. The ability to send a selectable set of wavelengths to the same port reduces the need for additional fibre/multiplexing components and increases flexibility. Furthermore the routing applied to each wavelength channel may be multicast, as well as unicast. Hence drop and continue operation may be provided in which the signal is routed to a drop port and also to the through port. If a transparent optical connection is required through to access and distribution networks this multicasting may also be applied to broadcast signals to a number of drop fibres. In this multicasting operation one or more of the previously described power control methods may be applied to equalise the channels on the through and drop fibres, as required for the transmission systems and receivers to function correctly.

[0453] The first module provides any channel equalisation and monitoring required for the drop ports. Channel equalisation and monitoring for the through channels may take place in the first module, or the second module, or both.

[0454] The second module provides multiple add ports: one for each added channel. Any single wavelength or any set of wavelengths can be received at any of the input ports. This allows each of the add inputs to be a tuneable laser, which would not be possible with a conventional non-reconfigurable wavelength multiplexer. In the conventional case there are two options for providing the added channels. A first option is to use conventional non-reconfigurable wavelength multiplexing to combine the added channels, because this is much more efficient in terms of insertion loss than a non-wavelength-specific multiplexer (such as a 1:N fibre splitter used in reverse, that is a N:1 combiner). However this requires each input port of the wavelength multiplexer to have a transmitter laser at a fixed wavelength. When a particular wavelength channel is added at the node the associated transmitter is in use. However when the network reconfigures its wavelength assignment that laser may no longer be in use. To allow complete reconfigurability a complete set of transmitter lasers must be provided, one for each system wavelength. This makes reconfigurable add drop nodes uneconomic when adding small numbers of channels, due to the large overhead of idle transmitter lasers. A second option is to use tuneable lasers, one for each added channel. With conventional optics this requires a non-wavelength-specific multiplexer, which imposes insertion loss penalties. The multi-wavelength architecture described provides a reconfigurable wavelength multiplexer with lower insertion loss than a N:1 combiner.

Furthermore the routing applied to each wavelength channel can be reconfigured without transient effects on other wavelength channels, as occurs in 'serial' multiplexing architectures that have a reconfiguration capability.

[0455] Any add port can receive a reconfigurable set of wavelength channels from a remote customer. The second module also provides any channel equalisation required for the added signals. Finally the second module routes the through channels entering on the port 671 to the output 677.

[0456] The spare ports 666,667,675,676 can be used for routing selected channels to optical regenerators if the signal quality demands it; to wavelength converters to avoid wavelength blocking; to another add/drop node to allow cross-connection between rings, as shown in FIG. 23, or to further modules to allow expansion, as shown in FIG. 24.

[0457] FIG. 23 shows a first to fourth routing modules 720, 730, 740 and 750. The first and fourth modules each have one input 721, 751, a through output 722, 752, a cross-connect output 723,753 and a number of drop outputs721, 754. The second and third modules 730,740 each have respective single output 731,741, a number of add inputs 732,742 a cross-connect input 733,743 and a through input 734, 744. The through output 722 of the first module 720 is connected to the through input 734 of the second module 730, and the through output 752 of the fourth module 750 is connected to the through input 744 of the third module 740. The cross-connect output 723 of the first module 720 is connected to the cross-connect input 743 of the third module 740, and the cross-connect output 753 of the fourth module 750 is connected to the cross-connect input 733 of the second module 730.

[0458] The first and second modules 720, 730 are on one ring and the third and fourth 740, 750 on a second ring. This cross connection capability allows a new ring network to be overlaid on an original ring network when the original ring capacity is becoming exhausted. Channels may be exchanged between the two rings at each node as required. Hence the ring network acts like a ring with two fibres per link (in each direction around the ring). The concept may be extended to three or more overlaid rings, and hence three or more fibres per link (in each direction around the ring). As is well known from many traffic studies, increasing the number of fibres per link reduces significantly a phenomenon known as wavelength blocking, such that more efficient use is made of the capacity of each fibre. Hence cross connection between rings makes better use of the available capacity, allowing more traffic to be carried for the same investment in infrastructure. Cross connection may also be used to exchange signals between diverging rings.

[0459] FIG. 24 shows expansion of a first (input) module 760 having a single input 761, and five outputs 762-6,via an optical amplifier 768 and an intermediate module 770 having four outputs 771-4. The first output 762 of the first module 760 is a through path, the third output 764 is an expansion port and provides an input to the optical amplifier 768, and the output 769 of the optical amplifier is to the intermediate module 770. The intermediate module 770 has an expansion port 771 and three new ports 772-4. Fourth and fifth outputs 765, 766 of the input module 760 form drop outputs. The same principle can also be applied to expansion of a second (output) module. The use of such modules allows extra add and drop ports to be provided without service interruption to the channels flowing through the add drop node. It also allows network operators to apply just in time provisioning, delaying investment in infrastructure until the demand is there to use it. Furthermore it is only the channels dropped or added through the expansion module(s) that are subject to an additional amplification stage. If every node in the ring were upgraded in this manner, the channels should only pass through an additional two amplification stages. This could be reduced to one additional stage by suitable assignment of the added and dropped channels to the original and expansion module.

[0460] Returning to the basic routing module shown in FIG. 21. This type of connectivity would be useful in mesh networks where each node is connected by a multi-fibre link to, typically, each of between two and five nearest neighbour nodes. Each link carries traffic to and from one of the nearest neighbour nodes. Usually individual fibres in the link carry traffic in just one direction but some are bi-directional. For an example where a link has an average of six pairs of external fibres and a node has five links, then there would be thirty external incoming fibres and thirty external outgoing fibres. The function of the node is to route any wavelength channel from any incoming fibre to any outgoing fibre. Each fibre may carry many wavelength channels. Currently up to 160 channel systems are being installed although 40 or 80 channel systems are more usual.

[0461] An ideal node architecture allows the network operator to start with one or more add/drop nodes connected to one or more rings and then allow the individual add/drop nodes to be connected so that the network topology can evolve towards a mesh. The node architecture should also allow extra fibres to be added to each link as required to meet the demand, with the extra parts or modules of the node being installed as and when required. Fibre management and installation between sub-components inside the routing node is also expensive.

[0462] A known architecture for such a routing node uses a separate wavelength demultiplexer for every input fibre. The separated wavelength channels are then carried over optical fibres to N*N optical switches. To avoid internal wavelength blocking then all channels at a particular wavelength must be connected to the same N*N switch. Hence the switch will receive channels at the same wavelength from every single input fibre. The channels leaving the switch are carried over optical fibres to a separate wavelength multiplexer for every output fibre. Hence the switch will route channels at the same wavelength towards every single output fibre.

[0463] These switches have a sufficient number of ports for added and dropped channels, and channels passing to and from wavelength conversion and optical regeneration. This sufficient number is estimated based on traffic analysis as it depends on the instantaneous mapping of channels between nodes and the wavelength and fibre allocation. Each switch may service one or more wavelength channels. In one device, the number of fibres is around b 3000 resulting in significant fibre management and installation costs. Even grouping together different fibres to or from the same link and grouping together the add fibres and regenerator fibres only reduces the number of separate entities to be managed to 560.

[0464] With such a large number of fibres it is not economic to provide optical amplifiers inside the routing node to compensate for insertion losses. Another problem with this architecture is how to add in extra external fibres once the switch capacity has been exhausted with the current number of external fibres. This cannot be done without replacing every single switch. In advance it is difficult to know how large to provision the switch to avoid or delay this problem.

[0465] An alternative node architecture uses one of the multi-wavelength architectures described to provide a separate module for every input fibre and a separate module for every output fibre. Consider first an input module. This should be designed so that none, one, many or all of the input channels may leave any of the output ports (as shown in FIG. 21). These output ports are used to carry channels towards output modules and towards other parts of the node providing wavelength conversion, regeneration and ports to electronic switches, for example. A connection between an input module and an output module carries every wavelength channel mapped between the corresponding input and output fibre. Hence the logical function of an input module is to sort the incoming channels according to their destination output fibre. This logical functionality was illustrated in FIG. 21.

[0466] A particular input module does not have connections to every output module. It does not have connections to output modules going back to the same neighbouring node from which the input channels have travelled, except perhaps for network monitoring and management functions. It might not need to have separate connections to every output module for the output fibres to the other neighbouring nodes. It is however provided with sufficient connectivity to the output channels on every output link to avoid unacceptable levels of wavelength blocking. For example each input module could be connected to a subset of the output modules, with an overflow system used to provide a connection to the other output modules, when required. An output module is designed like an input module but works in the opposite direction. Hence the logical function of the output module is to collect the channels coming from each input module and direct them to a common output port.

[0467] In this architecture, the dropped channels and channels needing wavelength conversion may exit from each module on a common port or a pair of ports. As a result of using the modules it can be shown that satisfactory performance is achieved using fewer than 1000 fibres and fewer than 50 fibre groups.

[0468] Hence the total number of fibres inside the node is reduced by a factor of over 3 while the total number of fibre entities to be installed and managed is reduced by a factor of 10 or more. This represents a significant reduction in cost and complexity.

[0469] An example wavelength-routing crossconnect using the modules is shown in FIG. 25. FIG. 25 shows four input routing modules 790-3, each with a respective input 790i-793i and four outputs 79001-79003 etc. and four output routing modules 794-7 each with four inputs and a respective single output 794o-797o to a respective output fibre. One output of each input module 790-3 forms a drop output. The input and output modules are associated together with input module 790 associated with output module 794, input module 791 associated with output module 795, input module 792 associated with output module 796 and input module 793 associated with output module 797. The remaining three outputs of each input module are cross-connected to the non associated output modules, so that for example the three non-drop outputs of input module 790 are coupled to respective inputs of output modules 795, 796 and 797. Specifically, output 79001 is connected to output module 795. Of the inputs to the four output modules, one per module is an add input and the remainder are connected to outputs of the input modules 790-3.

[0470] In the example the routing function carried out by each input module 790-3 is to sort the incoming channels with respect to the selected output fibre 794o-797o for example, and with reference to the figure, all wavelength channels entering the cross-connect on input 790i that need to leave the cross-connect on 795o are routed by the input module 790 to the output 79001. This output carries these channels to the output module 795 which is collecting frequency channels for output 795o. The output module combines all incoming channels onto a respective single. output.

[0471] In this architecture channel equalisation may be carried out independently for all channels routed through the cross connect.

[0472] The cross connect architecture of FIG. 25 is modular in that it can be used to build a range of nodes of different connectivity and dimension. The modules can be used to assemble a node like that described above, starting with only 1 or 2 fibre pairs per link and adding in extra modules to allow more fibres per link. Extra modules can be added in and connected up as and when required, allowing the network operator to delay investment in infrastructure for as long as possible. When the node has reached, for example, 6 fibre pairs per link and the capacity begins to be exhausted there are three ways to upgrade the node. The first way is to upgrade the numbers of wavelength channels on particular fibres in each link. This requires replacing the associated modules with modules processing more channels. However the other modules (and the fibre interconnections) can remain in service. In contrast for the conventional architecture as well as upgrading the demultiplexers and multiplexers associated with the particular fibres to be upgraded, a whole set of N*N switches must be installed, one for every new system wavelength. These switches will remain under-utilised until all the fibre systems have been upgraded.

[0473] A second way to upgrade the node is to replace selected modules with models providing an increased number of fibre choices per output link allowing more fibres per link. This requires the installation of more fibre groups inside the node. In contrast for the conventional architecture every N*N switch must be replaced meaning the associated system wavelengths would be out of service on every fibre entering or leaving the node.

[0474] A third way to upgrade the node is to upgrade selected modules by cascading another module from a spare, or expansion output port, as shown in FIG. 26.

[0475] FIG. 26 shows a somewhat similar arrangement to FIG. 24, and has an input module 860, with an input 861, five outputs 862-6, an optical amplifier 870 and an intermediate module 880 receiving the output of the optical amplifier 870 and providing four outputs 881-4. The input module has three outputs 862-4 to existing output modules, fourth output 865 to the optical amplifier 870 and fifth output as a drop output. The first to third outputs 881-3 of the intermediate module 880 connect to new or later output modules.

[0476] The advantage of this third way is that service interruption is not required during installation.

[0477] The smallest node can have as few as two modules, which would act as an add/drop node. Several pairs of such modules can service a stacked set of rings, allowing interconnection between different rings. Adjacent rings can also be interconnected. A hybrid ring/mesh network can be created. Hence the same modular system can be used for ring networks, mesh networks and mixes of the two. It can also allow re-use of existing plant and allow an add/drop node to grow and evolve into a wavelength-routing cross-connect.

[0478] It will be clear to those skilled in the art that the use of reflective SLMs may allow optical folding to be accomplished and provide a compact system. Thus folding mirrors which may be found in some systems are replaced by SLMs that serve the dual function of folding and performance management for the system. The performance management may include managing direction change, focus correction, correction of non-focus aberration, power control and sampling. When taken together with the controller and sensors, the SLM can then act as an intelligent mirror.

[0479] As an example, this application of SLMs would be attractive in the context of free-space wavelength demultiplexers as it would help to suppress the problems associated with long path lengths.

[0480] Another example is to provide correction for alignment tolerances and manufacturing tolerances in systems requiring alignment between fibre arrays and lens arrays. In particular focal length errors in the lenses (due to chromatic aberration or manufacturing tolerance) can be compensated by focus correction at the SLM or SLMs, while transverse misalignment between a fibre and lens which leads to an error in the beam direction after the lens, can be compensated by beam deflection at the SLM or SLMs.

[0481] It will also be clear to those skilled in the art that although the described embodiments refer to routing in the context of one-to-one, it would also be possible to devise holograms for multicast and broadcast, i.e. one-to-many and one-to-all, if desired.

[0482] Although the invention has been described with reference to a number of embodiments, it will be understood that the invention is not limited to the described details. The skilled artisan will be aware that many alternatives may be employed within the general concepts of the invention as defined in the appended claims.

CLAIMS

What is claimed is:

1. An optical processor having a reflective SLM, a dispersion device and a focussing device, wherein the SLM has an array of controllable elements; wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over at least part of the SLM, and wherein the processor is configured such that the controllable elements display different holograms at chosen locations of the SLM where said light is incident, for controlling directions at which light from respective said locations emerges.

2. The optical processor of claim 1, having control circuitry adapted to provide plural different holograms to the SLM.

3. The optical processor of claim 2, wherein said plural different holograms include respective holograms each for performing a different function, whereby controllable elements at respective chosen locations of the SLM may operate as selected ones of the group comprising: an optical add/drop multiplexer, an optical monitoring device, a channel equaliser, a channel controller, a programmable optical source, a programmable optical filter, an optical spectrum analyser, an evaluation device, a reconfigurable wavelength demultiplexer, and a reconfigurable wavelength multiplexer.

4. The optical processor of claim 1, having a single SLM.

5. The optical processor of claim 1, having more than one SLM, each having a respective array of controllable elements wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over at least part of each SLM.

6. The optical processor of claim 1, configured so that said light from a common point on the dispersion device is substantially collimated when incident upon the SLM.

7. The optical processor of claim 1, further comprising at least one light sensor arranged to provide signals indicative of emergent light.

8. The optical processor of claim 7, having at least one light sensor arranged to provide signals indicative of light specularly reflected at the SLM.

9. The optical processor of claim 1, wherein the SLM is a Liquid Crystal on Silicon SLM.

10. The optical device of claim 1, wherein the SLM incorporates a quarter wave-plate.

11. The optical processor of claim 1, wherein each hologram occupies an array of controllable elements that has between 10 and 50 controllable elements in at least one dimension.

12. The optical processor of claim 1, wherein each hologram occupies an array of controllable elements that has a size in at least one dimension that is at least 2 times the 1/e spot half-width of the amplitude distribution of an incident beam in the corresponding direction.

13 The optical processor of claim 1, wherein the controllable elements are phase-modulating elements

14. An optical processor having at least one input and at least two outputs and operable to select between the outputs, the module comprising an SLM having an array of pixels, with circuitry constructed and arranged to display holograms on the pixels to route light of different frequencies to respective outputs.

15. A method of controlling light comprising

applying an input light beam having plural wavelengths to a controllable optical device;

controlling the controllable optical device thereby to select desired wavelengths from the input light beam; and

directing the desired wavelengths to respective output directions.

16. The method of claim 15, comprising varying the control of the controllable optical device whereby a subset of the plural wavelengths to a respective output direction is varied.

17. The method of claim 15, wherein at least two of the output directions contain at least one common wavelength.

18. The method of claim 17, adapted for multicasting.

19. An optical processor having plural inputs and an output, comprising a controllable device for combining wavelengths from the inputs to appear at the output, wherein each input signal may contain any desired set of the plural wavelengths of the output.

20. The optical processor of claim 19, wherein the or each input signal is at least one broadband optical source.

21. The optical processor of claim 20, arranged to perform at least one of the group of functions comprising: production of a desired output spectrum and synthesising a comb spectrum.

22. The optical processor of claim 21, having a controller for varying control of the controllable device whereby an output spectrum may be varied.

23. A method of operating an optical processor having a reflective SLM having an array of controllable elements, a dispersion device and a focussing device wherein light beams from a common point on the dispersion device are spatially separate when incident upon the SLM, and wherein the SLM is configured to display holograms at respective locations of incidence of light to provide emergent beams having controllable directions, the method comprising delineating groups of individual controllable elements; selecting, from stored control data, control data for each group of - controllable elements of the SLM; generating from the respective selected control data a respective hologram at each group of - controllable elements; and varying the delineation of the groups and/or the selection of control data whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

24. A method of operating an optical device according to claim 23, comprising selecting control of said light beams from the group comprising: control of direction, control of power, focussing, aberration compensation, sampling and beam shaping.

25. A method according to claim 23, comprising determining, by means of a control device, selection of the groups, selection of control data and delineation of the group boundaries in response to signals from sensors arranged to provide signals indicative of said emerging light.

26. A method of controlling light comprising:-

causing said light to become angularly dispersed by a dispersion device; focussing, by a focussing device, angularly dispersed light from the dispersion device to provide focussed light;

making said focussed light incident upon a reflective SLM, whereby the light is spatially distributed across at least a part of the SLM, wherein the SLM has an array of controllable elements; and

displaying respective holograms at respective locations of incidence of light to provide emergent light whose direction is controlled by respective holograms.

27. A method of directing light using a reflective SLM, a dispersion device and a focussing device, wherein the reflective SLM has an array of controllable elements and wherein the arrangement is such that light from a common point on the dispersion device is spatially distributed over the reflective SLM, the method comprising:

causing the - controllable elements to display different holograms at chosen locations whereon light is incident, whereby light from said locations emerges in controllable directions.

28. The method of claim 27, wherein the controllable elements are phase-modulating elements

29. A method of measuring at least one spectral property selected from: channel power, channel centre wavelength, channel bandwidth occupied and noise power between channels, the method comprising the method of directing light of claim 26.

30. An optical processor arranged to function as at least one of the following: an optical add/drop multiplexer, an optical monitoring device, a channel equaliser, a channel controller, a programmable optical source, a programmable optical filter, an optical spectrum analyser, an evaluation device, a reconfigurable wavelength demultiplexer, and a reconfigurable wavelength multiplexer, the processor having a reflective SLM,, a dispersion device and a focussing device, wherein the SLM has an array of controllable elements; wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over the SLM, and wherein the processor is configured such that the controllable elements display different holograms at chosen locations, whereby light from said locations emerges in respective directions, the directions deviating from a direction of specular reflection.

ABSTRACT OF THE DISCLOSURE

A modular routing node includes a single input port and a plurality of output ports. The modular routing node is arranged to produce a plurality of different deflections and uses small adjustments to compensate for wavelength differences and alignment tolerances in an optical system. An optical device is arranged to receive a multiplex of many optical signals at different wavelengths, to separate the optical signals into at least two groups, and to process at least one of the groups adaptively.

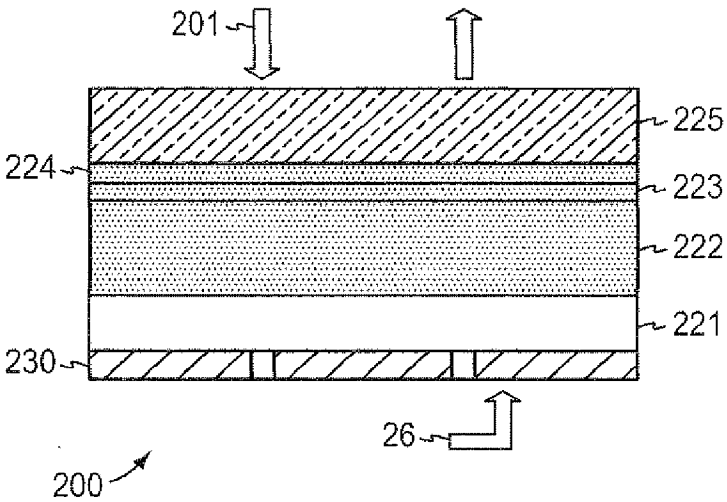


FIG. 1

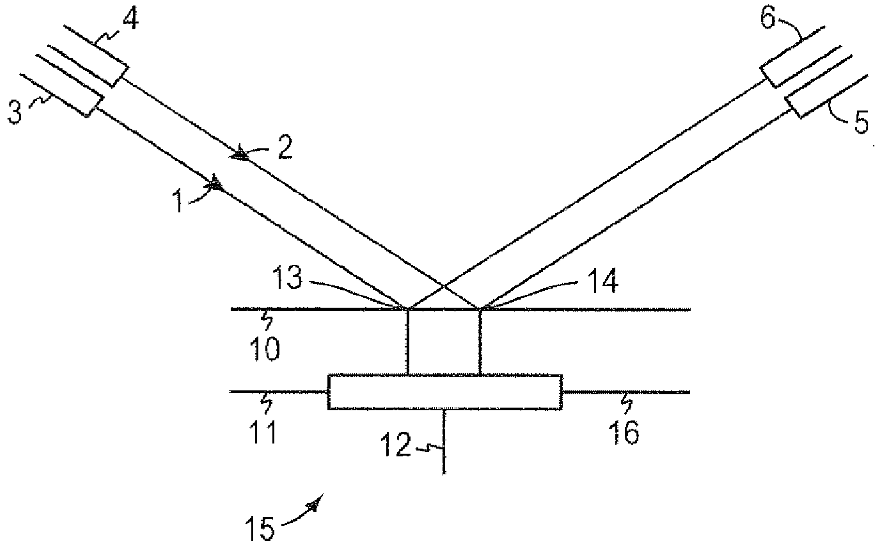


FIG. 2

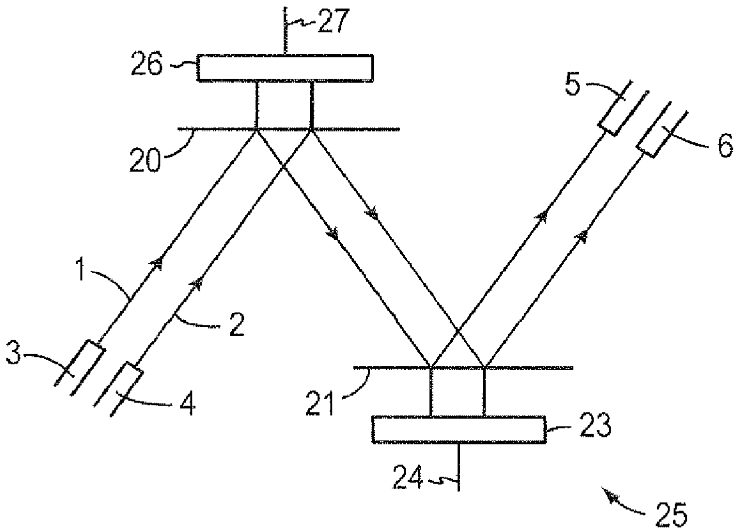


FIG. 3

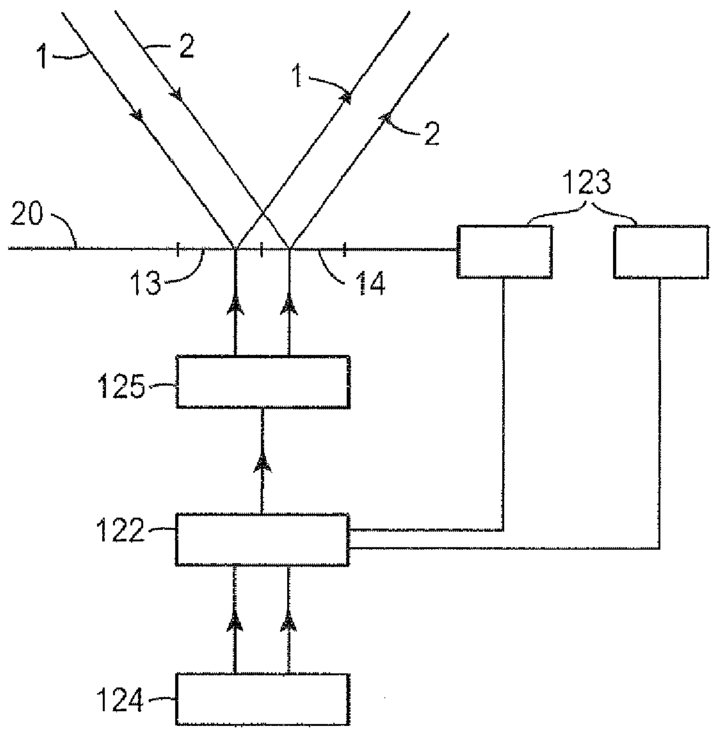


FIG. 4

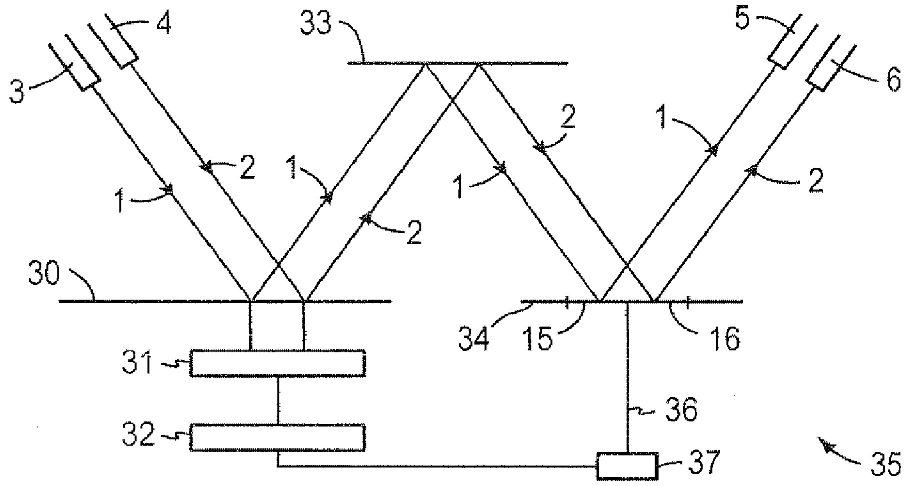


FIG. 5

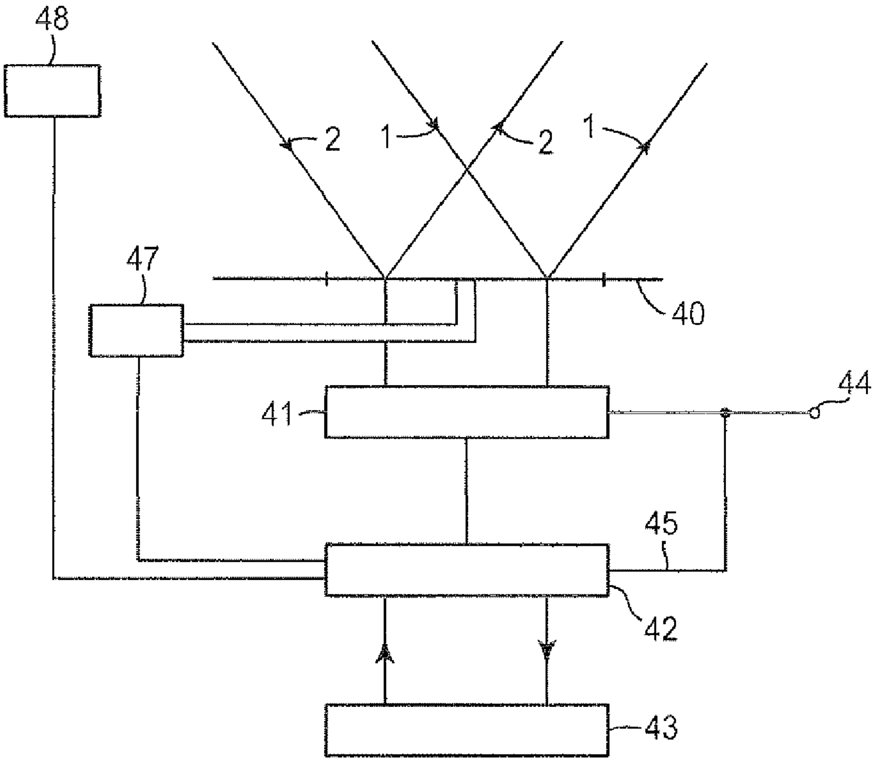


FIG. 6

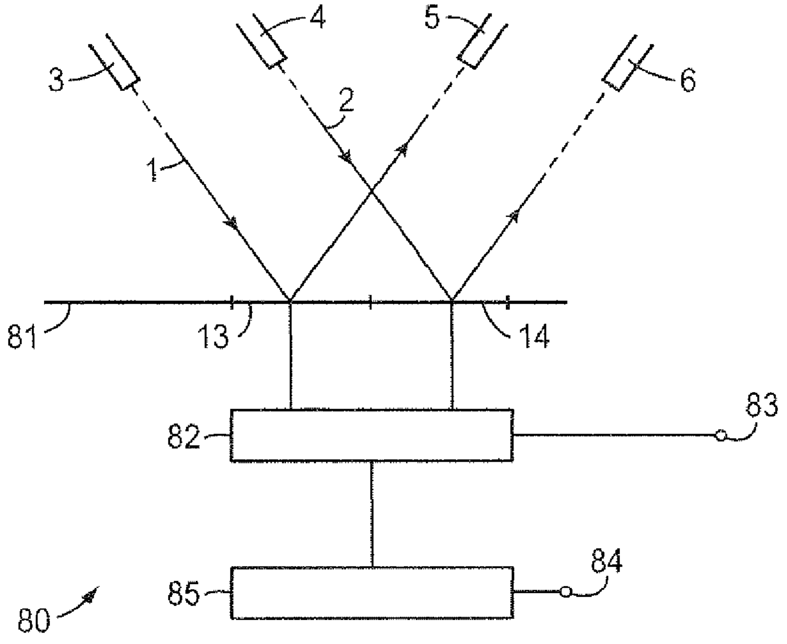


FIG. 7

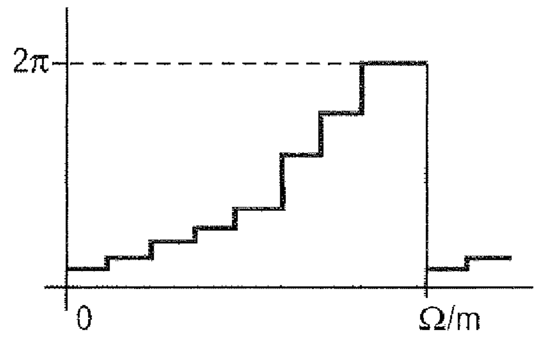


FIG. 8A

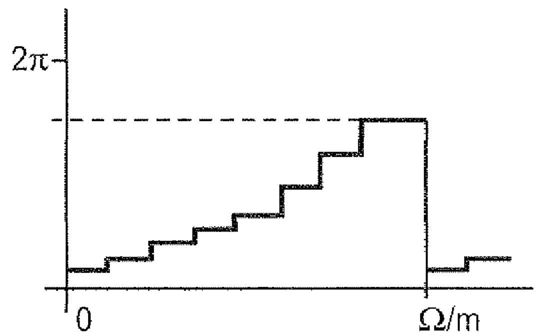


FIG. 8B

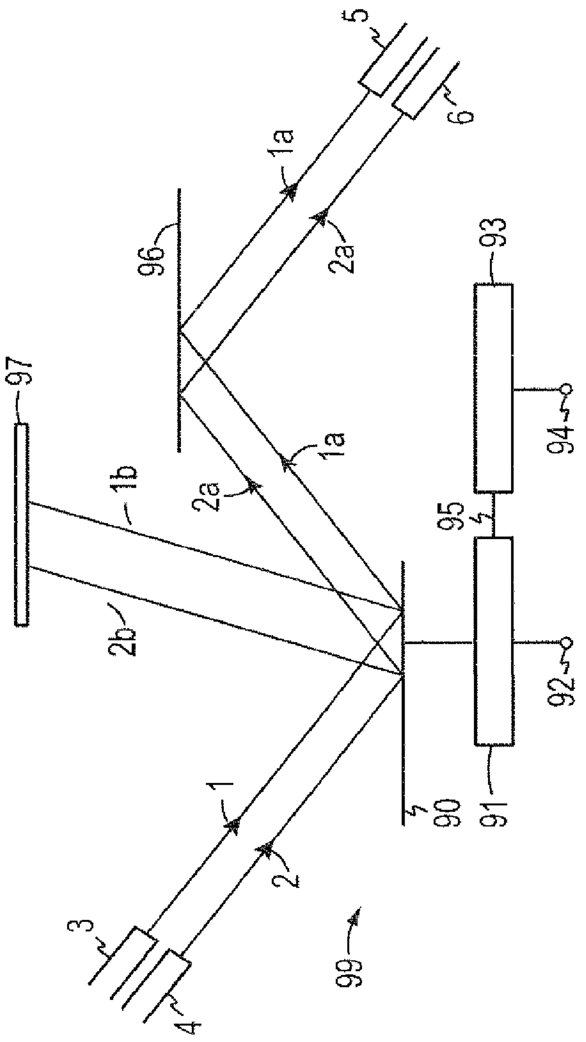


FIG. 9

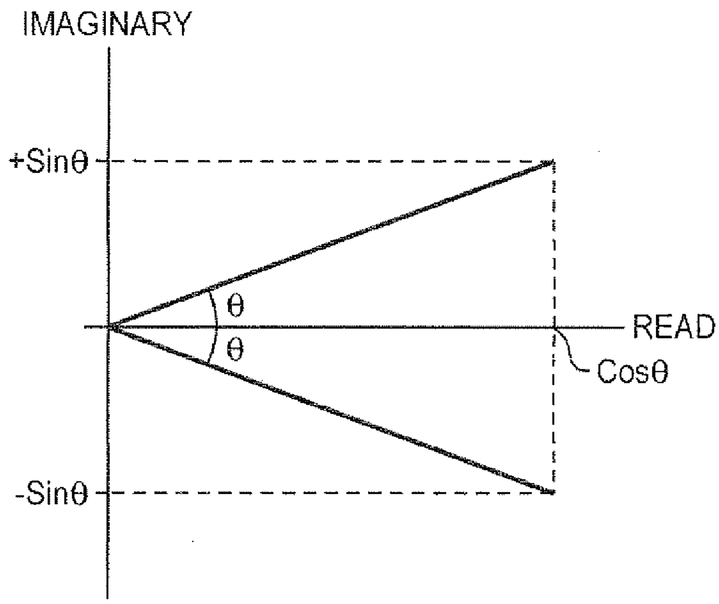


FIG. 10

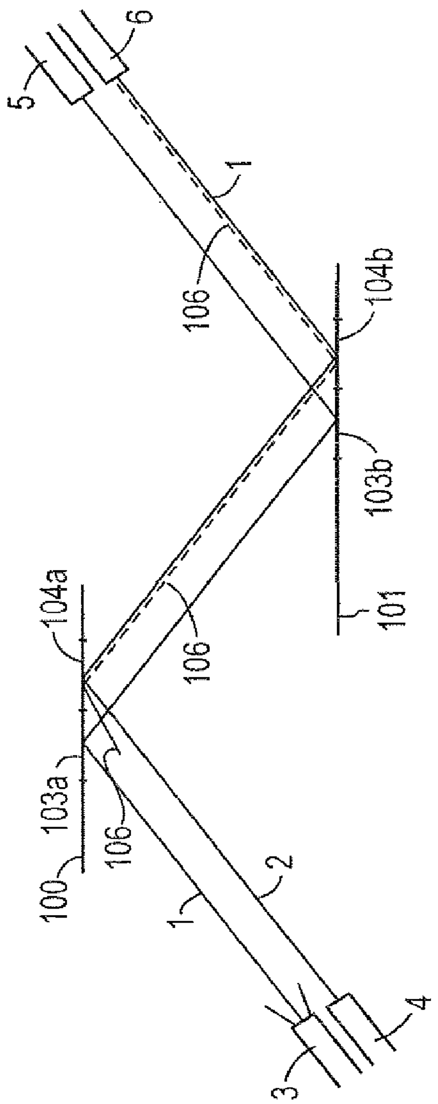
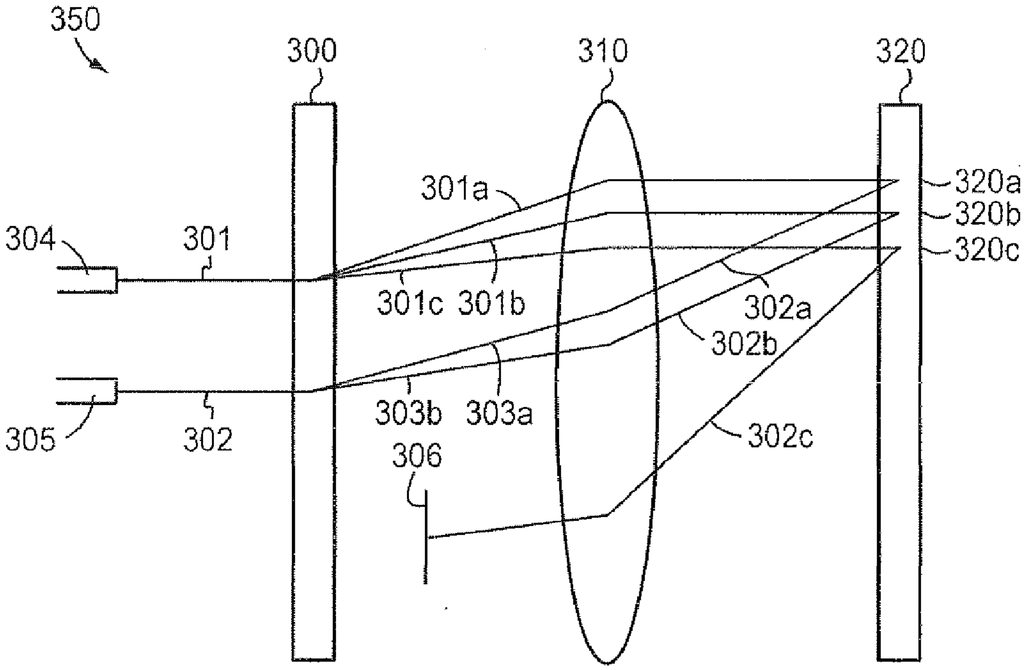


FIG. 11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301c 301b
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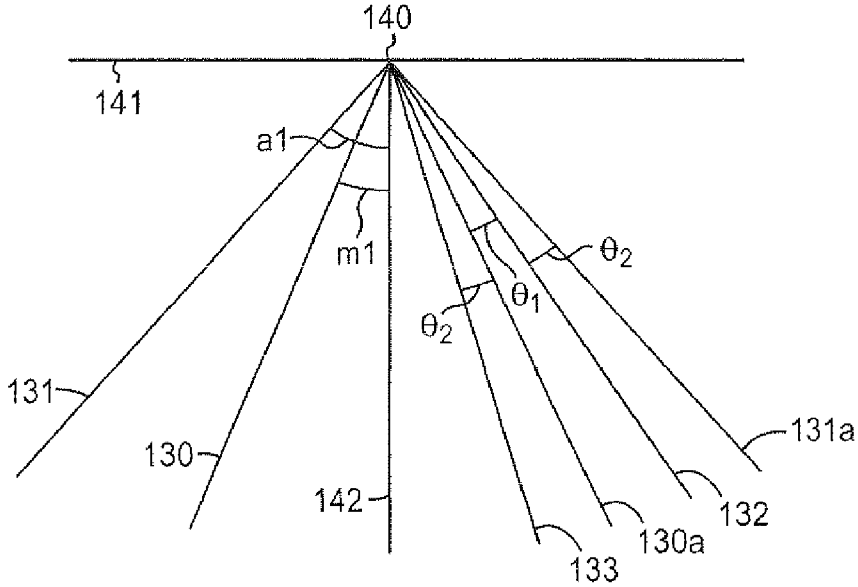
302b
303b 303a
305
302
306
302c

FIG. 12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a1
m1
θ_2
θ_1
θ_2
131
130
142
133
130a
132
131a

FIG. 13A

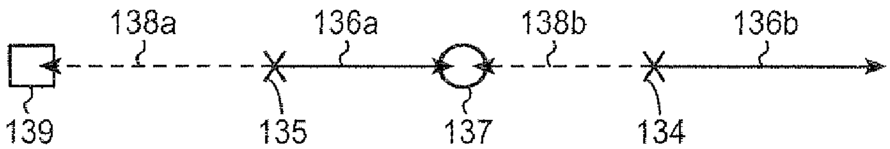

FIG. 13B

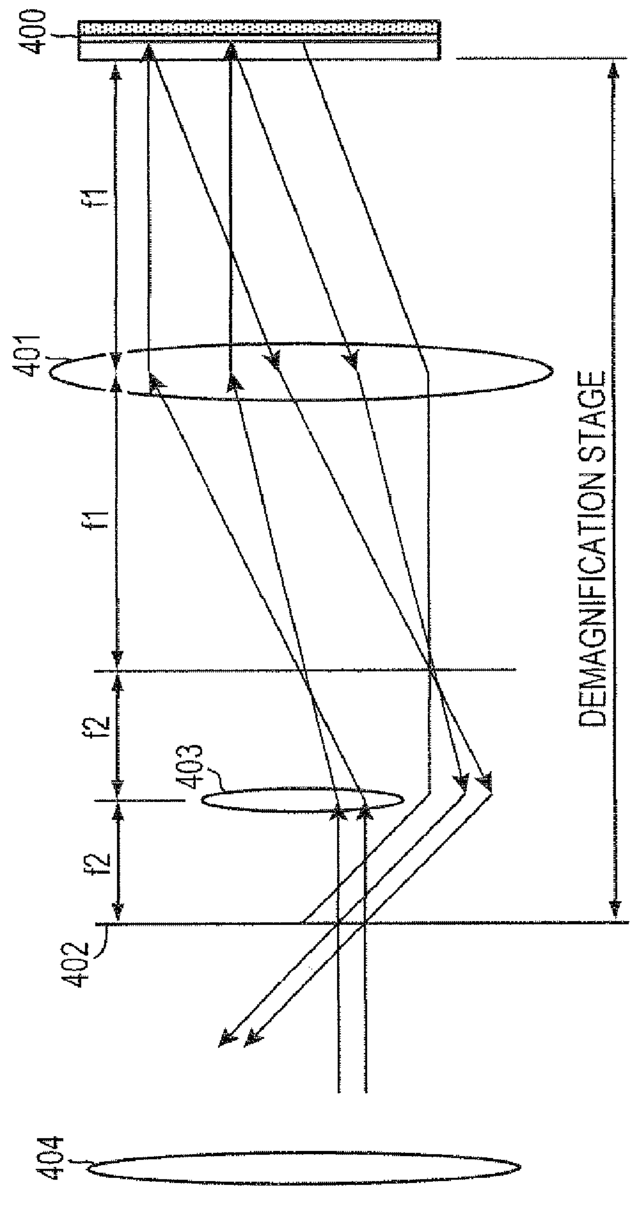

FIG. 14

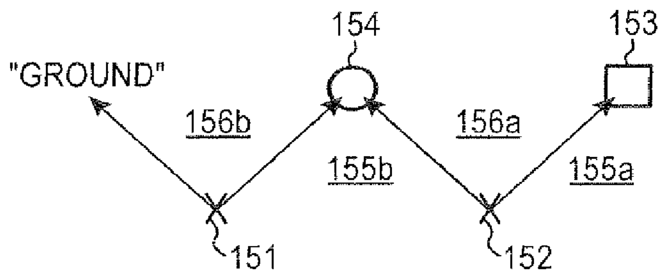

FIG. 15

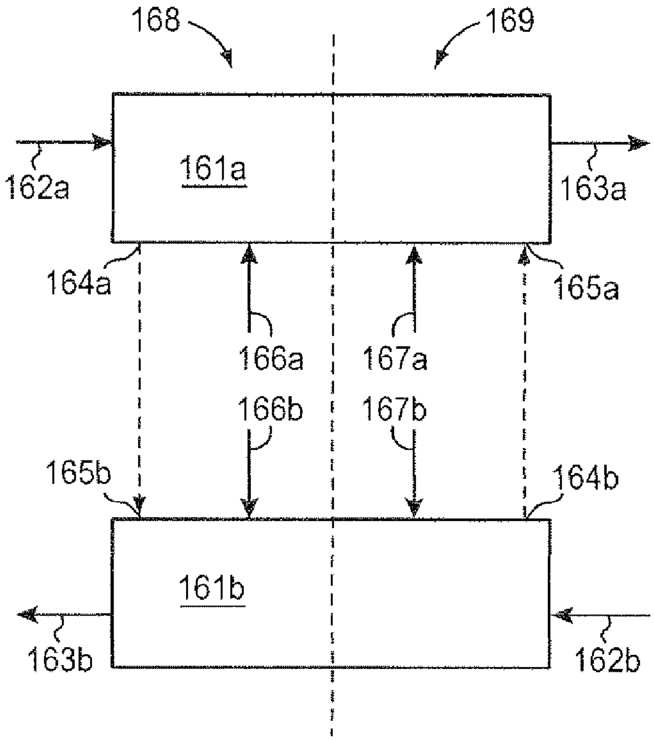
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FIG. 16

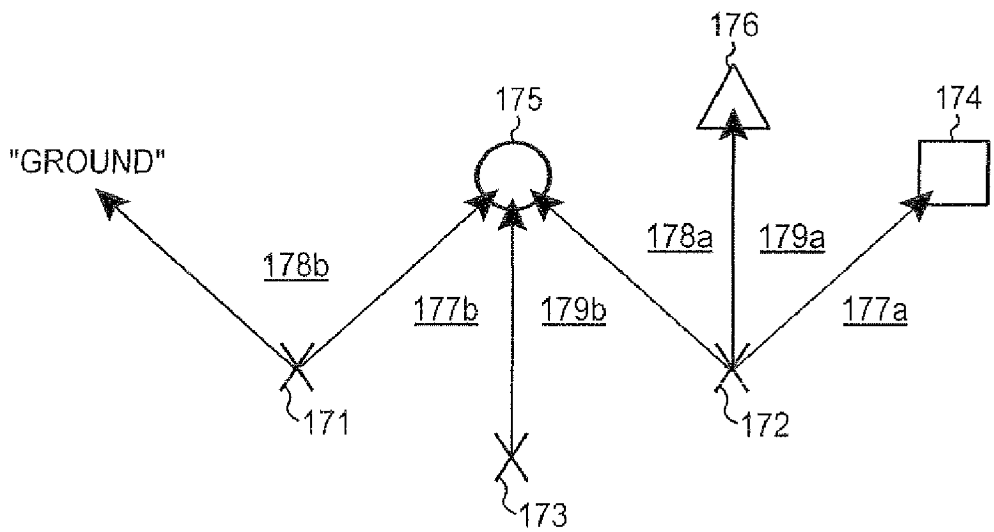
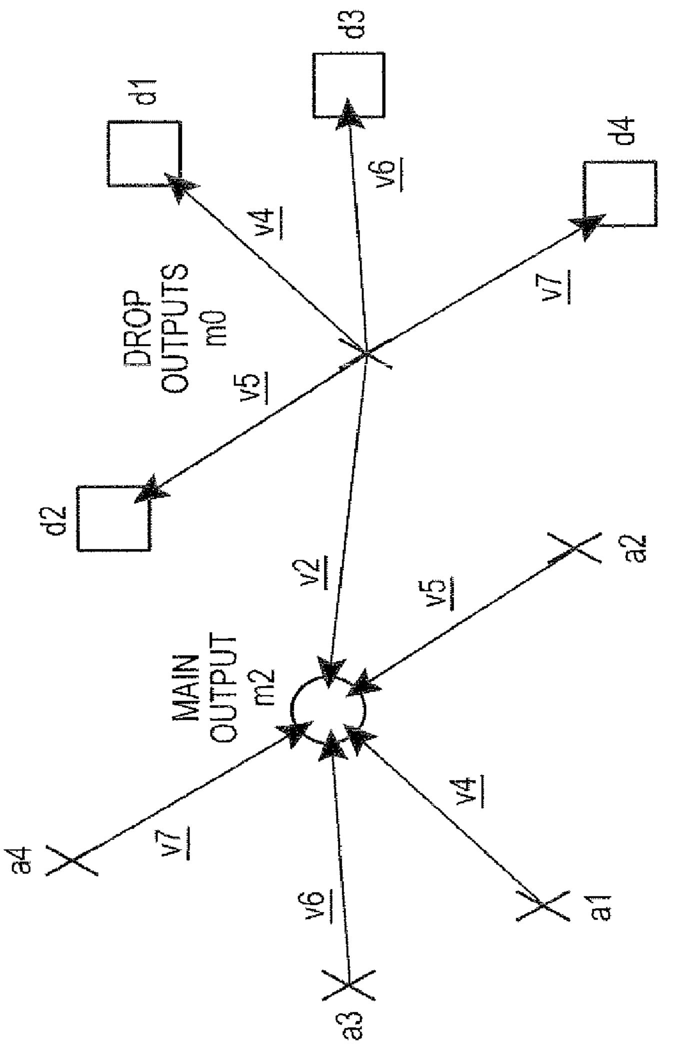


FIG. 17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d2
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v6
v7
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v2
MAIN
OUTPUT
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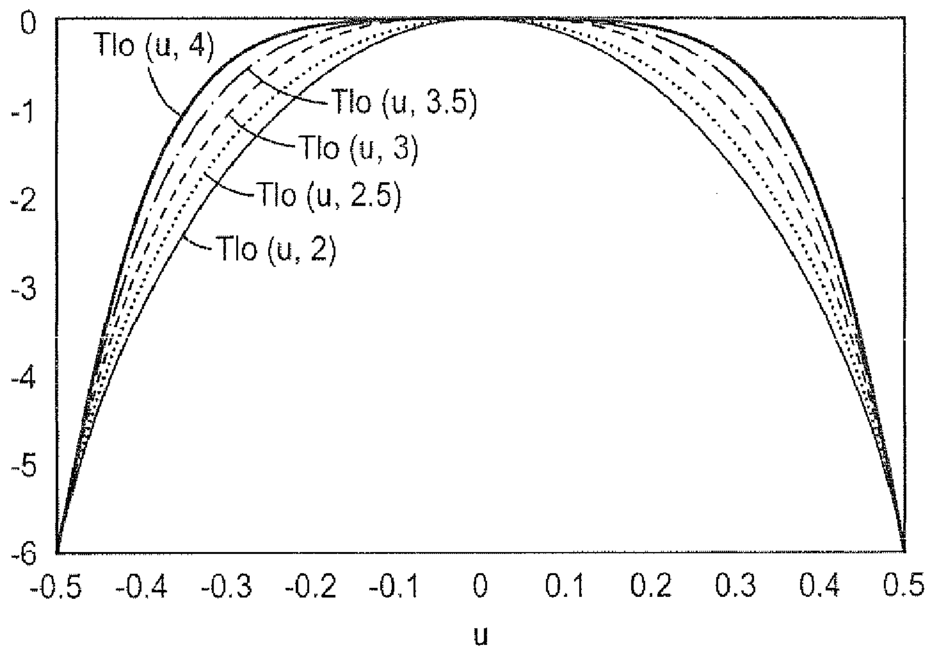
v4
v7
v6
a1
a2
a3
a4

FIG. 18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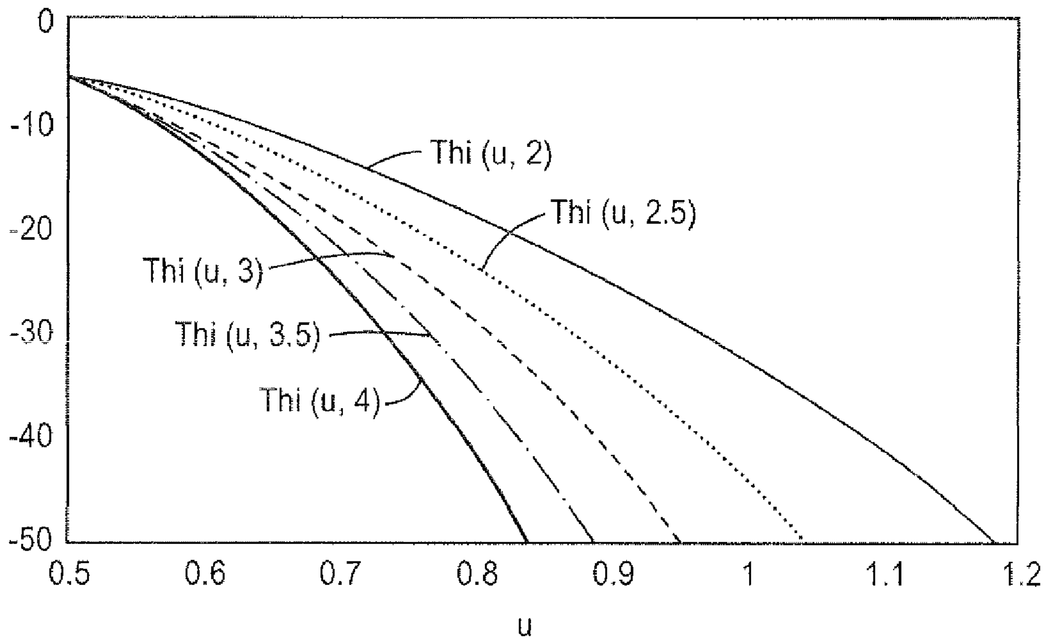
0.2
0.3
0.4
0.5
u
Tlo (u, 4)
Tlo (u, 3.5)
Tlo (u, 3)
Tlo (u, 2.5)
Tlo (u, 2)

FIG. 19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-50
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0.9
1
1.1
1.2
u
Thi (u, 2)
Thi (u, 2.5)
Thi (u, 3)
Thi (u, 3.5)
Thi (u, 4)

FIG. 20

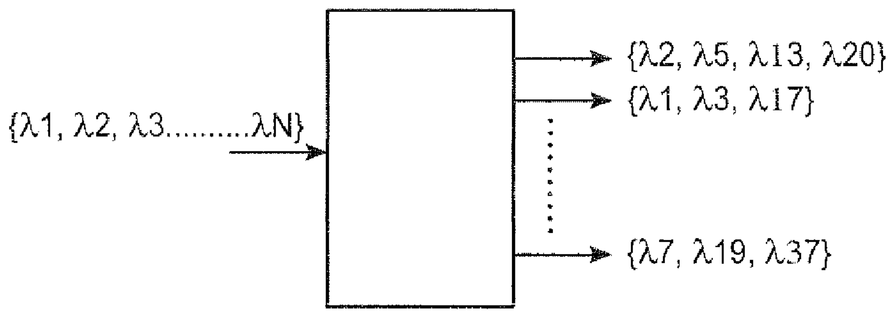

FIG. 21

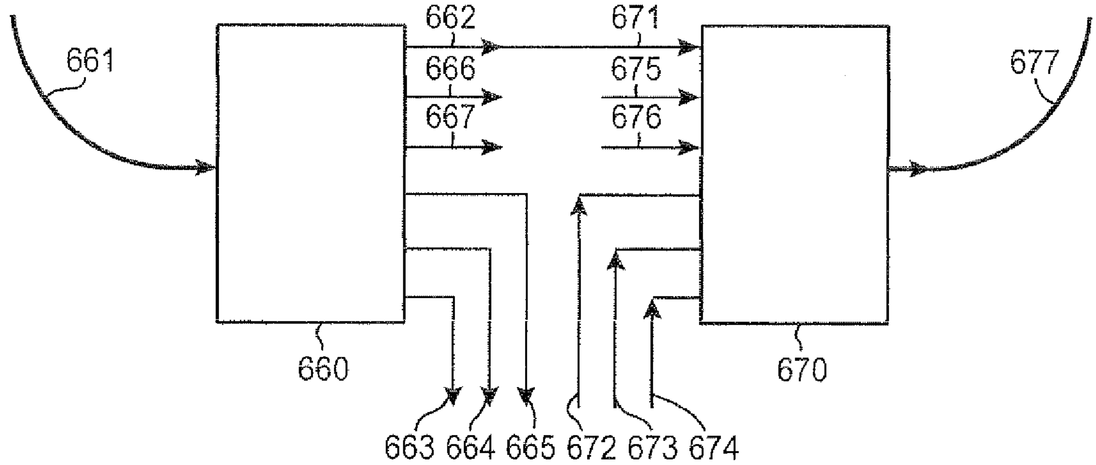

FIG. 22

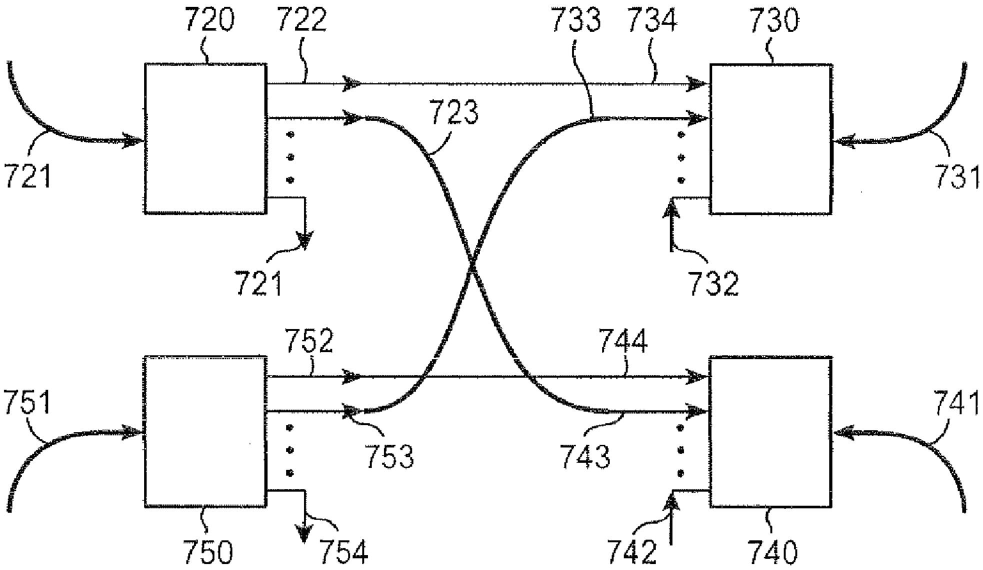
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FIG. 23

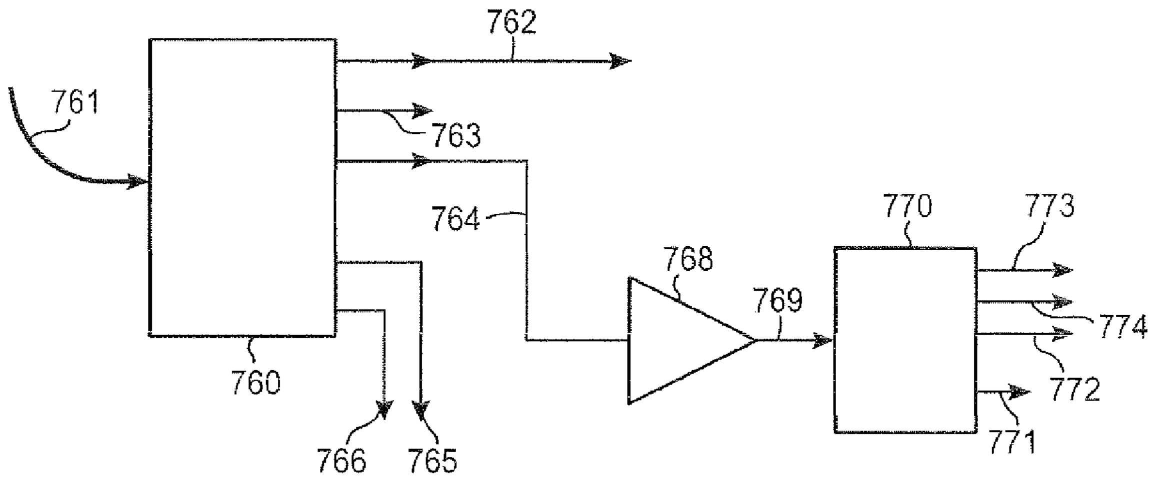

FIG. 24

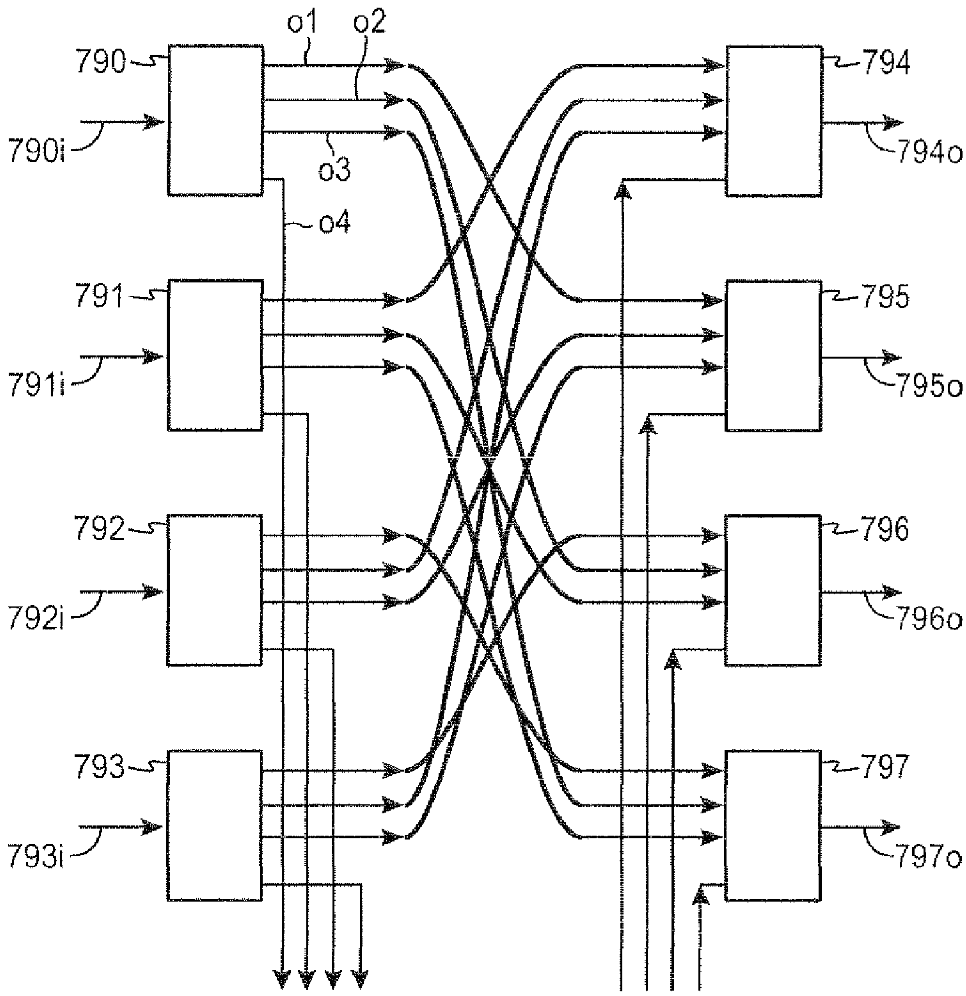
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FIG. 25

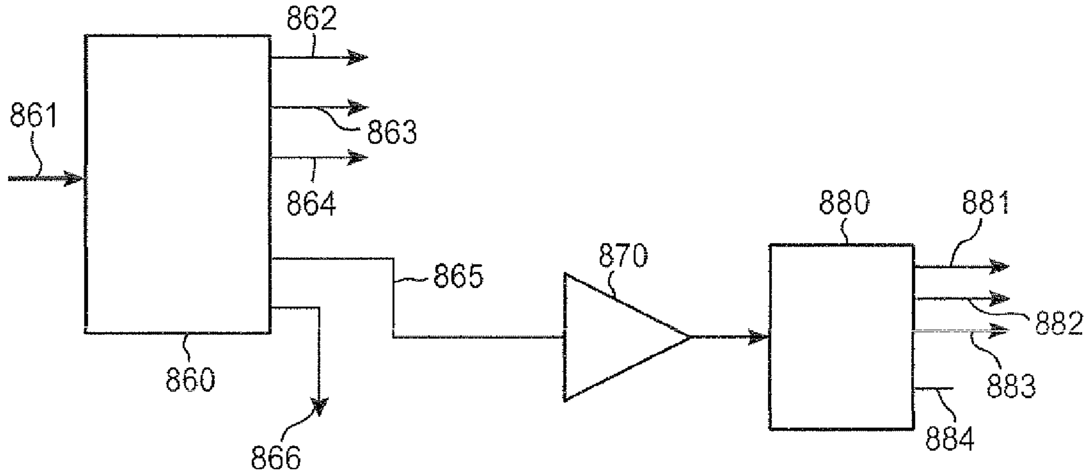


FIG. 26

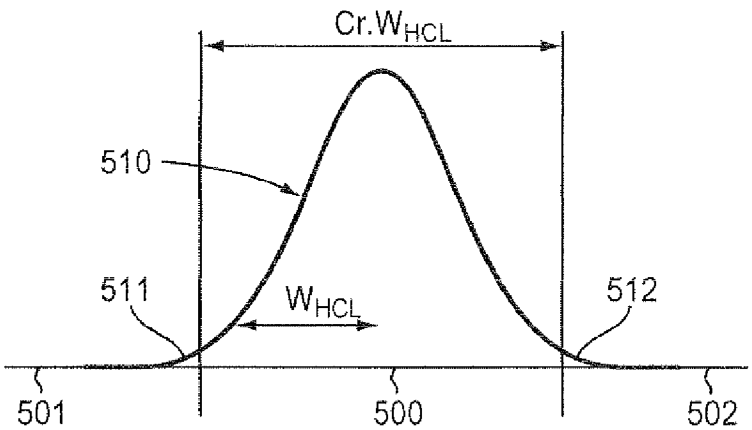
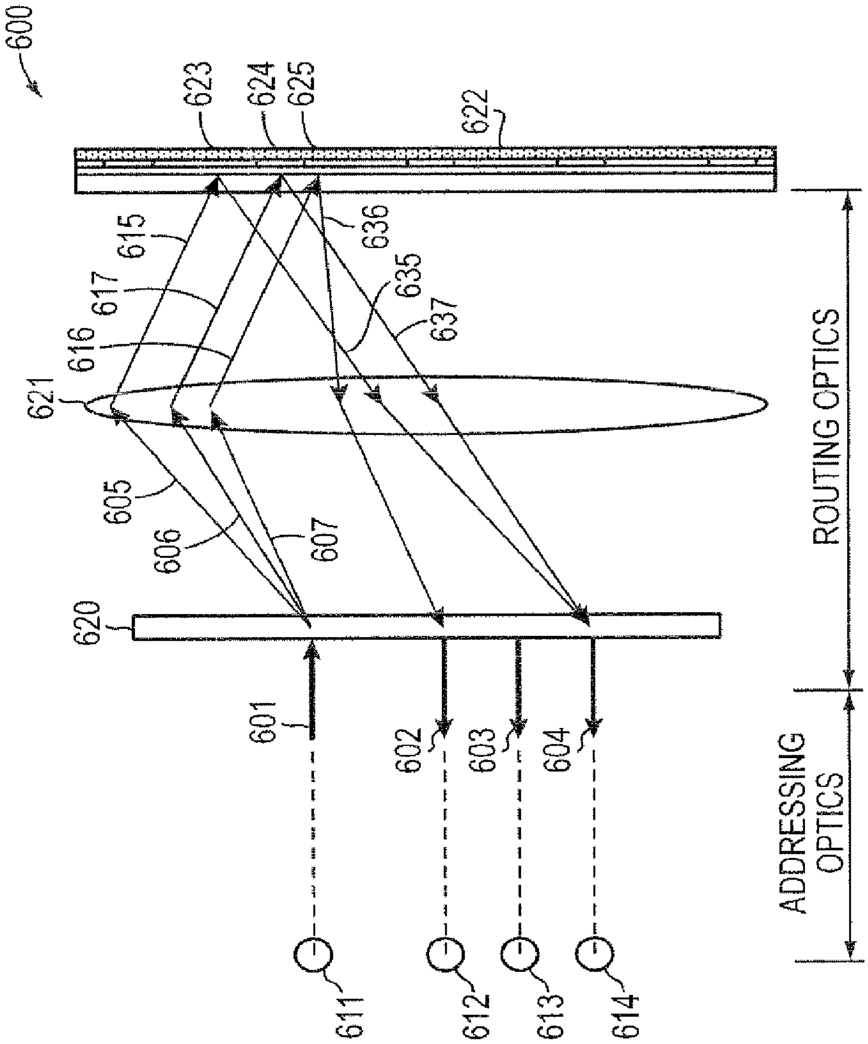


FIG. 27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ROUTING OPTICS
ADDRESSING OPTICS

FIG. 28

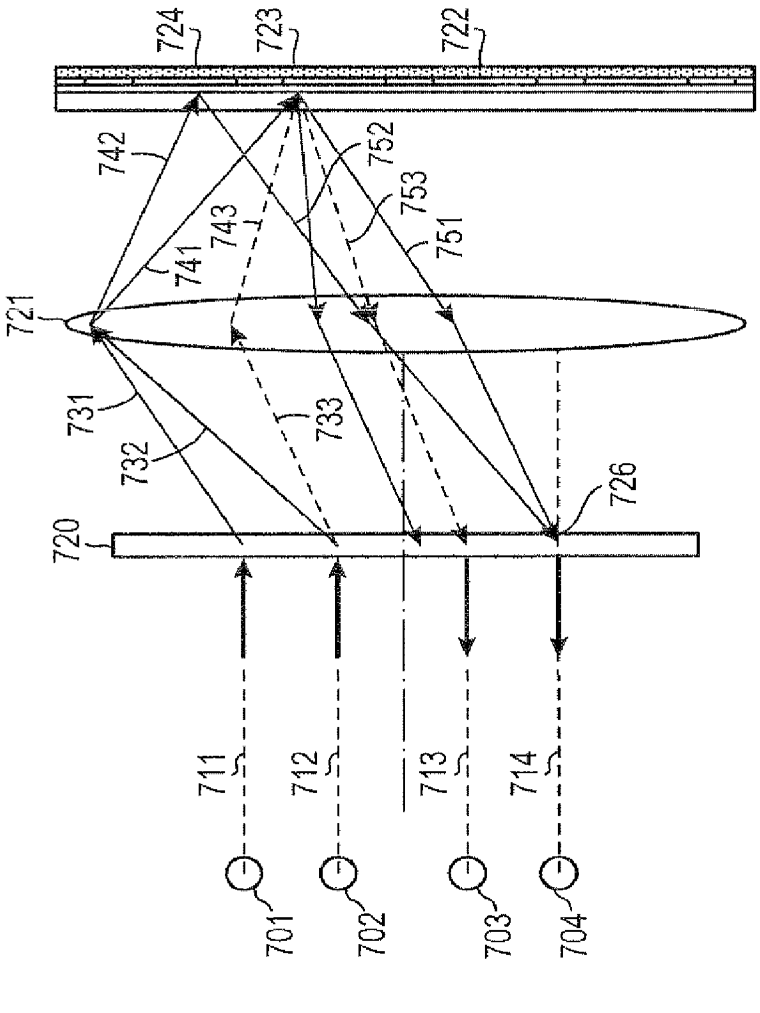
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FIG. 29

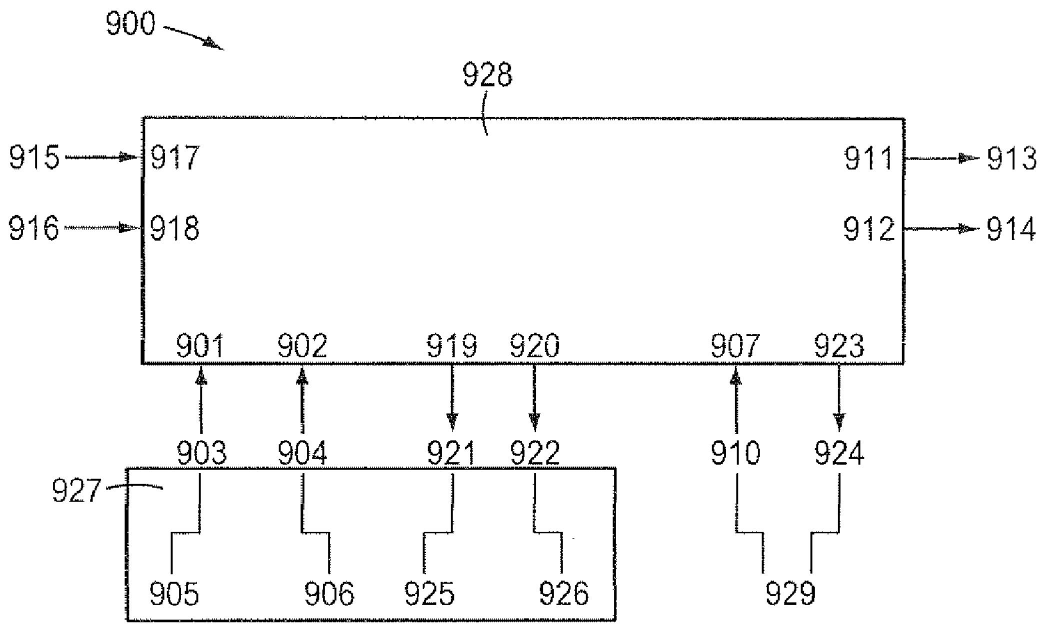
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FIG. 30

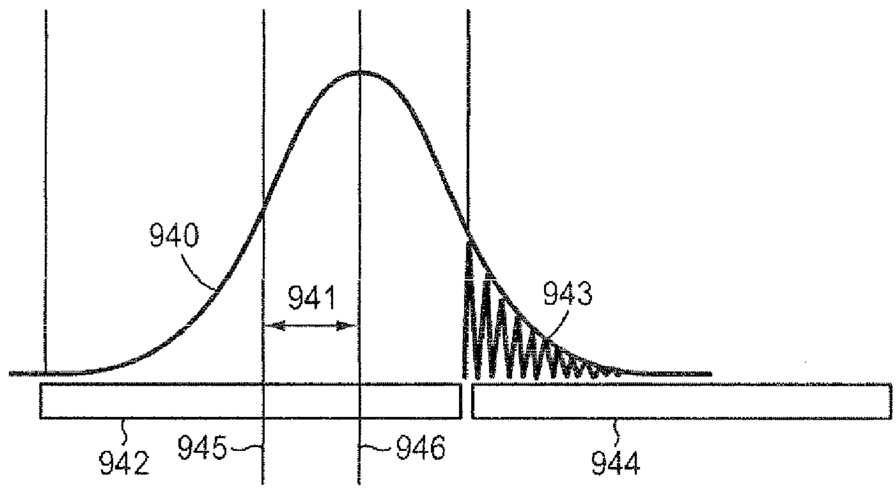

FIG. 31

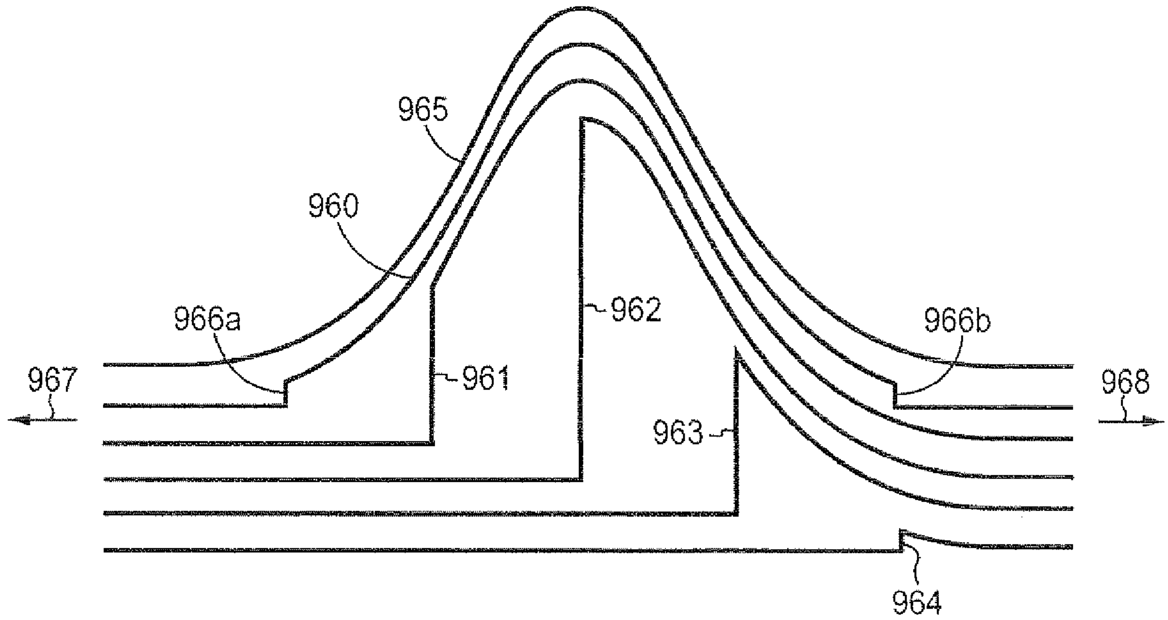

FIG. 32

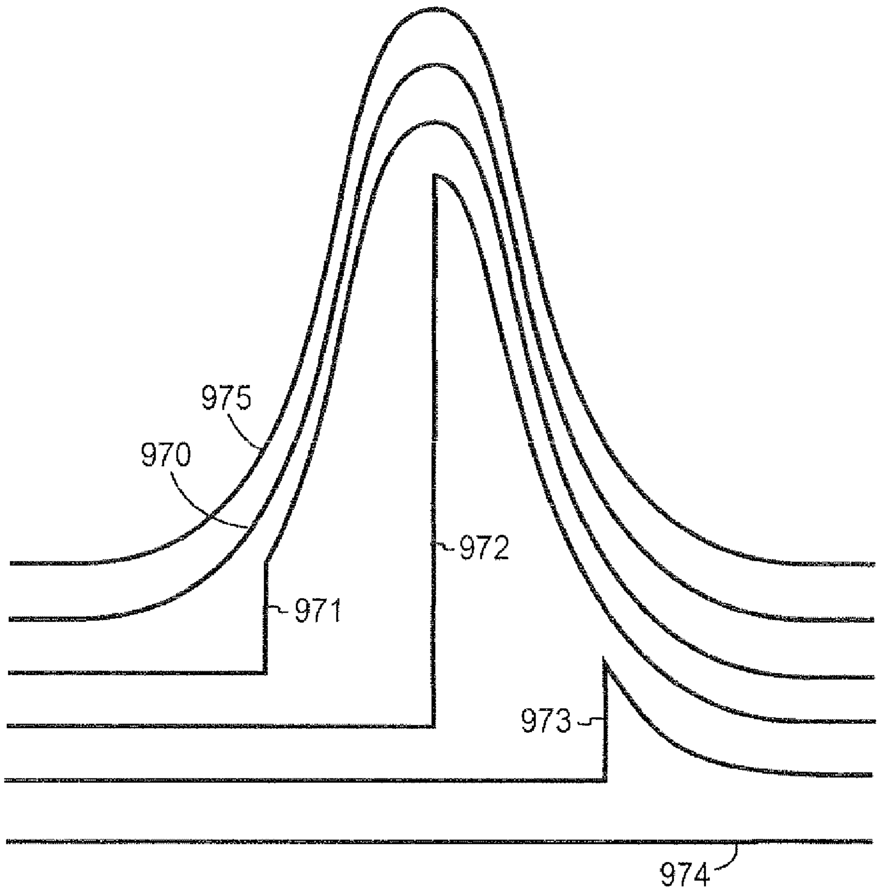

FIG. 33

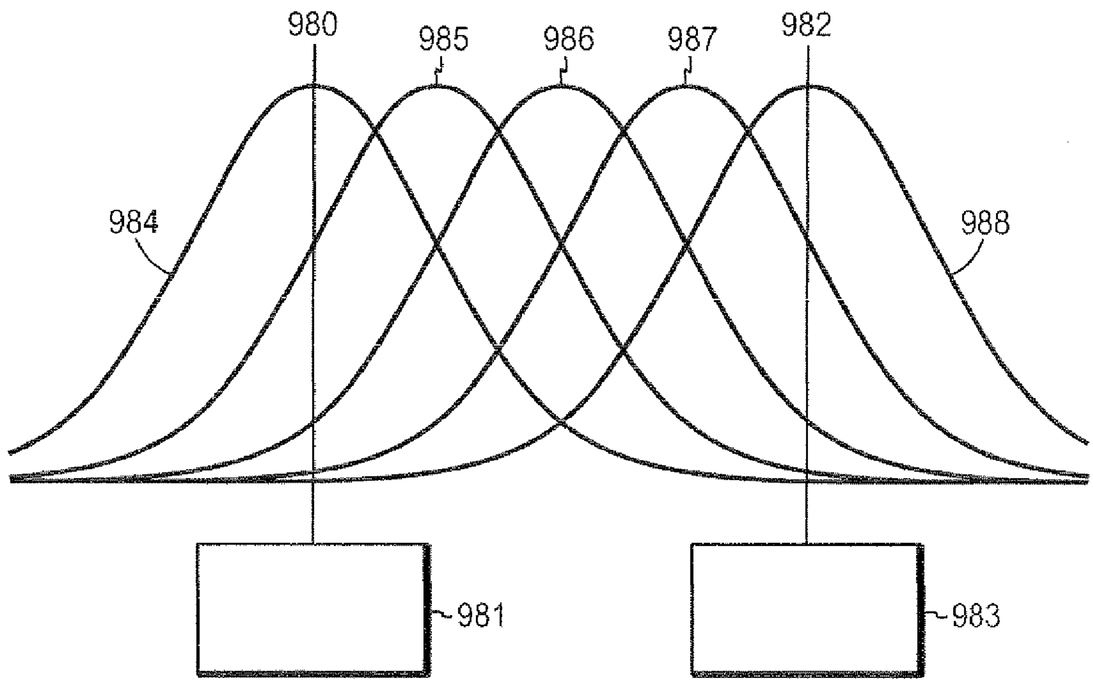

FIG. 34

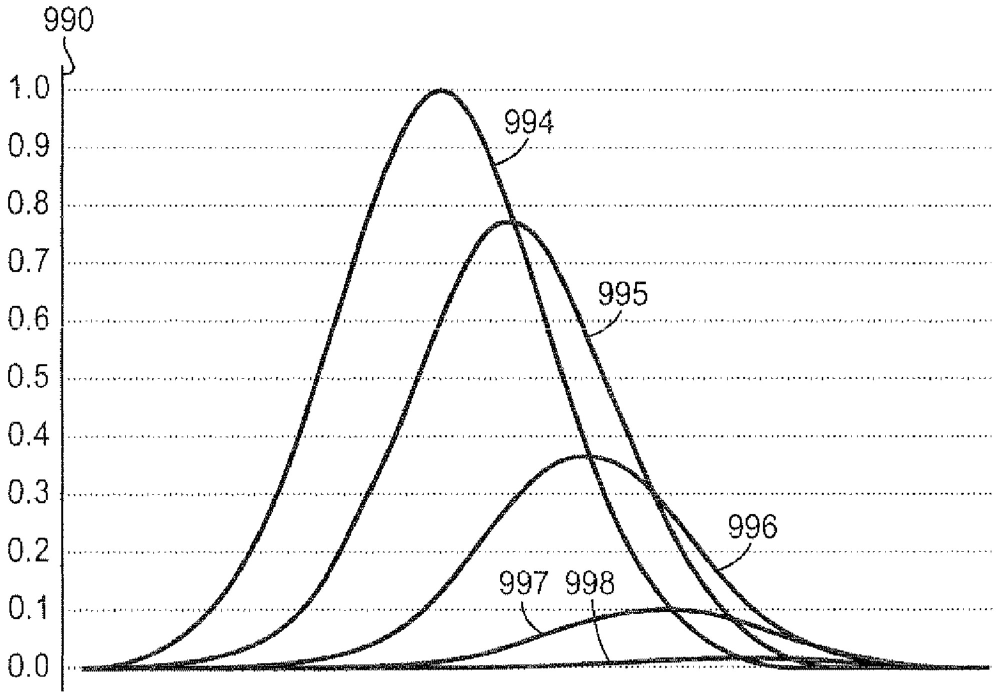

FIG. 35

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Melanie Holmes

Continuation Application of:

Application No.: 11/978,258

Filed: October 29, 2007

For: OPTICAL PROCESSING

CERTIFICATE OF MAILING OR TRANSMISSION

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Date Signature

Typed or printed name of person signing certificate

INFORMATION DISCLOSURE STATEMENT

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Information Disclosure Statement is submitted:

☒ under 37 CFR 1.97(b), or
(Within any one of the following time periods: three months of filing national application (other than a CPA) or date of entry of the national stage in an international application; or before the mailing date of a first office action on the merits; or before the mailing of a first office action after the filing of a Request for Continued Examination).

☐ under 37 CFR 1.97(c) together with either:
- ☐ a Statement under 37 CFR 1.97(e), as checked below, or
- ☐ a $180.00 fee under 37 CFR 1.17(p), or

(After the 37 CFR 1.97(b) time period, but before any of a final action, notice of allowance, or an action that closes prosecution, whichever occurs first)

☐ under 37 CFR 1.97(d) together with:
- ☐ a Statement under 37 CFR 1.97(e), as checked below, and
- ☐ a $180.00 fee under 37 CFR 1.17(p), or

(Filed after final action, notice of allowance, whichever occurs first, or if prosecution otherwise closes, but on or before payment of the issue fee)

☐ under 37 CFR 1.97(i):
Applicant requests that the IDS and cited reference(s) be placed in the application file.
(Filed after payment of issue fee)

Statement Under 37 CFR 1.97(e)

☐ Each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement; or

☐ No item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the undersigned, after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of this Information Disclosure Statement.

Statement Under 37 CFR 1.704(d) (Patent Term Adjustment)
Applies to original applications (other than design) filed on or after May 29, 2000

☐ Each item of information contained in the Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart application and this communication was not received by any individual designated in § 1.56(c) more than thirty days prior to the filing of the Information Disclosure Statement.

☒ Enclosed herewith is a Listing of References:

- ☐ Copies of the cited references are enclosed except as indicated below.
- ☒ Copies of issued U.S. patents and published U.S. applications are not required and are not being provided.
- ☒ Copies of the cited references submitted with an Information Disclosure Statement in prior application, U.S. Application No. 11/978,258, to which priority under 35 U.S.C. 120 is claimed, are not required under 37 CFR 1.98(d)(1) and (2) and are thus not provided.
- ☐ Pending non-published applications are not being provided, since the applications are available to the examiner.

☐ The listed references were cited in the enclosed Search Report in counterpart foreign application [add application number], which is listed in the attached Listing of References.

☐ The "concise explanation" requirement (non-English references) for reference(s) [ ] under 37 CFR 1.98(a)(3) is satisfied by:

- ☐ the explanation provided on the attached sheet.
- ☐ the explanation provided in the Specification.
- ☐ submission of the enclosed International Search Report.
- ☐ submission of the enclosed English-language version of a foreign Search Report and/or foreign Office Action.
- ☐ the enclosed English language abstract.

Method of payment:

☐ A check for the fee noted above is enclosed, or the fee has been included in the check with the accompanying Reply.

☐ Please charge Deposit Account 08-0380 in the amount of $[ ].

☒ Please charge any deficiency in fees and credit any overpayment to Deposit Account 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By ______________________

Timothy J. Meagher
Registration No. 39,302
Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133

Dated: 2/23/10

Substitute for form 1449B/PTO **INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **February 23, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		CONTINUATION APPLICATION NO. 11/978,258
	FIRST NAMED INVENTOR Melanie Holmes		CONTINUATION FILING DATE October 29, 2007
	EXAMINER Loha Ben	CONFIRMATION NO. 4697	GROUP 2873

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
	A1	2002/0060760	05-23-2002	Weiner
	A2	6,954,252	10-11-2005	Crossland, et al.
	A3	5,315,423	05-24-1994	Hong
	A4	5,526,171	06-11-1996	Warren
	A5	2001/0050787	12-13-2001	Crossland, et al.
	A6	US 5,629,802	05-13-1997	Clark, Natalie
	A7	US 3,773,401	11-20-1973	Douklias, et al.
	A8	6,747,774 B2	06/08/2004	Kelly, *et al.*
	A9	6,760,511 B2	07/06/2004	Garrett, *et al.*
	A10	6,529,307 B1	03/04/2003	Peng, *et al.*
	A11	6,594,082 B1	07/15/2003	Li, *et al.*
	A12	5,960,133	09/28/1999	Tomlinson
	A13	2005/0270616 A1	12/08/2005	Weiner
	A14	2004/0126120 A1	07/01/2004	Cohen, *et al.*
	A15	2007/0035803 A1	02/15/2007	Holmes
	A16	2007/0268537 A1	11/22/2007	Holmes
	A17	5,107,359	04-21-92	Ohuchida
	A18	5,539,543	07-23-96	Liu, et al.
	A19	5,589,955	12-1996	Amako, et al.
	A20	5,428,466	06-1995	Rejman-Greene, et al.
	A21	4,952,010	08-1990	Healey, et al.

EXAMINER	DATE CONSIDERED

Substitute for form 1449B/PTO **INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **February 23, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		CONTINUATION APPLICATION NO. 11/978,258	
	FIRST NAMED INVENTOR Melanie Holmes		CONTINUATION FILING DATE October 29, 2007	
	EXAMINER Loha Ben	CONFIRMATION NO. 4697		GROUP 2873

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
	A22	6,710,292 B2	03-2004	Fukuchi, et al.
	A23	6,975,786 B1	12-2005	Warr, et al.
	A24	6,115,123	09-2000	Stappaerts, et al.
	A25	5,995,251	11-1999	Hesselink, et al.
	A26	5,959,747	09-1999	Psaltis, et al.
	A27	6,072,608	06-2000	Psaltis, et al.
	A28	6,714,309 B2	03-2004	May
	A29	6,243,176	06-2001	Ishikawa et al.
	A30	5,938,309	08-1999	Taylor

We are not listing separately any prior U.S. Patent Office communications regarding the cited application(s) because the Examiner has access to any such actions through PAIR.

EXAMINER	DATE CONSIDERED

961592_1

Substitute for form 1449B/PTO **INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **February 23, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		CONTINUATION APPLICATION NO. 11/978,258
	FIRST NAMED INVENTOR Melanie Holmes		CONTINUATION FILING DATE October 29, 2007
	EXAMINER Loha Ben	CONFIRMATION NO. 4697	GROUP 2873

FOREIGN PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Country Code-Number-Kind Code (if known)	DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT	TRANSLATION YES	NO
	B1	EP 1 207 418 A1	05/22/2002	Alcatel		
	B2	WO 01 90823 A1	11-29-01	Intelligent Pixels, Inc.		
	B3	WO 01 25848 A2	04-12-01	Thomas Swan & Co., Ltd.		
	B4	WO 01 25840 A1	04-12-01	Thomas Swan & Co., Ltd.		
	B5	WO 02 101451 A1	12-19-02	Honeywell International, Inc.		
	B6	WO 02 079870 A2	10-10-02	Thomas Swan & Co., Ltd.		
	B7	EP 1 050 775 A1	11-08-00	Thomas Swan & Co., Ltd.		
	B8	EP 1 053 501 B1	07-23-03	Thomas Swan & Co., Ltd.		

EXAMINER	DATE CONSIDERED

961592_1

Substitute for form 1449B/PTO **INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **February 23, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		CONTINUATION APPLICATION NO. 11/978,258
	FIRST NAMED INVENTOR Melanie Holmes		CONTINUATION FILING DATE October 29, 2007
	EXAMINER Loha Ben	CONFIRMATION NO. 4697	GROUP 2873

Examiner's Initials	Ref. No.	**OTHER DOCUMENTS** *(Including Author, Title, Date, Pertinent Pages, Etc.)*
	C1	Yamazaki, H., *et al.*, "4 x 4 Free Space Optical Switching Using Real-Time Binary Phase-Only Holograms Generated by a Liquid-Crystal Display," *Optical Society of America*, 16(18):1415-1417 (1991).
	C2	Mears, R. J., et al., "Telecommunications Applications of Ferroelectric Liquid-Crystal Smart Pixels," IEEE Journal of Selected Topics in Quantum Electronics, Vol. 2, No. 1, April 1996, pp. 35-46.
	C3	Mears, R. J., et al., "WDM Channel Management Using Programmable Holographic Elements," IEE Colloquim on Multiwavelength Optical Networks: Devices, Systems and Network Implementations," IEE, London, GB, 18 June 1998, pp. 11-1 - 11-6.
	C4	Pan, Ci-Ling, et al., "Tunable Semiconductor Laser with Liquid Crystal Pixel Mirror in Grating-Loaded External Cavity," Electronics Letters, IEE Stevenage, GB, Vol. 35, No. 17, 19 August 1999, pp. 1472-1473.
	C5	Marom, D.M., *et al.*, "Wavelength-Selective 1x4 Switch for 128 WDM Channels at 50 Ghz Spacing," *OFC Postdeadline Paper*, pp. FB7-1-FB7-3 (2002).
	C6	Yamazaki, H., and Yamaguchi, M., "4 x 4 Free-Space Optical Switching Using Real-Time Binary Phase-Only Holograms Generated By a Liquid-Crystal Display," Optics Letters, Vol. 16, No. 18, pp. 1415-1417, 15 September 1991.

EXAMINER	DATE CONSIDERED

961592_1

Electronic Acknowledgement Receipt

EFS ID:	7067986
Application Number:	12710913
International Application Number:	
Confirmation Number:	9661
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Customer Number:	21005
Filer:	Timothy J. Meagher/Dawn Myers
Filer Authorized By:	Timothy J. Meagher
Attorney Docket Number:	3274.1003-004
Receipt Date:	23-FEB-2010
Filing Date:	
Time Stamp:	17:10:36
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal of New Application	32741003004Transmittal.pdf	76319 03e00892ce2c44c25aa9ccabced453c0ff7ce9aa	no	1

Warnings:

Information:

TS0002171

2	Miscellaneous Incoming Letter	32741003004Remarks.pdf	28368 c9b850908332e27ecee4f598ae792928d29b0545	no	1
Warnings:					
Information:					
3		32741003004Application.pdf	4305539 2bac20fdcdcde277c46cc093bacc886302d7312c	yes	104

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	97
Claims	98	103
Abstract	104	104

Warnings:					
Information:					
4	Drawings-only black and white line drawings	32741003004Drawings.pdf	372970 02c09a9e4eba139a972b241524af968e153306e7	no	36
Warnings:					
Information:					
5	Transmittal Letter	32741003004IDS.pdf	97062 97e4759c5c267abf8ce4c0c0222fd407b3bc3f79	no	3
Warnings:					
Information:					
6	Information Disclosure Statement (IDS) Filed (SB/08)	32741003004ListingofRefs.pdf	199798 2e02fa0c9d00ec12daae97fe75f6875c120d3406	no	4
Warnings:					
Information:					
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Total Files Size (in bytes):			5080056		

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (12-04)

Date: 02/23/10

Approved for use through 7/31/2006. OMB 0651-0032
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PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number: 12/710,913

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY RATE ($)	SMALL ENTITY FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	330
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	540
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	220
TOTAL CLAIMS (37 CFR 1.16(i))	30 minus 20 =	10	x$26		OR	x$52	520
INDEPENDENT CLAIMS (37 CFR 1.16(h))	8 minus 3 =	* 5	x$110			x$220	1100
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $260 ($130 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR						270
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))			195			390	
			TOTAL			TOTAL	2980

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

AMENDMENT A

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X =		OR	X =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X =		OR	X =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
					TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

OR

AMENDMENT B

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)	OR	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X =		OR	X =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X =		OR	X =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
					TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
12/710,913	02/23/2010	2872	0.00	3274.1003-004	30	8

CONFIRMATION NO. 9661

FILING RECEIPT

OC000000040444858

21005
HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

Date Mailed: 03/05/2010

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Melanie Holmes, Residence Not Provided;

Assignment For Published Patent Application

Thomas Swan & Co. Ltd.

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of 11/978,258 10/29/2007
which is a CON of 11/515,389 09/01/2006 PAT 7,612,930
which is a DIV of 10/487,810 09/10/2004 PAT 7,145,710
which is a 371 of PCT/GB02/04011 09/02/2002

Foreign Applications

UNITED KINGDOM 0121308.1 09/03/2001

If Required, Foreign Filing License Granted: 03/04/2010

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/710,913**

Projected Publication Date: To Be Determined - pending completion of Missing Parts

Non-Publication Request: No

Early Publication Request: No

Title

OPTICAL PROCESSING

Preliminary Class

359

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Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

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For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

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Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

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Alexandria, Virginia 22313-1450
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004

CONFIRMATION NO. 9661

FORMALITIES LETTER

OC000000040444859

21005
HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

Date Mailed: 03/05/2010

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
  *Applicant must submit $**330** to complete the basic filing fee for a non-small entity. If appropriate, applicant may make a written assertion of entitlement to small entity status and pay the small entity filing fee (37 CFR 1.27).*
- The oath or declaration is missing.
  A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
  Note: If a petition under 37 CFR 1.47 is being filed, an oath or declaration in compliance with 37 CFR 1.63 signed by all available joint inventors, or if no inventor is available by a party with sufficient proprietary interest, is required.

The application is informal since it does not comply with the regulations for the reason(s) indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- A substitute specification in compliance with 37 CFR 1.52, 1.121(b)(3), and 1.125, is required. The substitute specification must be submitted with markings and be accompanied by a clean version (without markings) as set forth in 37 CFR 1.125(c) and a statement that the substitute specification contains no new matter (see 37 CFR 1.125(b)). The specification, claims, and/or abstract page(s) submitted is not acceptable and cannot be scanned or properly stored because:
  - The application papers (including any electronically submitted papers) are not in compliance with 37 CFR 1.52 because pages 45 contain text that is written in unacceptable font or font size. The text must be written in nonscript type font (e.g., Arial, Times Roman, Courier, preferably a font size of 12) lettering style having capital letters that should be at least 0.3175 cm. (0.125 inch) high. A font with capital letters smaller than 0.3175 cm. (0.125 inch) high is only acceptable if the writing is clear and legible.

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

The applicant needs to satisfy supplemental fees problems indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- Additional claim fees of $**1620** as a non-small entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due.
- To avoid abandonment, a surcharge (for late submission of filing fee, search fee, examination fee or oath or declaration) as set forth in 37 CFR 1.16(f) of $**130** for a non-small entity, must be submitted with the missing items identified in this notice.

SUMMARY OF FEES DUE:

Total additional fee(s) required for this application is $**3110** for a non-small entity

- $**330** Statutory basic filing fee.
- $**130** Surcharge.
- The application search fee has not been paid. Applicant must submit $**540** to complete the search fee.
- The application examination fee has not been paid. Applicant must submit $**220** to complete the examination fee for a non-small entity.
- The specification and drawings submitted electronically contain the equivalent of more than 100 pages. Applicant owes $**270** for **5** pages in excess of **100** pages for a non-small entity.
- Total additional claim fee(s) for this application is $**1620**
  - $**1100** for **5** independent claims over 3.
  - $**520** for **10** total claims over 20.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.
https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at **1-866-217-9197** or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

/spathammavong/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2872
Filed:	February 23, 2010	Examiner:	Not Yet Assigned
Confirmation No.:	9661		
For:	OPTICAL PROCESSING		

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or is being facsimile transmitted to the United States Patent and Trademark Office on:

Date _______________ Signature _______________

____
Typed or printed name of person signing certificate

REPLY TO NOTICE TO FILE MISSING PARTS OF APPLICATION

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In reply to the Notice to File Missing Parts dated March 5, 2010, the following documents and fees are being submitted for filing in the captioned application.

☒ **COPY OF EXECUTED DECLARATION FOR PATENT APPLICATION**
(Separate transmittal letter and postcard not required)

☒ **POWER OF ATTORNEY DOCUMENT**
- ☐ Granted by Inventor(s)
- ☒ Granted by Assignee, including Statement under 37 CFR § 3.73(b)
(Separate transmittal letter and postcard not required)

☐ **PRELIMINARY AMENDMENT**
(Separate transmittal letter and postcard not required)

☒ **FILING FEE - with Fee Transmittal for Patent Applications**
Fee calculations based on:
- ☒ Claims as originally filed
  - ☐ The Notice to File Missing Parts states an erroneous number of claims.
- ☐ Claims upon entry of the Preliminary Amendment filed **[OPTION** [herewith][with the application**]**
(Separate transmittal letter and postcard not required)

☒ **SURCHARGE - surcharge fee of $130**
(Separate transmittal letter and postcard not required)

☐ **SEQUENCE LISTING - Filed concurrently and is attached**

☐ Preliminary Amendment included in Sequence Listing Transmittal
(Separate transmittal letter and postcard required)

☐ **REPLACEMENT DRAWINGS - [ ] sheets of replacement drawings consisting of Figs. 1 - [ ] are enclosed** *(Separate transmittal letter and postcard not required)*

☐ A Petition to Accept Color Drawings/Photographs (Fig(s). [ ]) are attached as required.
(Separate check for fees and postcard required)

☐ **PETITION FOR EXTENSION OF TIME**

☐ Applicant hereby petitions to extend the time to respond to the Notice to File Missing Parts dated [ ] for [ ] month(s) from [ ] to [ ]. The appropriate fee of $[ ] is included as indicated in the Method of Payment section below.

☐ A [ ] month extension of time to respond to the Notice to File Missing Parts dated [ ] was filed on [ ] with payment of a $[ ] fee

☐ Applicant hereby petitions for an additional [ ] month extension of time to respond to the Notice to File Missing Parts. The appropriate fee of $[ ] is included as indicated in the Method of Payment section below.
(Separate Petition for Extension of Time and postcard not required)

☐ **REQUEST FOR CORRECTED FILING RECEIPT - Filed concurrently and is attached**
(Separate transmittal letter and postcard required)

☐ **STATEMENT CLAIMING SMALL ENTITY STATUS**

☐ Was filed on [ ]

☐ Is enclosed herewith
(Separate transmittal letter and postcard not required)

☐ In view of the small entity status of the captioned application, we hereby request a reimbursement of 50% of the filing fees in the amount of $[ ] which were paid on [ ] to be deposited in Deposit Account No. 08-0380

☒ **OTHER** Substitute Specification (pgs. 1 – 97)

☒ **METHOD OF PAYMENT**

☐ The fees required for filing the indicated documents are enclosed in the form of a check in the total amount of $[ ].

☒ Please charge Deposit Account 08-0380 in the amount of $3110 for the fees required for filing the indicated documents.

☒ Please charge any deficiency in fees and credit any overpayment to Deposit Account 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By [signature]

Timothy J. Meagher
Registration No.: 39,302
Tel.: (978) 341-0036
Fax: (978) 341-0136

Concord, Massachusetts 01742-9133
Date: 5/5/10

DOCKET NO. 3274.1003-004

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Declaration for Patent Application

☐ Supplemental (37 CFR § 1.67)

As a named inventor, I hereby declare that:

My residence, mailing address and citizenship are as stated next to my name;

I believe I am the original, first and sole inventor (if only one name is listed) or an original, first and joint inventor (if plural names are listed in the signatory page(s) commencing at page 2 hereof) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Optical Processing

the specification of which:

☐ is attached hereto.

☒ was filed on February 23, 2010 as United States Application Number 12/710,913.

☐ was filed on [PCT filing date] as PCT International Application No. [PCT Appl'n No.] [and assigned United States Application No. [ ]].

☐ and was amended on [ ] (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby expressly authorize the filing of an International Patent Application under the Patent Cooperation Treaty which corresponds to and claims the priority of the above-identified application.

I hereby claim foreign priority benefits under 35 U.S.C. 119 or 365 of any foreign application(s) for patent or inventor's certificate, or of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Not Claimed	Certified Copy Filed? YES	NO
0121308.1 (Number)	Great Britain (Country)	03 September 2001 (Day/Month/Year filed)	☐	☐	☒
(Number)	(Country)	(Day/Month/Year filed)	☐	☐	☐
(Number)	(Country)	(Day/Month/Year filed)	☐	☐	☐

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor: Melanie Holmes

Inventor's Signature: Melanie Holmes

Residence:

City	State	Country	Citizenship
~~Ipswich~~ Woodbridge	Suffolk	United Kingdom	United Kingdom

Mailing Address (Business or Residential)

Street or P.O. Box: ~~39 Oxford Street~~ [illegible]

City	State	ZIP	Country
~~Ipswich~~ [illegible]	[illegible]	~~IP7 3PE~~ [illegible]	United Kingdom

961938 1

Mailing Address:

Thomas Swan & Co Ltd

Rotary Way

City: Consett

State: County Durham

ZIP: DH8 7ND

Country: United Kingdom

Initials: MJH

Date: 9.4.2010

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

POWER OF ATTORNEY and CORRESPONDENCE ADDRESS INDICATION FORM		
	Application Number	12/710,913
	Filing Date	February 23, 2010
	First Named Inventor	Melanie Holmes
	Confirmation Number	9661
	Group Art Unit	Not provided
	Examiner Name	Not provided
	Attorney Docket Number	3274.1003-004
Title	Optical Processing	

I hereby appoint

☒ Practitioners associated with **Customer No. 021005**

☐ Practitioner(s) named below:

as my/our attorneys/agents to prosecute the application identified above, including any continuation or divisional applications thereof, and to transact all business in the United States Patent and Trademark Office connected therewith.

Please recognize or change the correspondence address for the above-identified application to:

☒ Customer Number 021005

Hamilton, Brook, Smith & Reynolds, P.C.
530 Virginia Road
P.O. Box 9133
Concord, Massachusetts 01742-9133

☐ Other

Please direct all telephone calls and facsimiles to:
Name Timothy J. Meagher, Esq. Tel. No. 978-341-0036 Fax No. 978-341-0136

I am the:

☐ Applicant/Inventor.

☒ Authorized representative of the Assignee, Thomas Swan & Co. Ltd., of the entire interest. See 37 CFR § 3.71. A Statement under 37 CFR § 3.73(b) is enclosed.

☐ Authorized representative of the Assignee, [ ], together with [ ], of the entire interest. A Statement under 37 CFR § 3.73(b) is enclosed.

SIGNATURE of Applicant or Assignee of Record	
Signature	D Cavet
Name & Title	DAVID CAVET FINANCE DIRECTOR & CO. SECRETARY
Date	9TH APRIL 2010

961941_1

Docket No. 3274.1003-004

STATEMENT UNDER 37 CFR § 3.73(b)

Applicant/Patentee: Melanie Holmes

Application No./Patent No.: 12/710,913 Filed/Issue Date: February 23, 2010

For: Optical Processing

Thomas Swan & Co. Ltd. (Name of Assignee), a Corporation (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is

A. ☒ the assignee of the entire right, title and interest in the patent application identified above; or

B. ☐ an assignee together with [ ] of the entire right, title and interest in the patent application identified above.

The right, title and interest of the above-named assignee in the patent application identified above is established by virtue of:

A. ☒ An assignment from the inventor(s) of the patent application identified above. The assignment was recorded in the Patent and Trademark Office at Reel [ ], Frame [ ], or a copy thereof is attached.

OR

B. ☐ A chain of title from the inventor(s) of the patent application identified above, to the current assignee as shown below:

1. From: [ ] To: [ ]
   The document was recorded in the United States Patent and Trademark Office at Reel [ ], Frame [ ], or a copy thereof is attached.

2. From: [ ] To: [ ]
   The document was recorded in the United States Patent and Trademark Office at Reel [ ], Frame [ ], or a copy thereof is attached.

3. From: [ ] To: [ ]
   The document was recorded in the United States Patent and Trademark Office at Reel [ ], Frame [ ], or a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet.

As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

Signature: D Cavet

Name: DAVID CAVET

Title: FINANCE DIRECTOR

Date: 9th APRIL 2010

961956_1

TS0002185

COPY
NOT FOR
RECORDATION

Docket No. 3274.1003-004

Sole

ASSIGNMENT

WHEREAS, I, **Melanie Holmes**, have invented a certain improvement in **Optical Processing**, described in an application for Patent,

☐ the specification of which is about to be filed in the United States Patent Office *(use for utility (37 CFR § 1.53(b)) and design filings only)*;

☐ is about to be filed in the United States Patent Office as a Provisional Application;

☒ the specification of which is United States Application No. **12/710,913**, filed **February 23, 2010**;

☐ the specification of which is a Patent Cooperation Treaty Application, International Application No. [ ], filed [ ], which designates the United States of America [and is assigned United States Application No. [ ]];

☐ which was patented under United States Patent No. [ ].

WHEREAS, **Thomas Swan & Co. Ltd.** (hereinafter "ASSIGNEE"), a corporation organized and existing under the laws of the **United Kingdom** and having a usual place of business at **Crookhall, Consett, Co. Durham DH8 7ND, United Kingdom** desires to acquire an interest therein in accordance with agreements duly entered into with me;

NOW, THEREFORE, to all whom it may concern be it known that for and in consideration of said agreements and of other good and valuable consideration, the receipt of which is hereby acknowledged, I have sold, assigned and transferred and by these presents do hereby sell, assign and transfer unto said ASSIGNEE, its successors, assigns and legal representatives, the entire right, title and interest in and throughout the United States of America, its territories and all foreign countries, in and to said invention as described in said application, together with the entire right, title and interest in and to said application and such Letters Patent as may issue on said invention; said invention, application and Letters Patent to be held and enjoyed by said ASSIGNEE for its own use and behalf and for its successors, assigns and legal representatives, to the full end of the term for which said Letters Patent may be granted as fully and entirely as the same would have been held by me had this assignment and sale not been made; I hereby convey all rights arising under or pursuant to any and all international agreements, treaties or laws relating to the protection of industrial property by filing any such applications for Letters Patent. I hereby acknowledge that this assignment, being of the entire right, title and interest in and to said invention, carries with it the right in ASSIGNEE to apply for and obtain from competent authorities in all countries of the world any and all Letters Patent by attorneys and agents of ASSIGNEE's selection and the right to procure the grant of all such Letters Patent to ASSIGNEE for its own name as assignee of the entire right, title and interest therein; I hereby expressly authorize the filing of an International Patent Application under the Patent Cooperation Treaty which corresponds to and claims the priority of the above-identified application;

Docket No. 3274.1003-004

AND, I hereby further agree for myself and my executors and administrators to execute upon request any other lawful documents and likewise to perform any other lawful acts which may be deemed necessary to secure fully the aforesaid invention to said ASSIGNEE, its successors, assigns and legal representatives, but at its or their expense and charges, including the execution of applications for patents in foreign countries, and the execution of any further applications including substitution, reissue, divisional or continuation applications, and preliminary or other statements and the giving of testimony in any interference or other proceeding in which said invention or any application or patent directed thereto may be involved;

AND, I do hereby authorize and request each Patent Office and the Commissioner of Patents of the United States to issue such Letters Patent as shall be granted upon said invention to said ASSIGNEE, its successors, assigns, and legal representatives.

Inventor *Melanie Holmes* Date *9th April 2010*
Melanie Holmes

Address ~~39 Oxford Street~~ *39 The Forge, The Street, Brundish,* *Initials: MH Date: 9.4.2010*
~~Ipswich IP1 3PE~~ United Kingdom *Woodbridge, Suffolk IP13 8BL United Kingdom*

Witness Signature *[signature]*

Print Witness Name *SIMON ROBSON*

Address *LOW FAWNLESS FARM, LEAZES LANE, WOLSINGHAM CO. DURHAM DL13 3LP*

Witness Signature *D Cavet*

Print Witness Name *D. CAVET*

Address *5 BRIAR VALE WEST MONKSEATON, TYNE & WEAR NE25 9AZ*

961927_1

TS0002187

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2872
Filed:	February 23, 2010	Examiner:	Not Yet Assigned
Confirmation No.:	9661		
For:	OPTICAL PROCESSING		

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or is being facsimile transmitted to the United States Patent and Trademark Office on:

Date ____________ Signature ____________

Typed or printed name of person signing certificate ____________

STATEMENT UNDER 37 CFR § 1.125(b)

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Statement is being filed in response to the Notice to File Missing Parts of Nonprovisional Application mailed from the U.S. Patent and Trademark Office on March 5, 2010 in the above-identified application.

Applicant submits concurrently herewith a substitute specification for replacement in the subject application filed on February 23, 2010 in compliance with 37 CFR § 1.52, § 1.121(b)(3) and § 1.125.

Enclosed please find a substitute specification consisting of pages 1 through 97. The text objected to on originally filed page 45 has been reproduced for clarity in acceptable font and font size. Reproduction of the text for clarity has not caused the specification page count to change. No new matter has been added to the substitute specification and, therefore, Applicant believes a marked-up version of the specification is not required in this instance.

Please charge any deficiency or credit any overpayment in the fees that may be due in this matter to Deposit Account No. 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By

Timothy J. Meagher
Registration No.: 39,302
Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133
Dated: 5/5/10

Date: ____________ Express Mail Label No.____________

Inventor: Melanie Holmes

Attorney's Docket No.: 3274.1003-004

OPTICAL PROCESSING

RELATED APPLICATIONS

This application is a continuation of U.S. Application No. 11/978,258, filed October 29, 2007, which is a continuation of U.S. Application No. 11/515,389, filed September 1, 2006, which is a divisional of U.S. Application No. 10/487,810, which is the U.S. National Stage of International Application No. PCT/GB02/04011, filed September 2, 2002, and published in English. This application claims priority under 35 U.S.C. § 119 or 365 to Great Britain Application No. 0121308.1, filed September 3, 2001. The entire teachings of the above application(s) are incorporated herein by reference.

FIELD OF THE INVENTION

[0001] The present invention relates to an optical device and to a method of controlling an optical device.

[0002] More particularly but not exclusively the invention relates to the general field of controlling one or more light beams by the use of electronically controlled devices. The field of application is mainly envisaged as being to fields in which reconfiguration between inputs and outputs is likely, and stability of performance is a significant requirement.

BACKGROUND OF THE INVENTION

[0003] It has previously been proposed to use so-called spatial light modulators to control the routing of light beams within an optical system, for instance from selected ones of a number of input optical fibres to selected ones of output fibres.

[0004] Optical systems are subject to performance impairments resulting from aberrations, phase distortions and component misalignment. An example is a multiway fibre connector, which although conceptually simple can often be a critical source of system failure or insertion loss due to the very tight alignment tolerances for optical fibres, especially for single-mode optical fibres. Every time a fibre connector is connected, it may provide a different alignment error. Another example is an optical switch in which aberrations, phase distortions and component misalignments result in poor optical coupling efficiency into the intended output optical fibres. This in turn may lead to high insertion loss. The aberrated propagating waves may diffract into intensity fluctuations creating significant unwanted coupling of light into other output optical fibres, leading to levels of crosstalk that impede operation. In some cases, particularly where long path lengths are involved, the component misalignment may occur due to ageing or temperature effects.

[0005] Some prior systems seek to meet such problems by use of expensive components. For example in a communications context, known free-space wavelength multiplexers and demultiplexers use expensive thermally stable opto-mechanics to cope with the problems associated with long path lengths.

[0006] Certain optical systems have a requirement for reconfigurability. Such reconfigurable systems include optical switches, add/drop multiplexers and other optical routing systems where the mapping of signals from input ports to output ports is dynamic. In such systems the path-dependent losses, aberrations and phase distortions encountered by optical beams may vary from beam to beam according to the route taken by the beam through the system. Therefore the path-dependent loss, aberrations and phase distortions may vary for each input beam or as a function of the required output port.

[0007] The prior art does not adequately address this situation.

[0008] Other optical systems are static in terms of input/output configuration. In such systems, effects such as assembly errors, manufacturing tolerances in the optics and also changes in the system behaviour due to temperature and ageing, create the desirability for dynamic direction control, aberration correction, phase distortion compensation or misalignment compensation.

[0009] It should be noted that the features of dynamic direction control, phase distortion compensation and misalignment control are not restricted to systems using input beams coming from optical fibres. Such features may also be advantageous in a reconfigurable optical system. Another static system in which dynamic control of phase distortion, direction and (relative) misalignment would be advantageous is one in which the quality and/or position of the input beams is time-varying.

[0010] Often the input and output beams for optical systems contain a multiplex of many optical signals at different wavelengths, and these signals may need to be separated and adaptively and individually processed inside the system. Sometimes, although the net aim of a system is not to separate optical signals according to their wavelength and then treat them separately, to do so increases the wavelength range of the system as a whole. Where this separation is effected, it is often advantageous for the device used to route each channel to have a low insertion loss and to operate quickly.

[0011] It is an aim of some aspects of the present invention at least partly to mitigate difficulties of the prior art.

[0012] It is desirable for certain applications that a method or device for addressing these issues should be polarisation-independent, or have low polarisation-dependence.

[0013] SLMs have been proposed for use as adaptive optical components in the field of astronomical devices, for example as wavefront correctors. In this field of activity, the constraints are different to the present field-for example in communication and like devices, the need for consistent performance is paramount if data is to be passed without errors. Communication and like devices are desirably inexpensive, and desirably inhabit and successfully operate in environments that are not closely controlled. By contrast, astronomical devices may be used in conditions more akin to laboratory conditions, and cost constraints are less pressing. Astronomical devices are unlikely to need to select successive routings of light within a system, and variations in performance may be acceptable.

SUMMARY OF THE INVENTION

[0014] According to a first aspect of the invention, there is provided a method of operating an optical device comprising an SLM having a two-dimensional array of controllable phase-modulating elements, the method comprising

[0015] delineating groups of individual phase-modulating elements;

[0016] selecting, from stored control data, control data for each group of phase-modulating elements;

[0017] generating from the respective selected control data a respective hologram at each group of phase-modulating elements; and

[0018] varying the delineation of the groups and/or the selection of control data whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

[0019] In some embodiments, the variation of the delineation and/or control data selection is in response to a signal or signals indicating a non-optimal performance of the device. In other embodiments, the variation is performed during a set up or training phase of the device. In yet other embodiments, the variation is in response to an operating signal, for example a signal giving the result of sensing non-performance system parameters such as temperature.

[0020] An advantage of the method of this aspect of the invention is that stable operation can be achieved in the presence of effects such as ageing, temperature, component, change of path through the system and assembly tolerances.

[0021] Preferably, control of said light beams is selected from the group comprising: control of direction, control of power, focussing, aberration compensation, sampling and beam shaping.

[0022] Clearly in most situations more than one of these control types will be needed-for example in a routing device (such as a switch, filter or add/drop multiplexer) primary changes of direction are likely to be needed to cope with changes of routing as part of the main system but secondary correction will be needed to cope with effects such as temperature and ageing. Additionally such systems may also need to control power, and to allow sampling (both of which may in some cases be achieved by direction changes).

[0023] Advantageously, each phase modulating element is responsive to a respective applied voltage to provide a corresponding phase shift to emergent light, and the method further comprises;

[0024] controlling said phase-modulating elements of the spatial light modulator to provide respective actual holograms derived from the respective generated holograms, wherein the controlling step comprises;

[0025] resolving the respective generated holograms modulo 2pi.

[0026] The preferred SLM uses a liquid crystal material to provide phase shift and the liquid crystal material is not capable of large phase shifts beyond plus or minus 2π. Some liquid crystal materials can only provide a smaller range of phase shifts, and if such materials are used, the resolution of the generated hologram is correspondingly smaller.

[0027] Preferably the method comprises:

[0028] providing a discrete number of voltages available for application to each phase modulating element;

[0029] on the basis of the respective generated holograms, determining the desired level of phase modulation at a predetermined point on each phase modulating element and choosing for each phase modulating element the available voltage which corresponds most closely to the desired level.

[0030] Where a digital control device is used, the resolution of the digital signal does not provide a continuous spectrum of available voltages. One way of coping with this is to determine the desired modulation for each pixel and to choose the individual voltage which will provide the closest modulation to the desired level.

[0031] In another embodiment, the method comprises:

[0032] providing a discrete number of voltages available for application to each phase modulating element;

[0033] determining a subset of the available voltages which provides the best fit to the generated hologram.

[0034] Another technique is to look at the pixels of the group as a whole and to select from the available voltages those that give rise to the nearest phase modulation across the whole group.

[0035] Advantageously, the method further comprises the step of storing said control data wherein the step of storing said control data comprises calculating an initial hologram using a desired direction change of a beam of light, applying said initial hologram to a group of phase modulating elements, and correcting the initial hologram to obtain an improved result.

[0036] The method may further comprise the step of providing sensors for detecting temperature change, and performing said varying step in response to the outputs of those sensors.

[0037] The SLM may be integrated on a substrate and have an integral quarter-wave plate whereby it is substantially polarisation insensitive.

[0038] Preferably the phase-modulating elements are substantially reflective, whereby emergent beams are deflected from the specular reflection direction.

[0039] In some aspects, for at least one said group of pixels, the method comprises providing control data indicative of two holograms to be displayed by said group and generating a combined hologram before said resolving step.

[0040] According to a second aspect of the invention there is provided an optical device comprising an SLM and a control circuit, the SLM having a two-dimensional array of controllable phase-modulating elements and the control circuit having a store constructed and arranged to hold plural items of control data, the control circuit being constructed and arranged to delineate groups of individual phase-modulating elements, to select, from stored control data, control data for each group of phase-modulating elements, and to generate from the respective selected control data a respective hologram at each group of phase-modulating elements,

[0041] wherein the control circuit is further constructed and arranged, to vary the delineation of the groups and/or the selection of control data

[0042] whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

[0043] An advantage of the device of this aspect of the invention is that stable operation can be achieved in the presence of effects such as ageing, temperature, component and assembly tolerances. Embodiments of the device can handle many light beams simultaneously. Embodiments can be wholly reconfigurable, for example compensating differently for a number of routing configurations.

[0044] Preferably, the optical device has sensor devices arranged to detect light emergent from the SLM, the control circuit being responsive to signals from the sensors to vary said delineation and/or said selection.

[0045] In some embodiments, the optical device has temperature responsive devices constructed and arranged to feed signals indicative of device temperature to said control circuit, whereby said delineation and/or selection is varied.

[0046] In another aspect, the invention provides an optical routing device having at least first and second SLMs and a control circuit, the first SLM being disposed to receive respective light beams from an input fibre array, and the second SLM being disposed to receive emergent light from the first SLM and to provide light to an output fibre array, the first and second SLMs each having a respective two-dimensional array of controllable phase-modulating elements and the control circuit having a store constructed and arranged to hold plural items of control data, the control circuit being constructed and arranged to delineate groups of individual phase-modulating elements, to select, from stored control data, control data for each group of phase-modulating elements, and to generate from the respective selected control data a respective hologram at each group of phase-modulating elements,

[0047] wherein the control circuit is further constructed and arranged, to vary the delineation of the groups and/or the selection of control data

[0048] whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

[0049] In a further aspect, the invention provides a device for shaping one or more light beams in which the or each light beam is incident upon a respective group of pixels of a two-dimensional SLM, and the pixels of the or each respective group are controlled so that the corresponding beams emerging from the SLM are shaped as required.

[0050] According to a further aspect of the invention there is provided an optical device comprising one or more optical inputs at respective locations, a diffraction grating constructed and arranged to receive light from the or each optical input, a focussing device and a continuous array of phase modulating elements, the diffraction grating and the array of phase modulating elements being disposed in the focal plane of the focussing device whereby diverging light from a single point on the diffraction grating passes via the focussing device to form beams at the array of phase modulating elements, the device further comprising one or more optical output at respective locations spatially separate from the or each optical input, whereby the diffraction grating is constructed and arranged to output light to the or each optical output.

[0051] This device allows multiwavelength input light to be distributed in wavelength terms across different groups of phase-modulating elements. This allows different processing effects to be applied to any desired part or parts of the spectrum.

[0052] According to a still further aspect of the invention there is provided a method of filtering light comprising applying a beam of said light to a diffraction grating whereby emerging light from the grating is angularly dispersed by wavelength, forming respective beams from said emerging light by passing the emerging light to a focussing device having the grating at its focal plane, passing the respective beams to an SLM at the focal plane of the focussing device, the SLM having a two-dimensional array of controllable phase-modulating elements, selectively reflecting light from different locations of said SLM and passing said reflected light to said focussing element and then to said grating.

[0053] Preferably the method comprises delineating groups of individual phase-modulating elements to receive beams of light of differing wavelength;

[0054] selecting, from stored control data, control data for each group of phase-modulating elements;

[0055] generating from the respective selected control data a respective hologram at each group of phase-modulating elements; and

[0056] varying the delineation of the groups and/or the selection of control data.

[0057] According to a still further aspect of the invention there is provided an optical add/drop multiplexer having a reflective SLM having a two-dimensional array of controllable phase-modulating elements, a diffraction device and a focussing device wherein light beams from a common point on the diffraction device are mutually parallel when incident upon the SLM, and wherein the SLM displays respective holograms at locations of incidence of light to provide emergent beams whose direction deviates from the direction of specular reflection.

[0058] In a yet further aspect, the invention provides a test or monitoring device comprising an SLM having a two-dimensional array of pixels, and operable to cause incident light to emerge in a direction deviating from the specular direction, the device having light sensors at predetermined locations arranged to provide signals indicative of said emerging light.

[0059] The test or monitoring device may further comprise further sensors arranged to provide signals indicative of light emerging in the specular directions.

[0060] Yet a further aspect of the invention relates to a power control device for one or more beams of lights in which the said beams are incident on respective groups of pixels of a two-dimensional SLM, and holograms are applied to the respective group so that the emergent beams have power reduced by comparison to the respective incident beams.

[0061] The invention further relates to an optical routing module having at least one input and at least two outputs and operable to select between the outputs, the module comprising a two dimensional SLM having an array of pixels, with circuitry constructed and arranged to display holograms on the pixels to route beams of different frequency to respective outputs.

[0062] According to a later aspect of the invention there is provided an optoelectronic device comprising an integrated multiple phase spatial light modulator (SLM) having a plurality of pixels, wherein each pixel can phase modulate light by a phase shift having an upper and a lower limit, and wherein each pixel has an input and is responsive to a value at said input to provide a phase modulation determined by said value, and a controller for the SLM, wherein the controller has a control input receiving data indicative of a desired phase modulation characteristic across an array of said pixels for achieving a desired control of light incident on said array, the controller has outputs to each pixel, each output being capable of assuming only a discrete number of possible values, and the controller comprises a processor constructed and arranged to derive, from said desired phase modulation characteristic, a non-monotonic phase modulation not extending outside said upper and lower limits, and a switch constructed and arranged to select between the possible values to provide a respective one value at each output whereby the SLM provides said non-monotonic phase modulation.

[0063] Some or all of the circuitry may be on-chip leading to built-in intelligence. This leads to more compact and ultimately low-cost devices. In some embodiments, some or all on-chip circuitry may operate in parallel for each pixel which may provide huge time advantages; in any event the avoidance of the need to transfer data off chip and thereafter to read in to a computer allows configuration and reconfiguration to be faster.

[0064] According to another aspect of the invention there is provided a method of controlling a light beam using a spatial light modulator (SLM) having an array of pixels, the method comprising:

[0065] determining a desired phase modulation characteristic across a sub-array of said pixels for achieving the desired control of said beam;

[0066] controlling said pixels to provide a phase modulation derived from the desired phase modulation, wherein the controlling step comprises

[0067] providing a population of available phase modulation levels for each pixel, said population comprising a discrete number of said phase modulation levels;

[0068] on the basis of the desired phase modulation, a level selecting step of selecting for each pixel a respective one of said phase modulation levels; and

[0069] causing each said pixel to provide the respective one of said phase modulation levels.

[0070] The SLM may be a multiple phase liquid crystal over silicon spatial light modulator having plural pixels, of a type having an integrated wave plate and a reflective element, such that successive passes of a beam through the liquid crystal subject each orthogonally polarised component to a substantially similar electrically-set phase change.

[0071] If a non-integrated wave plate is used instead, a beam after reflection and passage through the external wave plate will not pass through the same zone of the SLM, unless it is following the input path, in which case the zero order component of said beam will re-enter the input fibre.

[0072] The use of the wave plate and the successive pass architecture allows the SLM to be substantially polarisation independent.

[0073] In one embodiment the desired phase modulation at least includes a linear component.

[0074] Linear phase modulation, or an approximation to linear phase modulation may be used to route a beam of light, i.e. to select a new direction of propagation for the beam. In many routing applications, two SLMs are used in series, and the displayed information on the one has the inverse effect to the information displayed on the other. Since the information represents phase change data, it may be regarded as a hologram. Hence an output SLM may display a hologram that is the inverse of that displayed on the input SLM. Routing may also be "one-to-many" (i.e. multicasting) or "one-to-all" (i.e. broadcasting) rather than the more usual one-to-one in many routing devices. This may be achieved by correct selection of the relevant holograms.

[0075] Preferably the linear modulation is resolved modulo 2pi to provide a periodic ramp.

[0076] In another embodiment the desired phase modulation includes a non-linear component.

[0077] Preferably the method further comprises selecting, from said array of pixels, a sub-array of pixels for incidence by said light beam.

[0078] The size of a selected sub-array may vary from switch to switch according to the physical size of the switch and of the pixels. However, a typical routing device may have pixel arrays of between 100*100 and 200*200, and other devices such as add/drop multiplexers may have arrays of between 10*10 and 50*50. Square arrays are not essential.

[0079] In one embodiment the level-selecting step comprises determining the desired level of phase modulation at a predetermined point on each pixel and choosing for each pixel, the available level which corresponds most closely to the desired level.

[0080] In another embodiment, the level-selecting step comprises determining a subset of the available levels, which provides the best fit to the desired characteristic.

[0081] The subset may comprise a subset of possible levels for each pixel.

[0082] Alternatively the subset may comprise a set of level distributions, each having a particular level for each pixel.

[0083] In one embodiment, the causing step includes providing a respective voltage to an electrode of each pixel, wherein said electrode extends across substantially the whole of the pixel.

[0084] Preferably again the level selecting step comprises selecting the level by a modulo 2pi comparison with the desired phase modulation. The actual phase excursion may be from A to A+2π where A is an arbitrary angle.

[0085] Preferably the step of determining the desired phase modulation comprises calculating a direction change of a beam of light.

[0086] Conveniently, after the step of calculating a direction change, the step of determining the desired phase modulation further comprises correcting the phase modulation obtained from the calculating step to obtain an improved result.

[0087] Advantageously, the correction step is retroactive.

[0088] In another embodiment the step of determining the desired phase modulation is retroactive, whereby parameters of the phase modulation are varied in response to a sensed error to reduce the error.

[0089] A first class of embodiments relates to the simulation/synthesis of generally corrective elements. In some members of the first class, the method of the invention is performed to provide a device, referred to hereinafter as an accommodation element for altering the focus of the light beam.

[0090] An example of an accommodation element is a lens. An accommodation element may also be an anti-astigmatic device, for instance comprising the superposition of two cylindrical lenses at arbitrary orientations.

[0091] In other members of the first class, the method of the invention is performed to provide an aberration correction device for correcting greater than quadratic aberrations.

[0092] The sub-array selecting step may assign a sub-array of pixels to a beam based on the predicted path of the beam as it approaches the SLM just prior to incidence.

[0093] Advantageously, after the sub-array is assigned using the predicted path, it is determined whether the assignment is correct, and if not a different sub-array is assigned.

[0094] The assignment may need to be varied in the event of temperature, ageing or other physical changes. The sub-array selection is limited in resolution only by the pixel size. By contrast other array devices such as MEMS have fixed physical edges to their beam steering elements.

[0095] An element of this type may be used in a routing device to compensate for aberrations, phase distortions and component misalignment in the system. By providing sensing devices a controller may be used to retroactively control the element and the element may maintain an optimum performance of the system.

[0096] In one embodiment of this first class, the method includes both causing the SLM to route a beam and causing the SLM to emulate a corrective element to correct for errors, whereby the SLM receives a discrete approximation of the combination of both a linear phase modulation applied to it to route the beam and a non-linear phase modulation for said corrections.

[0097] Synthesising a lens using an SLM can be used to change the position of the beam focused spot and therefore correct for a position error or manufacturing tolerance in one or more other lenses or reflective (as opposed to transmissive) optical elements such as a curved mirror.

[0098] The method of the invention may be used to correct for aberrations such as field curvature in which the output 'plane' of the image(s) from an optical system is curved, rather than flat.

[0099] In another embodiment of the first class, intelligence may be integrated with sensors that detect the temperature changes and apply data from a look-up table to apply corrections.

[0100] In yet another embodiment of this class, misalignment and focus errors are detected by measuring the power coupled into strategically placed sensing devices, such as photodiode arrays, monitor fibres or a wavefront sensor. Compensating holograms are formed as a result of the discrete approximations of the non-linear modulation. Changes or adjustments may then be made to these holograms, for example by applying a stimulus and then correcting the holograms according to the sensed response until the system alignment is measured to be optimised.

[0101] In embodiments where the method provides routing functions by approximated linear modulation, adaptation of non-linear modulation due to changes in the path taken through the system desirably takes place on a timescale equivalent to that required to change the hologram routing, i.e. of the order of milliseconds.

[0102] A control algorithm may use one or more of several types of compensation.

[0103] In one embodiment a look-up table is used with pre-calculated 'expected' values of the compensation taking account of the different routes through the system.

[0104] In another embodiment the system is trained before first being operated, by repeated changes of, or adjustments to, the compensating holograms to learn how the system is misaligned.

[0105] A further embodiment employs intelligence attached to the monitor fibres for monitoring and calculation of how these compensating holograms should adapt with time to accommodate changes in the system alignment. This is achieved in some embodiments by integrating circuitry components into the silicon backplane of the SLM.

[0106] In many optical systems there is a need to control and adapt the power or shape of an optical beam as well as its direction or route through the optical system. In communications applications, power control is required for network management reasons. In general, optical systems require the levelling out or compensation for path and wavelength-dependent losses inside the optical system. It is usually desirable that power control should not introduce or accentuate other performance impairments.

[0107] Thus in a second class of embodiments, the modulation applied is modified for controlling the attenuation of an optical channel subjected to the SLM.

[0108] In one particular embodiment, the ideal value of phase modulation is calculated for every pixel, and then multiplied by a coefficient having a value between 0 and 1, selected according to the desired attenuation and the result is compared to the closest available phase level to provide the value applied to the pixels.

[0109] In another embodiment, the method further comprises selecting by a discrete approximation to a linear phase modulation, a routing hologram for display by the SLM whereby the beams may be correctly routed; selecting by a discrete approximation to a non-linear phase modulation, a further hologram for separating each beam into main and subsidiary beams, wherein the main beam is routed through the system and the or each subsidiary beam is diffracted out of the system; combining the routing and further holograms together to provide a resultant hologram; and causing the SLM to provide the resultant hologram.

[0110] The non-linear phase modulation may be oscillatory.

[0111] In yet another embodiment, the method further comprises selecting by a discrete approximation to a linear phase modulation, a routing hologram for display by the SLM whereby the beams may be correctly routed; selecting by a discrete approximation to a non-linear phase modulation, a further hologram for separating each beam into main and subsidiary beams, wherein the main beam is routed through the system and at least one subsidiary beam is incident on an output at an angle such that its contribution is insignificant; combining the routing and further holograms together to provide resultant hologram; and causing the SLM to display the resultant hologram.

[0112] The non-linear phase modulation may be oscillatory.

[0113] In a closely allied class of embodiments, light may be selectively routed to a sensor device for monitoring the light in the system. The technique used may be a power control technique in which light diverted from the beam transmitted through the system to reduce its magnitude is made incident on the sensor device.

[0114] In another class of embodiments, a non-linear phase modulation profile is selected to provide beam shaping, for example so as to reduce cross-talk effects due to width clipping. This may use a pseudo amplitude modulation technique.

[0115] In a further class of embodiments, the method uses a non-linear modulation profile chosen to provide wavelength dependent effects.

[0116] The light may be at a telecommunications wavelength, for example 850 nm, 1300 nm or in the range 1530 nm to 1620 nm.

BRIEF DESCRIPTION OF THE DRAWINGS

[0117] Exemplary embodiments of the invention will now be described with reference to the accompanying drawings in which:

[0118] FIG. 1 shows a cross-sectional view through an exemplary SLM suitable for use in the invention;

[0119] FIG. 2 shows a sketch of a routing device in which a routing SLM is used additionally to provide correction for performance impairment due to misalignment;

[0120] FIG. 3 shows a sketch of a routing device in which a routing SLM is used to route light beams and an additional SLM provides correction for performance impairment due to misalignment;

[0121] FIG. 4 shows a block diagram of an adaptive corrective SLM;

[0122] FIG. 5 shows an adaptive optical system using three SLMs;

[0123] FIG. 6 shows a partial block diagram of a routing device with a dual function SLM and control arrangements;

[0124] FIG. 7 shows a block diagram of an SLM for controlling the power transferred in an optical system;

[0125] FIG. 8a shows a diagram of phase change distribution applied by a hologram for minimum attenuation;

[0126] FIG. 8b shows a diagram of phase change distribution applied by a hologram enabling attenuation of the signal;

[0127] FIG. 9 shows a power control system;

[0128] FIG. 10 shows a phasor diagram showing the effect of non-linear oscillatory phase modulation applied to adjacent pixels;

[0129] FIG. 11 shows a schematic diagram of a part of an optical routing system illustrating the effects of clipping and cross talk;

[0130] FIG. 12 shows a partial block diagram of a system enabling beams of different wavelength from a composite input beam to be separately controlled before recombination; and

[0131] FIG. 13 shows a schematic diagram of an add/drop multiplexer using an SLM.

[0132] FIG. 14 is a diagram similar to FIG. 12 but showing a magnification stage for increasing the effective beam deflection angle;

[0133] FIG. 15 shows a vector diagram of the operation of an add/drop multiplexer;

[0134] FIG. 16 shows a block diagram showing how loop back may be effected;

[0135] FIG. 17 is a vector diagram illustrating the operation of part of FIG. 16;

[0136] FIG. 18 is a vector diagram of a multi-input/multi-output architecture;

[0137] FIG. 19 is a graph showing the relative transmission Tlo for in-band wavelengths as a function of the ratio of the wavelength offset u to centre of the wavelength channel separation;

[0138] FIG. 20 is a graph showing the relative transmission Thi inside adjacent channels;

[0139] FIG. 21 shows a logical diagram of the sorting function;

[0140] FIG. 22 shows a block diagram of an add/drop node using two routing modules;

[0141] FIG. 23 shows a block diagram of modules used to cross-connect two rings;

[0142] FIG. 24 shows a block diagram of routing modules connected to provide expansion;

[0143] FIG. 25 shows a block diagram of an optical cross-connect;

[0144] FIG. 26 shows a block diagram of an upgrades node having a cascaded module at an expansion output port;

[0145] FIG. 27 is a graph showing the effect of finite hologram size of the field of a beam incident on a hologram;

[0146] FIG. 28 shows a schematic layout of a wavelength filter device; and,

[0147] FIG. 29 shows a schematic layout of an add/drop device;

[0148] FIG. 30 shows a block diagram of an optical test set;

[0149] FIG. 31 is a diagram showing the effect of finite hologram size on a beam at a wavelength different to the centre wavelength associated with the hologram;

[0150] FIG. 32 shows the truncated beam shapes for wavelengths at various wavelength differences from the centre of the wavelength channel dropped in isolation;

[0151] FIG. 33 shows the overlap integrands of the beams of FIG. 32 with the fundamental mode of the fibre;

[0152] FIG. 34 shows beam output positions for different wavelengths with respect to two optical fibres; and

[0153] FIG. 35 shows the overlap integrand between the beams of FIG. 34 and the fundamental mode of one of the optical fibres.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0154] Many of the embodiments of the invention centre upon the realisation that the problems of the prior art can be solved by using a reflective SLM having a two-dimensional array of phase-modulating elements that is large in number, and applying a number of light beams to groups of those phase-modulating elements. A significant feature of these embodiments is the fact that the size, shape and position of those groups need not be fixed and can, if need be, be varied. The groups may display holograms which can be set up as required to deflect the light so as to provide a non-specular reflection at a controllable angle to the specular reflection direction. The holograms may additionally or alternatively provide shaping of the beam.

[0155] The SLM may thus simulate a set of highly flexible mirrors, one for each beam of light. The size, shape and position of each mirror can be changed, as can the deflection and the simulated degree of curvature.

[0156] Devices embodying the invention act on light beams incident on the device to provide emerging light beams which are controlled independently of one another. Possible types of control include control of direction, control of power, focussing, aberration compensation, sampling and beam shaping.

[0157] The structure and arrangement of polarisation-independent multiple phase liquid crystal over silicon spatial light modulators (SLMs) for routing light beams using holograms are discussed in our co-pending patent application PCT/GB00/03796. Such devices have an insertion loss penalty due to the dead-space between the pixels. As discussed in our co-pending patent application GB0107742.9, the insertion loss may be reduced significantly by using a reflecting layer inside the substrate positioned so as to reflect the light passing between the pixels back out again.

[0158] Referring to FIG. 1, an integrated SLM 200 for modulating light 201 of a selected wavelength, e.g. 1.5 μm, consists of a pixel electrode array 230 formed of reflective aluminium. The pixel electrode array 230, as will later be described acts as a mirror, and disposed on it is a quarter-wave plate 221. A liquid crystal layer 222 is disposed on the quarter-wave plate 221 via an alignment layer (not shown) as is known to those skilled in the art of liquid crystal structures. Over (as shown) the liquid crystal layer 222 are disposed in order a second alignment layer 223, a common ITO electrode layer 224 and an upper glass layer 225. The common electrode layer 224 defines an electrode plane. The pixel electrode array 230 is disposed parallel to the common electrode plane 224. It will be understood that alignment layers and other intermediate layers will be provided as usual. They are omitted in FIG. 1 for clarity.

[0159] The liquid crystal layer 222 has its material aligned such that under the action of a varying voltage between a pixel electrode 230 and the common electrode 224, the uniaxial axis changes its tilt direction in a plane normal to the electrode plane 224.

[0160] The quarter wave plate 221 is disposed such that light polarised in the plane of tilt of the director is reflected back by the mirror 230 through the SLM with its plane of polarisation perpendicular to the plane of tilt, and vice-versa.

[0161] Circuitry, not shown, connects to the pixel electrodes 230 so that different selected voltages are applied between respective pixel electrodes 230 and the common electrode layer 224.

[0162] Considering an arbitrary light beam 201 passing through a given pixel, to which a determined potential difference is applied, thus resulting in a selected phase modulation due to the liquid crystal layer over the pixel electrode 230. Consider first and second orthogonal polarisation components, of arbitrary amplitudes, having directions in the plane of tilt of the director and perpendicular to this plane, respectively. These directions bisect the angles between the fast and slow axes of the quarter-wave plate 221.

[0163] The first component experiences the selected phase change on the inward pass of the beam towards the aluminium layer 230, which acts as a mirror. The second component experiences a fixed, non-voltage dependent phase change.

[0164] However, the quarter-wave plate 221 in the path causes polarisation rotation of the first and second components by 90 degrees so that the second polarisation component of the light beam is presented to the liquid crystal for being subjected to the selected phase change on the outward pass of the beam away from the mirror layer 230. The first polarisation component experiences the fixed, non-voltage dependent phase change on the outward pass of the beam. Thus, both of the components experience the same overall phase change contribution after one complete pass through the device, the total contribution being the sum of the fixed, non-voltage dependent phase and the selected voltage dependent phase change.

[0165] It is not intended that any particular SLM structure is essential to the invention, the above being only exemplary and illustrative. The invention may be applied to other devices, provided they are capable of multiphase operation and are at least somewhat polarisation independent at the wavelengths of concern. Other SLMs are to be found in our co-pending applications WO01/25840, EP1050775 and EP1053501 as well as elsewhere in the art.

[0166] Where liquid crystal materials other than ferroelectric are used, current practice indicates that the use of an integral quarter wave plate contributes to the usability of multiphase, polarisation-independent SLMs.

[0167] A particularly advantageous SLM uses a liquid crystal layer configured as a pi cell.

[0168] Referring to FIG. 2, an integrated SLM 10 has processing circuitry 11 having a first control input 12 for routing first and second beams 1,2 from input fibres 3,4 to output fibres 5,6 in a routing device 15. The processing circuitry 11 includes a store holding control data which is processed to generate holograms which are applied to the SLM 10 for control of light incident upon the SLM 10. The control data are selected in dependence upon the data at the control input 12, and may be stored in a number of ways, including compressed formats. The processing circuitry 11, which may be at least in part on-chip, is also shown as having an additional input 16 for modifying the holograms. This input 16 may be a physical input, or may be a "soft" input-for example data in a particular time slot.

[0169] The first beam 1 is incident on, and processed by a first array, or block 13 of pixels, and the second beam 2 is incident on and processed by a second array, or block 14 of pixels. The two blocks of pixels 13,14 are shown as contiguous. In some embodiments they might however be separated from one another by pixels that allow for misalignment.

[0170] Where the SLM is used for routing the beams 1,2 of light, this is achieved by displaying a linearly changing phase ramp in at least one direction across the blocks or arrays 13,14. The processing circuitry 11 determines the parameters of the ramp depending on the required angle of deflection of the beam 1,2. Typically the processing circuitry 11 stores data in a look-up table, or has access to a store of such data, to enable the required ramp to be created in response to the input data or command at the first control input 12. The angle of deflection is probably a two dimensional angle where the plane common to the direction of the incident light and that of the reflected light is not orthogonal to the SLM.

[0171] Assigning x and y co-ordinates to the elements of the SLM, the required amount of angular shift from the specular reflection direction may be resolved into the x and y directions. Then, the required phase ramp for the components is calculated using standard diffraction theory, as a "desired phase characteristic".

[0172] This process is typically carried out in a training stage, to provide the stored data in the look-up table.

[0173] Having established a desired phase modulation characteristic across the array so as to achieve the desired control of said beam the processing circuitry 11 transforms this characteristic into one that can be displayed by the pixels 13,14 of the SLM 10. Firstly it should be borne in mind that the processing circuitry 11 controlling the pixels of an SLM 10 is normally digital. Thus there is only a discrete population of values of phase modulation for each pixel, depending on the number of bits used to represent those states.

[0174] To allow the pixels 13,14 of the SLM 11 to display a suitable phase profile, the processing circuitry 11 carries out a level selecting operation for each pixel. As will be appreciated, the ability of the SLM to phase modulate has limits due to the liquid crystal material, and hence a phase ramp that extends beyond these limits is not possible. To allow for the physical device to provide the effects of the ideal device (having a continuously variable limitless phase modulation ability), the desired phase ramp may be transformed into a non-monotonic variation having maxima and minima within the capability limits of the SLM 10. In one example of this operation, the desired phase modulation is expressed modulo 2pi across the array extent, and the value of the desired modulo-2pi modulation is established at the centre of each pixel. Then for each pixel, the available level nearest the desired modulation is ascertained and used to provide the actual pixel voltage. This voltage is applied to the pixel electrode for the pixel of concern.

[0175] For small pixels there may be edge effects due to fringing fields between the pixels and the correlations between the director directions in adjacent pixels. In such systems the available phase level nearest to the value of the desired modulo-2pi modulation at the centre of each pixel (as described above) should be used as a first approximation. A recursive algorithm is used to calculate the relevant system performance characteristic taking into account these 'edge' effects and to change the applied level in order to improve the system performance to the required level.

[0176] "Linear" means that the value of phase across an array of pixels varies linearly with distance from an arbitrary origin, and includes limited linear changes, where upon reaching a maximum phase change at the end of a linear portion, the phase change reverts to a minimum value before again rising linearly.

[0177] The additional input 16 causes the processing circuitry 11 to modify the holograms displayed by applying a discrete approximation of a non-linear phase modulation so that the SLM 10 synthesises a corrective optical element such as a lens or an aberration corrector. As will be later described, embodiments may also provide power control (attenuation), sampling and beam shaping by use of the non-linear phase modulation profile. "Non-linear" is intended to signify that the desired phase profile across an array of pixels varies with distance from an arbitrary origin in a curved and/or oscillatory or like manner that is not a linear function of distance. It is not intended that "non-linear" refer to sawtooth or like profiles formed by a succession of linear segments of the same slope mutually separated by "flyback" segments.

[0178] The hologram pattern associated with any general non-linear phase modulation exp $j\phi(u)$ = exp $j(\phi_0(u) + \phi_1(u) + \phi_3(u) \ldots)$ where j is the complex operator, can be considered as a product. In this product, the first hologram term in the product exp j $\phi_0(u)$implements the routing while the second hologram term exp j $\phi_1(u)$ implements a corrective function providing for example lens simulation and/or aberration correction. The third hologram term exp j $\phi_2(u)$ implements a signal processing function such as sampling and/or attenuation and/or beam shaping. The routing function is implemented as a linear phase modulation while the corrective function includes non-linear terms and the signal processing function includes non-linear oscillatory terms.

[0179] Different methods of implementing the combination of these three terms are possible. In one embodiment the total required phase modulation $\phi_0(u) + \phi_1(u) + \phi_2(u)$ including linear routing and corrective function and the signal processing function is resolved modulo 2 pi and approximated to the nearest available phase level before application by the pixels. In another embodiment the summation of the phase modulation required for the linear and corrective function $\phi_0(u) + \phi_1(u)$ is resolved modulo 2 pi and approximated to the nearest phase level in order to calculate a first phase distribution. A second phase distribution $\phi_2(u)$ is calculated to provide sampling and/or attenuation and/or beam shaping. The two phase distributions are then added, re-resolved modulo 2 pi and approximated to the nearest available phase level before application by the pixels. Other methods are also possible.

[0180] Mathematically the routing phase modulation is periodic due to the resolution modulo 2pi and by nature of its linearity.

[0181] Therefore the routing phase modulation results in a set of equally spaced diffraction orders. The greater the number of available phase levels the closer the actual phase modulation to the ideal value and the stronger the selected diffraction order used for routing.

[0182] By contrast, the corrective effects are realised by non-linear phase changes $\phi_1(u)$ that are therefore non-periodic when resolved modulo 2pi. This non-periodic phase modulation changes the distribution of the reflected beam about its centre, but not its direction. The combined effect of both linear (routing) and non-periodic phase modulation is to change both the direction and distribution of the beam, as may be shown using the convolution theorem.

[0183] The signal processing effects are usually realised by a method equivalent to 'multiplying' the initial routing and/or hologram exp $j(\phi_0(u)+\phi_1(u))$ by a further hologram exp j $\phi_2(u)$ in which $\phi_2(u)$ is non-linear and oscillatory. Therefore the set of diffraction orders associated with the further hologram creates a richer structure of subsidiary beams about the original routed beam, as may be shown using the convolution theorem.

[0184] While this explanation is for a one-dimensional phase modulator array the same principle may be applied in 2-D.

[0185] Hence in a reconfigurable optical system this non-linear phase modulation may be applied by the same spatial light modulator(s) that route the beam. It will be understood by those skilled in the art that the SLM may have only a single control input and the device may have processing circuitry for combining control data for routing and control data for corrective effects and signal processing effects to provide an output to control the SLM.

[0186] The data may be entered into the SLM bit-wise per pixel so that for each pixel a binary representation of the desired state is applied. Alternatively, the data may be entered in the form of coefficients of a polynomial selected to represent the phase modulation distribution of the pixel array of concern in the SLM. This requires calculating ability of circuitry of the SLM, but reduces the data transfer rates into the SLM. In an intermediate design the polynomial coefficients are received by a control board that itself sends bit-wise per pixel data to the SLM. On-chip circuitry may interpret data being entered so as to decompress that data.

[0187] The pixel array of concern could be all of the pixels associated with a particular beam or a subset of these pixels. The phase modulation distribution could be a combined phase modulation distribution for both routing and corrective effects or separate phase modulation distributions for each. Beam shaping, sampling and attenuation phase modulation distributions, as will be described later, can also be included. In some cases it may not be possible to represent the phase modulation distribution as a simple polynomial. This difficulty may be overcome by finding a simple polynomial giving a first approximation to the desired phase modulation distribution. The coefficients of this polynomial are sent to the SLM. A bit-wise correction is sent for each pixel requiring a correction, together with an address identifying the location of the pixel. When the applied distribution is periodic only the corrections for one period need be sent.

[0188] The processing circuitry 11 may be discrete from or integral with the SLM, or partly discrete and partly integral.

[0189] Referring to FIG. 3, a routing device 25 includes two SLMs 20,21 which display holograms for routing light 1,2 from an input fibre array 3,4 to an output fibre array 5,6. The two SLMs are reflective and define a zigzag path. The first SLM 20 hereinafter referred to as a "corrective SLM" not only carries out routing but also synthesises a corrective optical element. The second SLM 21 carries out only a routing function in this embodiment, although it could also carry out corrections or apply other effects if required. The second SLM 21 is hereinafter referred to as a "routing SLM". Although the corrective SLM 20 is shown disposed upstream of the routing SLM 21, it may alternatively be disposed downstream of the routing SLM 21, between two routing SLMs, or with systems using routing devices other than the routing SLM 21.

[0190] The routing SLM 21 has operating circuitry 23 receiving routing control data at a routing control input 24, and generating at the SLM 21 sets of holograms for routing the beams 1,2. The corrective SLM 20 has operating circuitry 26 receiving compensation or adaptation data at a control input 27 to cause the SLM 20 to display selected holograms. In this embodiment, the SLM 20 forms a reflective lens.

[0191] Synthesising a lens at the SLM 20 can be used to change the position of the beam focused spot and therefore correct for a position error or manufacturing tolerance in one or more other lenses or reflective (as opposed to transmissive) optical elements, such as a curved mirror. The synthesised lens can be spherical or aspheric or cylindrical or a superposition of such lenses. Synthesised cylindrical lenses may have arbitrary orientation between their two long axes and the lens focal lengths can both be positive, or both be negative, or one can be positive and the other negative.

[0192] To provide a desired phase modulation profile for a lens or curved mirror to compensate for an unwanted deviation from a required system characteristic, the system is modelled without the lens/mirror. Then a lens/mirror having the correction to cancel out the deviation is simulated, and the parameters of the lens/mirror are transformed so that when applied to an SLM the same effect is achieved.

[0193] In one application what is required is to adjust the position and width of the beam waist, of a Gaussian-type beam at some particular point in the optical system, in order to compensate for temperature changes or changes in routing configuration. Hence two properties of the beam must be adjusted and so it is necessary to change two properties of the optical system. In a conventional static optical system both a lens focal length and the position of the lens are selected to achieve the required beam transformation. In the dynamic systems under consideration it is rarely possible deliberately to adjust the position of the optical components. A single variable focus action at a fixed position changes both the position and the width of the beam waist and only in special circumstances will both properties be adjusted to the required value.

[0194] One method to overcome this problem is to apply both corrective phase and corrective 'pseudo-amplitude' modulation (to be described later) with a single SLM. However the amplitude modulation reduces the beam power which may be undesirable in some applications. A further and preferred method is to apply corrective phase modulation with two separate SLMs.

[0195] For example consider coupling from one input fibre (or input beam) through a routing system into the selected output fibre (or output beam). Inside the routing system there are at least two SLMs carrying out a corrective function. They may also be routing and carrying out other functions (to be described in this application). In between a given pair of SLMs carrying out focus correction there is an intermediate optical system.

[0196] At the first SLM carrying out a corrective function there may be calculated and/or measured the incident amplitude and phase distribution of the input beam that had propagated from the input fibre or beam. At the second SLM carrying out a corrective function there may be calculated and/or measured the ideal amplitude and phase distribution that the output beam would adopt if coupling perfectly into the output fibre or beam. This can be achieved by backlaunching from the output fibre or beam or by a simulation of a backlaunch. The required focus correction functions of these two SLMs is to transform the incident amplitude and phase distribution arriving at the first SLM to the ideal amplitude and phase distribution at the second SLM to achieve perfect (or the desired) coupling efficiency into the output fibre or output beam.

[0197] The corrective phase modulation to be applied at the first SLM should be calculated, so as to achieve the ideal amplitude distribution at the second SLM as the beam arrives at the second SLM after passing from the first SLM and through the intermediate system. This calculation should take into account propagation through the intermediate system between the first and second SLMs. Hence the function of the first SLM is to correct the beam so as to achieve the ideal amplitude distribution for the output beam. The beam phase distribution should also be calculated as it arrives at the second SLM. The corrective phase distribution to be applied at the second SLM should be calculated so as to transform the phase distribution of the beam incident upon it from the intermediate system to the ideal phase distribution required for the output beam at the second SLM.

[0198] Two variables available at the SLM to effect corrections from an optimal or other desired level of performance are firstly the blocks of pixels that are delineated for the incident light beam, and secondly the hologram that is displayed on the block(s) of concern.

[0199] Starting with the delineation of blocks, it should be borne in mind that the point of arrival of light on the SLM can only be predicted to a certain accuracy and that the point may vary according to physical changes in the system, for example due to temperature effects or ageing. Thus, the device allows for assessment of the results achieved by the current assignment, and comparison of those results with a specified performance. In response to the comparison results, the delineation may be varied so as to improve the results.

[0200] In one embodiment a training phase, uses for example a hill climbing approach to control and optimise the position of the centre of the block. Then if the "in-use" results deviate by more than a specified amount from the best value, the delineation of the block is varied. This process reassignment may step the assigned block one pixel at a time in different directions to establish whether an improved result is achieved, and if so continuing to step to endeavour to reach an optimum performance. The variation may be needed where temperature effects cause positional drift between components of the device. It is important to realise that unlike MEMS systems and the like, all the pixels are potentially available for all the beams. Also the size, shape and location of a delineated block is not fixed.

[0201] Equally the size and shape of a block may be varied if required. Such changes may be necessary under a variety of situations, especially where a hologram change is needed. If for example a hologram requiring a larger number of pixels becomes necessary for one beam, the size of the block to display that hologram can be altered. Such changes must of course usually be a compromise due to the presence of other blocks (possibly contiguous with the present block) for displaying holograms for other beams of light.

[0202] Monitoring techniques for determining whether the currently assigned block is appropriate include the techniques described later herein as "taking moments".

[0203] Turning to variation of the hologram that is displayed on the block of concern, one option to take into account for example physical changes in the system, such as movement out of alignment, is to change one normal linear-type routing hologram for another, or to adjust the present hologram in direct response to the sensed change. Thus if, due for example to temperature effects, a target location for a beam moves, it may be necessary to change the deflection currently being produced at a pixel block. This change or adjustment may be made in response to sensed information at the target location, and may again be carried out "on-line" by varying the hologram step by step. However, it may be possible to obtain an actual measure of the amount and direction of change needed, and in this case either a new hologram can be read in to the SLM or a suitable variation of the existing hologram carried out.

[0204] As well as, or instead of, linear changes to linear routing holograms, corrective changes may be needed, for example to refocus a beam or to correct for phase distortion and non-focus aberrations.

[0205] Having corrected the beam focus other aberrations may remain in the system. Such aberrations distort the phase distributions of the beams. These aberrations will also change with routing configuration as the beams are passing through different lenses and/or different positions on the same lenses. Similarly the aberrations will change with temperature. To obtain stable and acceptable performance of a reconfigurable optical system, the aberrations can be corrected dynamically.

[0206] To provide a desired phase modulation profile for these aberrations the system may be modelled or measured to calculate the phase distortion across the SLM, compared to the ideal phase distribution. The ideal phase distribution may again be found by modelling the system 'backwards' from the desired output beam, or by backlaunching and measurement, while the actual phase distribution may be found by modelling the system forwards from the input beam or measurement. The calculations will include the effects of reflection from the SLM itself. The corrective function of the SLM is to transform between the actual and ideal phase distortion. The phase distortion is defined as the phase difference between the actual phase distribution and the ideal phase distribution. The desired corrective profile is the conjugate phase of the phase distortion.

[0207] Alternatively, these corrective functions can be shared by two SLMS, which allows an extra degree of freedom in how the beam propagates inside the intermediate system between the two SLMs.

[0208] Further, given a real system a sampling method (as will be described later) may be used to direct a fraction of the beam towards a wavefront sensor that may assess the beam. So far the process is deterministic. Then the changes are applied to the real system, and perturbations on the parameters are applied while monitoring the sensor and/or the input/output state, so as to determine whether an optimum configuration is achieved. If not, the parameters are changed until a best case is achieved. Any known optimising technique may be used. It is preferred to provide a reasonable starting point by deterministic means, as otherwise local non-optimum performance maxima may be used instead of the true optimum.

[0209] The method or device of the invention may be used to correct for aberrations such as field curvature in which the output 'plane' of the image(s) from an optical system is curved, rather than flat.

[0210] Equally, even if in use the SLM forms a corrective element by having non-linear phase modulation applied across it, if it is operated in separate training and use phases, it may be desirable while training for the SLM to route as well. In this case the SLM scans the processed beam over a detector or routes the beam, for example using one or more dummy holograms, into a monitor fibre.

[0211] Referring now to FIG. 4, the corrective SLM 20, used purely for synthesising a corrective element, has operating circuitry 125, and further comprises processing circuitry 122 and temperature sensors 123. In this embodiment the operating circuitry, temperature sensors and processing circuitry are integrated on the same structure as the rest of the SLM, but this is not critical to the invention. Associated with the processing circuitry is a store 124 into which is programmed a lookup table. The sensors detect temperature changes in the system as a whole and in the SLM, and in response to changes access the look up table via the processing circuitry 122 to apply corrections to the operating circuitry. These corrections affect the holograms displayed on the blocks 13, 14 of pixels. The sensors may also be capable of correction for temperature gradients.

[0212] This technique may also be applied to an SLM used for routing.

[0213] Referring now to FIG. 5, an optical system 35 has a corrective SLM 30 with operating circuitry 31, and processing circuitry 32. The system includes further devices, here second and third SLMs 33 and 34, disposed downstream of the corrective SLM 30. The second SLM 33 is intended to route light to particular pixel groups 15, 16 of the third SLM 34. The third SLM 34 has monitor sensors 37 for sensing light at predetermined locations. In one embodiment these sensors 37 are formed by making the reflective layer partially transmissive, and creating a sensing structure underneath. In another, the pixel electrode of selected pixels is replaced by a silicon photodetector or germanium sensor structure.

[0214] In either case, circuitry may be integrated into the silicon backplane to process the output of the sensors 37, for example to compare the outputs of adjacent sensors 37, or to threshold one sensor against neighbouring sensor outputs. Where possible, processing circuitry is on chip, as it is possible to reduce the time taken after light has been received to respond to it in this way. This is because there is no need to read information off-chip for processing, and also because calculations may be able to be performed in parallel.

[0215] Provided the routing-together with any compensation effects from the corrective SLM 30-is true, the sensors 37 will receive only a minimal amount of light. However where misalignment or focus errors are present, the extent of such errors is detected by measuring the power coupled into the monitor sensors. To that end, the sensors 37 provide data, possibly after some on-chip processing, to the processing circuitry 32. The processing circuitry 32 contains a control algorithm to enable it to control the operating circuitry 31 to make changes of, or adjustments to, the compensating holograms displayed on the corrective SLM 30 until the system alignment is measured to be optimised. In some embodiments, changes to the sub-arrays to which beam affecting holograms are applied may be made in response to the sensor output data.

[0216] In another embodiment a determined number of dummy ports are provided. For example for a connector two or more such ports are provided and for routing devices three or more dummy ports are provided. These are used for continuous misalignment monitoring and compensation, and also for system training at the start.

[0217] Although some embodiments can operate on a trial and error basis, or can be adapted "on the fly", a preferred optical system uses a training stage during which it causes to be stored in the look-up table data enabling operation under each of the conditions to be encountered in use.

[0218] In one embodiment, in the training stage, a set of initial starting values is read in for application to the SLM 30 as hologram data, then light is applied at a fibre and the result of varying the hologram is noted. The variations may include both a change of pixels to which the hologram is applied, and a change of the hologram. Where more than one fibre is provided, light is applied to each other fibre in turn, and similar results obtained. Then other environmental changes are applied and their effects noted, e.g. at the sensors 37, and the correction for input data either calculated or sought by varying the presently-applied data using optimisation techniques to seek best or acceptable performance.

[0219] Then, in use, the system may be operated on a deterministic basis-i.e. after ascertaining what effect is sought, for example responding to a temperature change or providing a change in routing, the change to the applied data for operating the device can be accessed without the need for experiment.

[0220] A preferred embodiment operates in the deterministic way, but uses one or more reference beams of light passed through the device using the SLM 30. In that way the effect of deviations due to the device itself can be isolated. Also it can be confirmed that changes are being correctly made to take into account environmental and other variations.

[0221] The device may also have further monitor sensors placed to receive the zero-order reflections from the SLM(s) to enable an assessment to be made of the input conditions. For example, where an input channel fails, this can be determined by observing the content of the specular reflection from the light beam representing that channel. Where there are two SLMs as in some routing systems, the specular reflections from each SLM may be sensed and compared.

[0222] Referring now to FIG. 6, a dual-function SLM 40 provides both routing and correction. The SLM 40 has operating circuitry 41 and processing circuitry 42. The operating circuitry 41 receives routing data at a first control input 44 for causing the processing circuitry 42 to generate the holograms on the SLM 40 to achieve the desired routing. The processing circuitry 42 also receives routing data on an input 45, and controls the operating circuitry 41 using an algorithm enabling adaptation due to changes in the path taken through the system to take place on a timescale equivalent to that required to change the hologram display, i.e. of the order of milliseconds.

[0223] The control algorithms for this embodiment may use one or more of several types of compensation.

[0224] In one embodiment a look-up table is stored in a memory 43, the look-up table storing pre-calculated and stored values of the compensation for each different route through the system.

[0225] In another embodiment the system is trained before first being operated, using changes of, or to the compensating holograms to learn how changing the compensating holograms affects the system performance, the resulting data being held in the memory 43.

[0226] In a further embodiment, the processing circuitry 42 employs intelligence responsive to signals from monitor sensors 47,48 for monitoring and calculation of how these compensating holograms should adapt with time to accommodate changes in the system alignment. This is achieved in some embodiments by integrating circuitry components into the silicon backplane of the SLM, or by discrete components such as germanium detectors where the wavelengths are beyond those attainable by silicon devices. In some embodiments sensors 47 are provided for sensing light at areas of the SLM, and in others the sensors 48 may instead or also be remote from the SLM 40 to sense the effects of changes on the holograms at the SLM 40.

[0227] Referring now to FIG. 7, an optical system 80 includes an SLM 81 for routing beams 1,2 of light from input fibres 3,4 to output fibres 5,6 by means of holograms displayed on pixel groups 13,14 of the SLM. The holograms are generated by processing circuitry 82 which responds to a control input 83 to apply voltages to an array of pixellated elements of the SLM, each of which is applied substantially uniformly across the pixel of concern. This result is a discrete approximation of a linear phase modulation to route the beams.

[0228] The processing circuitry 82 calculates the ideal linear phase ramp to route the beams, on the basis of the routing control input 83 and resolves this phase modulo 2Pi. The processing circuitry at each of the pixels then selects the closest available phase level to the ideal value. For example if it is desired to route into the m'th diffraction order with a grating period Ω the ideal phase at position u on the SLM 81 is 2pi.mu/Ω. Therefore, approximately, the phase goes linearly from zero up to 2pi over a distance

Ω/m after which it falls back to zero, see FIG. 8a.

[0229] Control of the power in individual wavelength channels is a common requirement in communication systems. Typical situations are the need to avoid receiver saturation, to maintain stable performance of the optical amplifiers or to suppress non-linear effects in the transmission systems that might otherwise change the information content of the signals. Power control may be combined with sampling or monitoring channels to allow adjustment of the power levels to a common power level (channel equalisation) or to some desired wavelength characteristic.

[0230] Deliberate changes to the value of 'Ω' can be used to reduce the coupling efficiency into the output in order to provide a desired attenuation. This is suitable for applying a low attenuation. However, it is not suitable for a high attenuation as, in that event, the beam may then be deflected towards another output fibre, increasing the crosstalk. If there is only one output fibre this method may be used regardless of the level of attenuation.

[0231] To provide a selected desired attenuation of the optical channel in the system, processing circuitry 85 responds to an attenuation control input 84 to modify the operation of the operating circuitry 83 whereby the operating circuitry selects a linear phase modulation such that by the end of each periodic phase ramp the phase has reached less than 2pi, see FIG. 8b.

[0232] This may be achieved by calculating the ideal value of phase for every pixel, and then multiplying this ideal value by a coefficient r between 0 and 1, determined on the basis of the desired attenuation. The coefficient is applied to every pixel of the array in order to get a reduced level per pixel, and then the available phase level nearest to the reduced level is selected.

[0233] The method of this embodiment reduces the power in this diffraction order by making the linear phase modulation incomplete, such that by the end of each periodic phase ramp the phase has only reached 2pi.r. It has however been found that the method of this embodiment may not provide sufficient resolution of attenuation. It also increases the strength of the unwanted diffraction orders likely to cause crosstalk. When combined with deliberate changes in the length of the ideal phase ramp the resolution of attenuation may be improved. Again if there is only a single output fibre the crosstalk is less important.

[0234] Resolution may also be improved by having a more complex incomplete linear phase modulation. However, the unwanted diffraction orders may still remain too strong for use in a wavelength-routed network. Hence to control the power by adapting the routing hologram may have undesirable performance implications in many applications, as crosstalk worsens with increase of attenuation. The problem can be overcome by use of a complex iterative design. This could be used to suppress the higher orders but makes the routing control more expensive.

[0235] Referring now to FIG. 9, a system 99 includes an SLM 90 controlled by applying a discrete approximation of a linear phase modulation to route beams 1,2 from input fibres 3,4 to output fibres 5,6 as previously described with respect to FIG. 7. Thus operating circuitry 91 selects a routing hologram for display by the SLM, in accordance with a routing input 92, whereby the beams may be correctly routed, using a look up table or as otherwise known. A memory holds sets of data each allowing the creation of a respective power controlling hologram. Processing circuitry 93 runs an algorithm which chooses a desired power controlling hologram corresponding to a value set at a power control input 94. The power controlling hologram is selected to separate each beam into respective main 1a, 2a and subsidiary 1b, 2b beams, such that the main beams 1a, 2a are routed through the system and the or each subsidiary beam(s) 1b, 2b is/are diffracted out of the system, for example to a non-reflective absorber 97.

[0236] The processing circuitry 93 applies the power controlling hologram data to a second input 95 of the operating circuitry 91 which acts on the routing hologram data so as to combine the routing and power controlling holograms together to provide a resultant hologram. The operating circuitry then selects voltages to apply to the SLM 90 so that the SLM displays the resultant hologram.

[0237] Thus power in a routing context is controlled by combining the routing hologram with another hologram that has the effect of separating the beam into a main beam and a set of one or more subsidiary beams of these the main beam is allowed to propagate through the system as required while the other(s) are diffracted out of the system.

[0238] For example consider a hologram that applies phases of $+\phi$ and $-\phi$ on adjacent pixels. In terms of real and imaginary parts this hologram has the same real part, cos ϕ, on every pixel, see FIG. 10, while the imaginary part oscillates between +- sin ϕ. It can be shown using Fourier theory that the net effect is to multiply the amplitude of the original routed beam by a factor cos ϕ, and to divert the unwanted power into a set of weak beams at angles that are integer multiples of $\pm\lambda/2p$ with respect to the original routed beam, where λ is the operating wavelength and p is the pixel pitch.

[0239] The system is designed from a spatial viewpoint such that light propagating at such angles falls outside the region of the output fibres 5,6 of FIG. 9. An alternative design directs the unwanted light into output fibres 5,6 at such a large angle of incidence that the coupling into the fundamental mode is very weak, and has no substantial effect. In this case the unwanted power is coupling into the higher-order modes of the fibre and so will be attenuated rapidly. A fibre spool or some other technique providing mode stripping is then used on the output fibre before the first splice to any other fibre.

[0240] In either case, the effective attenuation of the beam is $10 \log_{10} \cos^2\phi$. Hence, in this way, polarisation-independent phase modulation may be used to create an effect equivalent to polarisation-independent amplitude modulation. This is termed herein "pseudo amplitude modulation". In this particular case the pseudo-amplitude modulation applied at every pixel is cos ϕ.

[0241] It will be clear to those skilled in the art that use of alternate pixels as the period of alternation is not essential, and may in some cases be undesirable. This is because of edge effects in the pixels.

[0242] The period and pattern of alternation can be varied so as to adjust the deflection angle of the 'unwanted power'. This light directed away from the output fibres can be collected and used as a monitor signal. Hence the pseudo-amplitude modulation can be used to sample the beam incident on an SLM as previously discussed. This sampling hologram can be combined with a routing and/or power control and/or corrective SLM.

In the latter case the sampled beam can be directed towards a wavefront sensor and then used to assess the quality of the beam correction. While the pseudo-amplitude modulation as described above is applied to the whole beam, it could be applied selectively to one or more parts of the beam.

[0243] A further modification to this pseudo-amplitude modulation is to multiply it by a further phase modulating hologram such as to achieve a net effect equivalent to a complex modulation.

[0244] It is often important that the sampling hologram takes a true sample of the output beam. Therefore in some cases the sampling hologram should be applied after the combination of all other desired effects including resolution modulo 2pi and approximation to the nearest available phase level. In this case the overall actual phase modulation distribution is achieved by a method equivalent to forming the product of the sampling hologram and the overall hologram calculated before sampling.

[0245] Similar pseudo-amplitude modulation techniques may be extended to suppress the crosstalk created by clipping of the beam tails at the edges of each hologram and to tailor the coupling efficiency vs. transverse offset characteristic of the output fibres. Since the transverse position at the output fibre is wavelength dependent, this tailoring of the coupling efficiency vs. offset can be used to tailor the wavelength response of the system. This is important in the context of wavelength division multiplexing (WDM) systems where the system wavelength can be expected to lie anywhere in the range of the available optical amplifiers. The output angle for beam steering using an SLM and periodic linear phase modulation is proportional to the wavelength while the focal length of corrective lenses is also wavelength-dependent. Therefore a hologram configured to give the optimum coupling efficiency at one wavelength will produce an output beam with transverse and/or longitudinal offset at another wavelength. These effects result in wavelength-dependent losses in systems required to route many wavelength channels as an ensemble. Hence a method designed to flatten or compensate for such wavelength-dependent losses is useful and important.

[0246] Among the envisaged applications are the flattening of the overall wavelength response and the compensation for gain ripple in optical amplifiers, especially Erbiumdoped fibre optic amplifiers (EDFA).

[0247] An SLM device may also be used to adapt the shape, e.g. the mode field shape, of a beam in order to suppress crosstalk.

[0248] Beam shaping is a type of apodisation. It is advantageously used to reduce crosstalk created at a device by clipping of the energy tails of the light beams. Such clipping leads to ripples in the far field. These ripples cause the beam to spread over a wider region than is desired. In telecommunications routing this can lead to crosstalk. Other applications may also benefit from apodisation of a clipped laser beam, such as laser machining, for example, where it is desired to process a particular area of a material without other areas being affected and laser scalpels for use in surgery.

[0249] Clipping occurs because the energy of the beam spreads over an infinite extent (although the amplitude of the beam tails tends to zero), while any device upon which the beam is incident has a finite width. Clipping manifests itself as a discontinuity in the beam amplitude at the edges of the device.

[0250] Referring to FIG. 11, two SLMs 100,101 are used for beam steering or routing of beams 1,2 from input fibres 3,4 to output fibres 5,6, as described in PCT GB00/03796. Each SLM 100,101 is divided into a number of blocks of pixels 103a, 104a; 103b, 104b. Each block 103a, 104a is associated with a particular input fibre 3,4- i.e. the fibre of concern points to the subject block. Each block displays a hologram that applies routing. As previously discussed herein the holograms may also or alternatively provide focus compensation, aberration correction and/or power control and/or sampling, as required.

[0251] The blocks 103a, 104a at the input SLM 100 each receive a beam from an associated input fibre 3,4 while the blocks 103b, 104b at the output SLM 101 each direct a beam towards an associated output fibre 5,6. Each block 103a, 103b has a finite width and height. As known to those skilled in the art and as previously noted, the beam width is infinite, therefore the block clips the beam from or to the associated fibre and this creates undesired ripples in the far field.

[0252] The ripples due to clipping of the beam 1 are figuratively shown as including a beam 106 which, it will be seen, is incident on the wrong output hologram, displayed on block 104b at the output SLM 101. "Wrong" signifies holograms other than that to which the beam of concern is being routed, for example holograms displayed by blocks around the block to which the beam should be routed. Some of these ripples will then be coupled into "wrong" output fibres 5,6-i.e. those to which the beam is not deliberately being routed-leading to crosstalk. It will be clear to those skilled in the art that these effects will be present on blocks other than those adjacent to the "correct" blocks, as the field of beam 1 is infinite in extent.

[0253] In any physical system the effect of the ripples created by clipping at the output SLM 101 depends on the optical architecture.

[0254] In practice the non-ideal transfer function of the optics (due to finite lens apertures and aberrations) means that a sharp change in the amplitude spreads out and causes crosstalk in adjacent output fibres. In effect the optics applies a limit to the range of spatial frequencies that can be transmitted. This frequency limit causes crosstalk.

[0255] The wider the device, compared to the beam spot size at the device, the weaker the ripples in the far field and the lower the crosstalk. In general a parameter C is defined such that the required width of SLM per beam is given by $H=C.\omega$, where ω is the beam spot size at the SLM. The value of C depends on the beam shape, the optical architecture and the allowable crosstalk. Typically for a Gaussian beam, with no beam shaping and aiming for crosstalk levels around -40 dB, C would be selected to have a value greater than or equal to three. Looking at this system from the spatial frequency viewpoint, the field incident on the SLM contains (for perfect optics) all the spatial frequencies in the input beam. The finite device width cuts off the higher spatial frequencies, so, again, the optics applies a limit to the range of spatial frequencies that can be transmitted and this frequency limit causes crosstalk.

[0256] Beam shaping can be used to decrease the crosstalk for a given value of C, and also allow the use of a lower value of C. Calculations for N*N switches have shown that decreasing the value of C leads to more compact optical switches and increases the wavelength range per port. Hence beam shaping can be employed to provide more compact optical switches and/or an increased wavelength range per port.

[0257] The idea behind using beam shaping or 'apodisation' to reduce crosstalk is based on an analogy with digital transmission systems. In these systems a sequence of pulses is transmitted through a channel possessing a limited bandwidth. The frequency response of the channel distorts the edges of pulses being transmitted so that the edges may interfere with one another at the digital receiver leading to crosstalk. The channel frequency response can, however, be shaped so as to minimise such crosstalk effects. Filters with responses that have odd-symmetry can be used to make the edges go through a zero at the time instants when pulses are detected.

[0258] Therefore beam-shaping with odd symmetry can be used to make the crosstalk go through a zero at the positions of the output fibres. Such a method is likely to be very sensitive to position tolerances.

[0259] Another method used in digital systems is to shape the frequency cut-off so that it goes smoothly to zero. In the present context the ideal case of 'smoothly' is that the channel frequency response and all derivatives of the frequency response become zero. In practice it is not possible to make all derivatives go to zero but a system may be designed in which the amplitude and all derivatives up to and including the k'th derivative become zero at the ends of the frequency range. The higher the value of k, the quicker the tails of the pulse decay. Therefore the beam shaping should go as smoothly as possible to zero.

[0260] To investigate the effects of beam shaping the amplitude modulation was treated as continuous. The system studied was a single lens 2f system where 2f is the length of the system between fibres and SLM, assuming f is the focal length with fibres in one focal plane, and an SLM in the other focal plane. The input fibre beam was treated as a Gaussian. Various amplitude modulation shapes were applied at the SLM and the coupling efficiency into the output fibre was calculated. In this architecture and from Abbe theory, the incident field at the SLM is proportional to the Fourier Transform of the field leaving the input fibre. In particular, different spatial frequencies in the fibre mode land on different parts of the SLM. Clipping removes the spatial frequencies outside the area of the hologram. Beam shaping at the SLM has the effect of modifying the relative amplitude of the remaining spatial frequencies.

[0261] Residual ripples may still remain due to the discontinuity in the beam derivative but the ripples will be reduced in amplitude and decay more quickly. Further reduction in the ripple amplitude and increase in the rate of decay may be achieved by shaping the beam such that both the amplitude and the first k derivatives go to zero at the edges.

[0262] Mathematical analysis of the effect has also been carried out. The results are as follows:

[0263] The n^{th} time derivative of a function can be expressed in terms of its Fourier Transform as shown in equation (1):

$$\frac{d^n g(t)}{dt^n} = \int_{-\infty}^{\infty} (i2\pi f)^n G(f) \exp i2\pi ft \, df \qquad (1)$$

[0264] Hence, by inversion, the frequency dependence of the Fourier Transform (FT) may be expressed as an FT of any one of the function's derivatives as shown in equation (2):

$$G(f) = \frac{1}{(i2\pi f)^n} \int_{-\infty}^{\infty} \frac{d^n g(t)}{dt^n} \exp - i2\pi ft \, dt \qquad (2)$$

[0265] Choosing the zeroth derivative provides the expression in equation (3):

$$G(f) = \int_{-\infty}^{\infty} g(t) \exp - i2\pi ft \, dt \qquad (3)$$

[0266] To apply the analysis to free-space beam-steering:

[0267] let x and y be the position co-ordinates at the fibre output from a switch, and u and v be the position co-ordinates at the SLM. Assume the SLM to be in one focal plane of a lens of focal length f, and the fibre array to be in the other focal plane:

$$E_{FIB}(x,y) = \frac{i}{f\lambda} \exp(-i\frac{2\pi}{\lambda}(2f + nt)) \iint E_{SLM}(u,v) \exp i \frac{2\pi f}{\lambda}(xu + yv) du dv \qquad (4)$$

[0268] such that the output field (see equation (4)) is a 2-D Fourier Transform of the field at the SLM, E_{SLM}. In this result t is the lens thickness and N its refractive index, while λ is the optical wavelength.

[0269] For the present purposes the 1-D equivalent is considered (relation 5):

$$E_{FIB}(x) = \frac{i}{f\lambda}\exp(-i\frac{2\pi}{\lambda}(2f+nt))\int E_{SLM}(u)\exp i\frac{2\pi f}{\lambda}(xu)du \qquad (5)$$

[0270] Comparing with (3) it is clear that the position co-ordinate at the SLM (u) is equivalent to the time domain and the position co-ordinate at the output (x) is equivalent to the frequency domain. Hence from (2) the output field may be expressed in terms of a derivative of the field at the SLM, as shown in equation (6):

$$E_{FIB}(x) = \frac{i}{f\lambda}\exp(-i\frac{2\pi}{\lambda}(2f+nt))\left(\frac{i}{2\pi x}\right)^n\int\frac{d^n E_{SLM}(u)}{du^n}\exp i\frac{2\pi f}{\lambda}(xu)du \qquad (6)$$

[0271] Let the k^{th} derivative of $E_{SLM}(u)$ be non-zero and smoothly varying over the range [-H/2, H/2], but zero outside this range, such that the derivative changes discontinuously at u = ±H/2:

$$\begin{aligned}\frac{d^k E_{SLM}(u)}{du^k} &= 0 && \forall u : u < -\tfrac{H}{2}\\ &= g^H && u = -\tfrac{H}{2}\\ &= s(u) + g^H && -\tfrac{H}{2} < u < \tfrac{H}{2}\\ &= g^H && u = +\tfrac{H}{2}\\ &= 0 && u > \tfrac{H}{2}\end{aligned} \qquad (7)$$

[0272] This representation assumes E_{SLM} to be even in u. Physically this situation represents a beam that is perfectly aligned with respect to the centre of a hologram of width H.

[0273] This derivative may be expressed as the sum of a rect function and a smoothly varying function, s(u), that is zero at and outside |u|=H/2:

$$\frac{d^k E_{SLM}(u)}{du^k} \equiv g_H rect\left(\frac{u}{H/2}\right) + s(u) \qquad (8)$$

[0274] For example consider a clipped (and unapodised) Gaussian beam; the zeroth derivative (k=0) may be expressed as:

$$\begin{aligned} s(u) &= \exp-\left(\frac{u}{\omega_{HOL}}\right)^2 - \exp-\left(\frac{H}{2\omega_{HOL}}\right)^2 \quad \forall|u| < \frac{H}{2} \\ &= 0 \quad \forall|u| \geq \frac{H}{2} \end{aligned} \tag{9}$$

$$g_H = \exp-\left(\frac{H}{2\omega_{HOL}}\right)^2 \tag{10}$$

[0275] Now returning to the general case (equation(8)) the k+1[th] derivative is calculated:

$$\frac{d^{k+1}E_{SLM}(u)}{du^{k+1}} \equiv g_H\left\{\delta\left(u+\frac{H}{2}\right)-\delta\left(u-\frac{H}{2}\right)\right\}+\frac{ds(u)}{du} \tag{11}$$

[0276] It is now convenient to calculate the output field. Set $n=k+1$ in (6) to obtain:

$$E_{FIB}(x) \propto \frac{1}{(i2\pi x)^{k+1}}\left\{\begin{aligned} &g_H\int_{-\infty}^{\infty}(\delta(t+H/2)+\delta(t-H/2))\exp-i2\pi xu\,du \\ &+\int_{-\infty}^{\infty}\frac{ds(u)}{du}\exp-i2\pi xu\,du \end{aligned}\right\} \tag{12}$$

[0277] which becomes equation (13):

$$E_{FIB}(x) \propto \frac{1}{(i2\pi x)^{k+1}}\left\{2ig_H\sin(\pi xH)+\int_{-\frac{H}{2}}^{\frac{H}{2}}\frac{ds(u)}{du}\exp-i2\pi xu\,du\right\} \tag{13}$$

[0278] As the position is increased, the exponential term in the 2[nd] integral of (13) oscillates more and more rapidly. Eventually the spatial frequency is so high that the derivative of s(u) can be considered to be constant, or nearly constant, over the spatial period. In which case the integral is zero, or nearly zero, when evaluated over each period of the oscillation. Therefore at high frequencies the whole of the second integral must approach zero.

[0279] It is assumed that the behaviour is dominated by the first integral. The first integral shows that if the amplitude changes discontinuously (k=0, i.e. an unapodised hologram), the spectrum (E_{FIB}) decays as 1/x. Now, if the amplitude and the first derivative are continuous, it is the second derivative that changes discontinuously, and so k=2 and the spectrum (E_{FIB}) decays as $1/x^3$. Numerical simulations have been carried out to confirm this behaviour.

[0280] A particularly advantageous shape is one in which the shaped beam has odd symmetry about points midway between the centre and the edges such that the beam amplitude and all of its derivatives go to zero at the beam edges.

[0281] The beam shaping may be effected to remove only a small amount of power from the central portion of the beam, to maintain acceptable system efficiency. A method for shaping a beam to achieve suppression of the ripples is now described.

[0282] Defining the middle of the beam as f(u), then f(u) can describe the original beam in its central portion, or what is left in the original beam after it has already been partially shaped, using, for example, pseudo-amplitude. To avoid ripples in the far field the edges of the beam go to zero at u = ±H/2, where H is the width of the hologram.

[0283] Hence, at the right-hand edge, describe the beam as in equation (14):

$$f_R(u) = f(0) - f(u-H/2) \qquad (14)$$

[0284] (The left-hand edge is considered later).

[0285] To get matching of the amplitude half-way between the middle and the edge it is required that

$$f(H/4) = f_R(H/4) \qquad (15)$$

[0286] From which there is obtained

$$f(H/4)+f(-H/4) = f(0) \qquad (16)$$

[0287] Now consider the derivatives at the joining point. The n[th] derivative of the right-hand edge function is given by equation (17):

$$\left.\frac{d^n f_{RH}}{du^n}\right|_{u=U} = -\left.\frac{d^n f}{du^n}\right|_{u=U-H/2} \qquad (17)$$

[0288] Hence at the joining point condition (18) is valid:

$$\left.\frac{d^n f_{RHEDGE}}{du^n}\right|_{u=H/4} = -\left.\frac{d^n f}{du^n}\right|_{u=-H/4} \qquad (18)$$

[0289] In order to avoid the creation of high frequency effects (crosstalk tails) by the joining point all derivatives are desirably continuous here. Hence it is required that condition (19) should be true:

$$\left.\frac{d^n f}{du^n}\right|_{u=H/4} = -\left.\frac{d^n f}{du^n}\right|_{u=-H/4}$$

(19)

[0290] To find out whether this is possible, expand the function f in a Taylor series about x=0 to obtain equation (20)

$$f = f(0) + a_1 u + a_2 u^2 + a_3 u^3 + a_4 u^4 + a_5 u^5 + a_6 u^6 + \dots\dots\dots\dots \qquad (20)$$

[0291] The first derivative is given by equation (21):

$$\frac{df}{du} = a_1 + 2a_2 u + 3a_3 u^2 + 4a_4 u^3 + \dots\dots \qquad (21)$$

[0292] The required condition (19) for the first derivative (n=1) can be obtained provided f is even in x, so that all the odd coefficients {a1, a3. . . } in (20) and (21) are zero. This makes the first derivative continuous at the joining point. Furthermore if *f* is an even function then *f(H/4)=f(-H/4)* in which case (16) becomes:

$$f(H/4)=\tfrac{1}{2}f(0) \qquad (22)$$

[0293] Given that f is now an even function, the second derivative of f is given by equation (23):

$$\frac{d^2 f}{du^2}=2a_2+12a_4u^2+....... \qquad (23)$$

[0294] Returning to the required condition in (19) it is clear that it cannot be satisfied for n=2. Hence the second derivative is discontinuous at the joining point u=H/4.

[0295] The left-hand edge is given by equation (24)

$$f_{LH}(u) = f(0)-f(u+H/2) \qquad (24)$$

[0296] Given that f is even, the overall function has odd symmetry in each half plane x = ± H/4.

[0297] To work out what happens at x = ± H/2, expand f_{RH} and f_{LH} in Taylor series, as shown in equations 25 and 26:

$$f_{RH}=a_2\left(u-\tfrac{H}{2}\right)^2+a_4\left(u-\tfrac{H}{2}\right)^4+a_6\left(u-\tfrac{H}{2}\right)^6+.......... \qquad (25)$$

$$f_{LH}=a_2\left(u+\tfrac{H}{2}\right)^2+a_4\left(u+\tfrac{H}{2}\right)^4+a_6\left(u+\tfrac{H}{2}\right)^6+.......... \qquad (26)$$

[0298] The function and its first derivative are both zero at u= ½H, but the second derivative has the value $2a_2$. Outside of the range [-½H, ½H] the beam drops to zero. Hence the second derivative is discontinuous at both u=±½H and u=±H/4, and the far field must therefore decay as the cube of the distance measured in the far field.

[0299] From the analysis, the required properties of f(u) for a hologram of width H are that firstly it should be even in u, and that secondly its amplitude at the position u=H/4 should be half the amplitude at u=0. After apodisation has been applied the shape of the beam in the region between u=H/4 and u=H/2 should be given by $f_{RH}(u)=f(0)-f(u-H/2)$ while in the region between u=-H/2 and u=-H/4 the shape of the beam should be given by fLH(u)=f(0)-f(u+H/2). In practice the shaping may not increase the local beam amplitude. Hence the hologram width and/or the shape of the central portion may have to be adjusted to avoid the requirement for 'amplifying' shaping.

[0300] As an example these conditions are satisfied by a Gaussian distribution given by equation (27):

$$f(u) = \exp-\left(\frac{u\sqrt{\ln(2)}}{H/4}\right)^2 \quad - \quad (27)$$

[0301] If the original beam satisfies the first two conditions it can be apodised without removing power from the central region. Otherwise shaping can be applied to the central region so that these two conditions are satisfied.

[0302] In some systems there may be a requirement to adapt the width of the beam in the far field: either to narrow the beam or to broaden the beam. This may be useful for laser processing of materials as well as for routing. It is advantageous that the method to change the width does not introduce side lobes. A particular application that would benefit is laser drilling of holes. The SLM could be used to narrow the drilling beam as well as to change its focus so that the drilled hole remains of uniform diameter (or has reduced diameter variation) as the hole is progressively bored.

[0303] In order to broaden the far field, the near field (at the SLM) needs to be made narrower. This may be implemented by applying shaping to the central portion of the beam so that its full width half maximum (FWHM) points become closer together and so that the beam shape has even symmetry about its centre. Preferably the amplitude at the very peak is not reduced so as not to lose too much power. The distance between the two FWHM points defines the effective half-width of the hologram. Further shaping should be applied to the left-hand and right-hand edges of this effective hologram, so that the beam shape has the required properties as described previously. Outside of the width of the effective hologram the beam shape should have zero amplitude.

[0304] To narrow the far field, the near field (at the SLM) needs to be made broader. This may be implemented by applying shaping to the central portion of the beam, so that the FWHM points become further apart, and so that the beam shape has even symmetry about its centre. Typically this will require reduction of the amplitude around its peak. The extent of this reduction is governed by the need to be able to apply shaping to the right and left hand edges of the hologram with the constraint that the shaping may only decrease the amplitude (and not increase it).

[0305] Amplitude-modulating SLMs can be used to implement the shaping but they are polarisation-dependent.

[0306] Another pseudo-amplitude modulation can be created to implement the beam shaping by using a phase-modulating SLM, which may be made polarisation-independent. This may be achieved by recognising that a phase modulation exp j ϕ (u), where j is the complex operator, is equivalent to a phase modulation cos ϕ (u)+j sin ϕ (u). Now choose ϕ (u) such that the modulus of ϕ (u) is varying slowly but the sign is oscillating.

[0307] Hence the real part of the modulation, cos ϕ (u), will be slowly varying and can act as the amplitude modulator to create the beam shape, while the imaginary part of the modulation, $\pm$ sin ϕ(u), will be oscillating rapidly with an equivalent period of two or more pixels. Hence the energy stripped off by the effective amplitude modulator will be diffracted into a set of beams that are beam-steered out of the system at large angles.

[0308] In a preferred embodiment, the system is designed such that light travelling at such angles will either not reach the output plane or will land outside the region defined by the output ports. Therefore the beam component shaped by sin ϕ (u) is rejected by the optical system, while the beam component shaped by cos ϕ (u) is accepted by the system and couples into one or more output ports, as required. While this explanation is for a one-dimensional phase modulator array the same principle is applicable in 2-D. If ϕ (u) varies from 0 at the centre of the beam to $\pi/2$ at the edges then the amplitude of the beam shaped by cos ϕ (u) varies from 1 at the centre of the beam to 0 at the edges, thus removing the amplitude discontinuity that creates rippling tails in the far field. This can be achieved with minimal change to the insertion loss of the beam as it passes through the system. Indeed, often the insertion loss due to clipping is due to interference from the amplitude discontinuity, rather than the loss of energy from the beam tails.

[0309] The beam-shaping hologram is non-periodic but oscillatory and may be applied as a combination with other routing and/or lens synthesis and/or aberration correcting and/or power control and/or sampling holograms.

[0310] Further advantages of the beam shaping are that it reduces the required value of C for a given required crosstalk, allowing more compact optical switches. Another advantage is that the crosstalk decays much more rapidly with distance away from the target output fibre. Hence, essentially, the output fibres receive crosstalk only from their nearest neighbour fibres.

[0311] Therefore in a large optical switch used as a shared N*N switch for a range of wavelengths, it should be possible to arrange the wavelength channel allocation such that no output fibre collects crosstalk from a channel at the same system wavelength as the channel it is supposed to be collecting. This would reduce significantly the homodyne beat noise accumulation in networks using such switches, and, conversely, allow an increase in the allowed crosstalk in each switch as heterodyne crosstalk has much less of an impact at the receiver, and can also be filtered out if necessary.

[0312] The crosstalk suppression method uses beam shaping to suppress ripples in the beam tails. The same method can be adapted to change the beam shape around the beam centre. For the case when the output beam is an image of the beam at the SLM the beam shaping is working directly on an image of the output beam. The fraction of the initial beam that is shaped by the slowly varying function $\cos \phi (u)$ can have the correct symmetry to couple efficiently into the fundamental mode of the output fibre. The fraction of the initial beam that is shaped by the rapidly varying function $\pm \sin \phi(u)$ has the wrong symmetry to couple into the fundamental mode and can be adjusted to be at least partially orthogonal to the fundamental mode.

[0313] Effectively, it is the fraction of the beam shaped by $\cos \phi (u)$ that dominates the coupling efficiency into the fundamental mode. Therefore the dependence of the coupling efficiency vs. transverse offset is dominated by the overlap integral between the $\cos \phi (u)$ shaped beam and the fibre fundamental mode.

[0314] When the incident beam is the same shape as the fundamental mode and for small transverse offsets the coupling efficiency decreases approximately parabolically with transverse offset. In many beam-steering systems using phase-modulating SLMs the transverse offset at the output fibre increases linearly with the wavelength difference from the design wavelength. Consequently the system coupling efficiency decreases approximately parabolically with wavelength difference from the design wavelength. Beam shaping can be used to adjust the shape of the incident beam and optimised to flatten the dependence on transverse offset and hence to flatten the wavelength response. Alternatively a more complex wavelength dependence could be synthesised to compensate for other wavelength-dependent effects.

[0315] Beam shaping may also be used during system assembly, training or operation in order to measure mathematical moments of a light beam. A description of the method and theory will be followed by a description of some example applications.

[0316] The method requires a first stage during which corrective phase modulation is applied by the SLM such that the phase profile of the beam leaving the SLM has no non-linear component. This may be confirmed with a collimeter or wavefront sensor or some other suitable device. In a first embodiment the phase profile has no linear component applied to deflect the beam such that the beam is reflected in a specular direction. An optical receiver is placed to receive the reflected beam. The power reflected exactly into the specular direction is proportional to the square of an integral A(n) given in equation (28) where f(n,u,v) is the complex amplitude of the beam leaving the SLM at co-ordinates u,v during the n^{th} stage of the method.

$$A(n) = \iint f(n,u,v)\,du\,dv \qquad (28)$$

[0317] The optical power received by the photodiode during the n^{th} stage of the method is given by equation (29)

$$P(n) = K(A(n))^2 \qquad (29)$$

[0318] where K is a constant of proportionality.

[0319] If received by an optical fibre the received power will be modified according to the fibre misalignment and mode field distribution, leading to possible ambiguities in the method. Hence it is preferred instead to receive the beam by a photodiode. During the first stage of the method the net phase modulation applied by the SLM is such that the beam is of uniform phase. Let b(u, v) be the beam amplitude distribution. Therefore during this first stage the integral A is equal to the zeroth moment, a0, of the beam amplitude distribution, as shown in equation (30), and f(n,u,v) is equal to

$$A(1) = a0 = \iint b(u,v)\,du\,dv \qquad (30)$$

[0320] Therefore the power, P(1), measured by the photodiode during this first stage is given by equation (31).

$$P(1) = Ka_0^{\ 2} \qquad (31)$$

[0321] In order to characterise a two-dimensional beam, moments of the beam distribution may be taken in two orthogonal directions, in this case the u and v directions. Consider the pixel block of concern to be broken up into a set of columns. To each column in the block a particular effective amplitude modulation may be applied using the pseudo-amplitude method or some other method. For example consider the pixel column with a centre at co-ordinate u*. By applying an alternating phase modulation of +ϕ (u*) and -ϕ (u*) to adjacent pixels in the same column the effective amplitude modulation applied to the particular column is cos(ϕ (u*)).

[0322] In order to calculate the first moment in the u direction, during the second stage of the method the values of cos(ϕ (u*)) are chosen such as to approximate to a linear distribution, as described in equation (32)

$$\cos(\phi(u^*)) \approx mu^* + c \qquad (32)$$

[0323] Therefore the power P(2) measured during the second stage of the process is given by (33).

$$P(2) \approx K\left(m^2 a_{1U}{}^2 + 2mca_{1U}a_0 + c^2 a_0{}^2\right) \qquad (33)$$

[0324] where a_{1U} is the first moment of the beam distribution in the u direction, as given by (34).

[0325] $a1u = \iint ub(u,v)\,du\,dv$ (34)

[0326] The ratio of the powers measured during the two stages is then given by equation (35)

$$\frac{P(2)}{P(0)} \approx m^2\left(\frac{a_{1U}}{a_0}\right)^2 + 2mc\frac{a_{1U}}{a_0} + c^2 \qquad (35)$$

[0327] Given the measured power ratio and the values of m and c as chosen to satisfy the constraints of the method, the quadratic equation given in (35) may be solved to calculate the ratio of the first order moment in the u direction to the zeroth order moment.

[0328] The constraints on m and c are such that the actual values of the alternating phase of each column need to be chosen from the available set and such that the total phase excursion across the expected area of the beam remains within the range $[0,\pi]$ or $[-\pi,0]$ so that the $\cos(\phi\,(u^*))$ term may decrease (or increase) monotonically. In practise a photodiode of finite size will receive power diffracted from the SLM within an angular distribution about the specular direction. A further constraint on the gradient 'm' in equation (32) is such that the side lobes created by the linear amplitude modulation fall outside the area of the photodiode.

[0329] Similar methods may be used to take approximate higher-order moments in the u direction, and also first and higher-order moments in the v direction. In the latter case to each row in the block a particular effective amplitude modulation is applied, e.g. by setting adjacent pixels in the row to alternating phases of $+\phi\,(v^*)$ and $-\phi\,(v^*)$, where v* is the position co-ordinate of the row. The second-order moments may also be calculated and used to estimate the beam spot size at the hologram. This estimate can be used as part of the control algorithm for focus adjustment.

[0330] In a second embodiment a further linear phase modulation is applied to the hologram during each stage so as to deflect the beam to be measured while taking the moments towards a particular photodiode.

[0331] Consider a Gaussian type beam b(u,v) centred at position co-ordinates (u0,v0). The even symmetry of the beam about axes parallel to the u and v directions and through the centre lead to the identities given by equations (36) and (37).

$$\iint (u - u0) b(u,v)\, du\, dv = 0 \qquad (36)$$

$$\iint (v - v0) b(u,v)\, du\, dv = 0 \qquad (37)$$

[0332] Hence approximate values of the first order moments measured as described previously, or by some other method, may be used to deduce approximate positions for the beam centres, as shown by equations (38) and (39).

$$u_0 \approx \frac{a_{1U}}{a_0} \qquad (38)$$

$$v_0 \approx \frac{a_{1V}}{a_0} \qquad (39)$$

[0333] In the next stage of the measurement the pixel block initially assigned to the beam is re-assigned such that it is centred within half a pixel in each of the u and v directions from the approximate centre of the beam, as just calculated.

[0334] Let the new centre of the pixel block be at (u1,v1). A new hologram should be calculated such that the beam leaving the SLM acts as the product of a beam of uniform phase distribution and an effective amplitude distribution given by equation (40)

$$\cos(\phi(u^*)) \approx m(u^* - u1) \qquad (40)$$

[0335] The principle is that if the beam centre lies exactly at u1 the measured power exactly in the specular direction will be zero. Taking into account the finite area of the photodiode the measured power cannot be zero but will be minimised when u1 is within half a pixel pitch of the beam centre.

[0336] This new hologram should be applied to the pixel block and the power measured. At this point the method can proceed in two ways.

[0337] In one embodiment a further estimate of the beam centre can be calculated, as described previously, a new centre position u1 calculated, the hologram recalculated according to equation (40) and the power measured again. This process can be repeated until the value of u1 appears to have converged.

[0338] In a second embodiment the centre of the pixel block, u1 can be re-assigned, the hologram recalculated according to (40) and the power measured again. At the current pixel block centre, u1, for which the beam centre is within half a pixel of u1, the measured power should be at a minimum value.

[0339] A further embodiment is to use a suitable combination of these two alternative methods.

[0340] The centre of the pixel block in the v direction can be measured using similar methods.

[0341] The size of the pixel block used should be chosen so as to cover the expected area of the beam. Outside of this area the phase can be modulated on a checkerboard of, for example, +-pi/2, so that the effective amplitude modulation is zero and the light from these regions is diffracted far away from the photodiode.

[0342] It can be shown that equations (36) and (37) are also satisfied if the beam waist is not coincident with the SLM, that is the beam is defocused. Although the method as described above will not be calculating the proper moments of the beam, it can be shown that the position of the beam centre may still be identified using the methods described.

[0343] The beam shaping method may be extended to control and adapt the amplitude of the beam steered through the system. If $\phi(u)$ varies from ψ at the centre of the beam to $\pi/2$ at the edges then the real part of the pseudo-amplitude modulation can be considered as cos ψ multiplied by an ideal beam-shaping function that causes insignificant insertion loss. In which case there is an associated additional insertion loss given by approximately $10\log_{10}(\cos^2 \psi)$. By varying the value of ψ the beam power can be varied. Therefore the same device can be used to achieve power control, otherwise known as channel equalisation, as well as changing the routing or direction of a beam. Deliberate changes in the beam shaping function can be used to increase the number of 'grey levels' possible for the beam attenuation, i.e. to provide an increased resolution. As for the beam shaping, the rejected power is diffracted out of the system. Therefore this attenuation method does not increase crosstalk.

[0344] Another technique for controlling beam power without increasing crosstalk is to deflect the unwanted energy in a direction orthogonal to the fibres susceptible to crosstalk.

[0345] This may be combined with yet another technique, namely distorting the beam phase in such a way that much of the energy couples in to the higher-order modes of the fibre, rather than the fundamental mode that carries the signal. The beam phase distortion may alternatively be used alone.

[0346] In an embodiment, these methods are achieved by dividing the area of the SLM on which the beam is incident into a set of 'power controlling' stripes. The long side of the stripes are at least substantially in the plane in which the input and output-beam are travelling. By varying the relative phase in the stripes the coupling efficiency into the fundamental mode of the output fibre is changed, and hence the throughput efficiency of the optical system is set. This method can be applied to a pixellated device that is also routing or otherwise adapting a beam. In this case each 'stripe' would contain between one and many of the pixels already in use.

[0347] Alternatively the long side of the power controlling stripes could be in one plane in one electrode, with the long side of the routing pixels in an orthogonal direction in the other electrode, of which either the stripe electrodes, or the pixellated electrodes, or both, are transparent.

[0348] Alternatively the device acts solely as a beam power controller, or channel equaliser. In this case each stripe could be a single pixel. The set of stripes for each beam defines a block. Many blocks could be placed side by side to form a row of blocks, with each block in the row providing channel equalisation for a different beam. Many rows could also be provided so as to provide channel equalisation for signals coming in on different input fibres.

[0349] If a pair of confocal focusing elements is disposed between the output fibre and SLM then the output fibre receives an image of the field at the SLM. In this case the attenuation at the output fibre is governed by the orthogonality between the image and the fundamental mode of the fibre. Assuming, and without loss of generality, that a perfect image is formed such that sharp phase discontinuities are preserved, it may be shown that the coupling efficiency into the fundamental mode is proportional to the square of a sum of weighted integrals. The weight is the modulation exp $j\phi$ applied by a stripe, and the associated integral is over the area onto which that stripe is imaged. The integrand is positive and depends on the square of the local electric field associated with the fundamental mode. Each integral is represented as a phasor, with a length depending on how much of the fundamental mode power passes through the region onto which the stripe is imaged, and a phasor angle depending on the phase modulation. The net coupling efficiency is given by the magnitude of the vector summation of the individual phasors associated with each stripe. For simple devices it may be advantageous to use as few stripes as possible as this reduces any losses due to dead space between the stripes and reduces the control complexity. With only two stripes of approximately equal area (and hence two phasors of approximately equal length) the possible vector sums lie on a semicircle and hence the number of possible grey levels is equal to the number of phase levels between 0 and π, which may not be sufficient. Transverse offset of the output fibre with respect to the centre of the image has the effect of making the two phasors unequal and hence complete extinction is not possible. These problems may be overcome by using three or more stripes per hologram. For example with three stripes the loci of vector sums lie on circles centred about the semicircle taking just two of the stripes into consideration. Hence many more values are possible. Increasing the number of stripes increases the number of grey levels and the depth of attenuation.

[0350] A fibre spool is used on the output fibre before any splices are encountered. It will clear to those skilled in the art that other mode stripping devices or techniques could be used instead.

[0351] This system can also be adaptive: given knowledge of the applied phase by each stripe and enough measurements of the coupling efficiency, the lengths of the different phasors associated with each stripe can be calculated. Given these lengths the performance can be predicted for any other applied phases. Hence suitable algorithms can be included in the SLM or interface to train and adapt the device performance to cater for transverse offset of the output fibre and other misalignments.

[0352] Sharp edges or phase discontinuities in this image will be eroded by the optical modulation transfer function (MTF) but, nevertheless, where a sufficient number of stripes is provided it is possible to vary the phase modulation of each and achieve a wide range of attenuation.

[0353] Ultimately what limits the depth of attenuation is the residual zero-order due to, for example, an imperfect quarter-wave plate or Fresnel reflections from different surfaces inside the SLM such that the reflected light has not yet been phase-modulated. An example reflection is from the interface between the cover glass and transparent electrode. Such residual zero orders will couple into the output fibre independently of the phase modulation. In many cases the residual zero order will have a different polarisation state to the beam that has been properly processed by the phase modulation, so even adapting the phase modulation will not recover the depth of attenuation.

[0354] In such cases it is advantageous to apply some routing to the output fibre, such that the zero order is offset from the output fibre and the intended output beam is steered into a diffraction order of the routing hologram. For a many-pixellated SLM this may be achieved using the standard routing algorithm described earlier. For a simple SLM with few pixels, e.g. the one with the stripes in the plane of the input and output fibres, these stripes can be subdivided in an orthogonal direction, that is to create a 2-D array of pixels. This however increases the device complexity.

[0355] An alternative simple device is to combine it with a tip-tilt beam-steering element, as described in Optics Letters, Vol. 19, No 15, Aug. 1, 1994 "Liquid Crystal Prisms For Tip-Tilt Adaptive Optics" G D Love et al. In this case the top 'common electrode' is divided into a set of top electrodes, one for each device, where each device is assumed to receive a separate beam or set of beams. Each top electrode has different voltages applied on two opposite sides. The shape of the top electrode is such that the voltage between the electrodes varies nonlinearly in such a way as to compensate for the non-linearity of the phase vs. applied volts characteristic of the liquid crystal. Hence with all the stripe electrodes at the same voltage the device provides a linear phase ramp acting like a prism and deflecting the phase-modulated beam in a pre-defined direction, such that the residual zero order falls elsewhere, as required. Changing the stripe electrode voltage causes phase changes in the imaged beam but does not prevent the deflection. Small adjustments in the phase ramp can be used to compensate for component misalignments and/or curvature of the SLM substrate and/or wavelength difference from the design wavelength for the tip-tilt device. Such small adjustments in the phase ramp can also be used to achieve fine control over the attenuation. Hence such a device would be useful whether or not the required attenuation is sufficiently strong for the residual zero order to become a problem. Alternatively the top electrode can be divided into two or more areas, with the shape of each so as to compensate for the phase vs. volts non-linearity. Varying the voltage on the ends of each electrode can be used to offset the phase modulation of each stripe in order to create the desired attenuation. In this case the aluminium electrode would be common to the device, removing dead-space effects.

[0356] In another embodiment of the tip-tilt device, the top electrode is common to all devices and a shaped transparent electrode is provided, e.g. by deposition, on top of the quarter-wave plate, with connections to the SLM circuitry to either side of the device. In this case the aluminium may act only as a mirror and not as an electrode. Again the shaped transparent electrode may be subdivided into two or more areas to provide the attenuation. This embodiment avoids dead-space effects and also a voltage drop across the quarter-wave plate.

[0357] In a further embodiment, such a tip-tilt device has a shaped transparent electrode on both cover glass and quarter-wave plate. The planes of tip-tilt for the two devices may be orthogonal or parallel. With two parallel tip-tilt electrodes the device may act as a power-controlling two-way switch, and also, as will be described later, can be used in a multi-channel add/drop multiplexer. With two orthogonal tip-tilt electrodes the device can beam steer in 2-dimensions such as to correct for positional errors. Either of the two tip-tilt electrodes can be subdivided so as to provide attenuation.

[0358] One advantageous SLM is that described in our co-pending patent application EP1053501.

[0359] If there is a single focusing element between the output fibre and SLM then the field at the output fibre is the Fourier Transform of the field leaving the SLM. In this case three classes of phase modulation can be used to change the coupling efficiency into the output fibre. The first two classes assume a many-pixellated SLM while the third class assumes a few-pixel SLM with or without tip-tilt features as described earlier. In the third class the tip-tilt feature may be used to compensate for transverse positional errors in the input and output fibre.

[0360] The different classes of phase modulation result in a variable coupling efficiency at the output fibres using the following methods:

[0361] As noted above, the first class uses a many-pixellated SLM. A periodic phase modulation is applied that creates a set of closely spaced diffraction orders at the output fibre. The spacing is comparable to the fibre mode spot size such that there is significant interference between the tails of adjacent diffraction orders. The phases of these diffraction orders are chosen such that the resulting superposition is rapidly alternating in phase and therefore couples into the higher-order fibre modes. Varying the strength, phase and position of each diffraction order changes the attenuation. If the long sides of the stripes used to create this alternating output field are in the plane of the input and output fibres, then diffraction orders landing outside the target optical fibre fall along a line orthogonal to the output fibre array, and therefore do not cause crosstalk.

[0362] In the second class, again using a many-pixellated SLM, a non-periodic smoothly varying non-linear phase modulation is applied at the SLM, in this case the SLM acts as a diffractive lens such that the beam is defocused and couples into higher-order modes.

[0363] In the third class, which uses a simple SLM with few pixels, the pixels are used to apply phase distortion across the beam incident on the SLM. Such phase modulation can be considered to be equivalent to the first class but with a long period. The phase distortion at the SLM results in amplitude and phase distortion in the reflected beam and hence reduces the coupling efficiency into the output fibre.

[0364] Again, all three methods require use of a mode stripper on the output fibre. Again suitable algorithms can be included in the SLM or interface to train the system.

[0365] Another embodiment, not illustrated, uses a graded-index (GRIN) lens secured to one face of an SLM, and having input and output fibres directed on or attached to the opposite face. The SLM may provide selective attenuation, and/or may selectively route between respective input fibres and selected output fibres. A requirement for stable performance is fundamental for optical devices used in communications and like fields. One of the dominant manufacturing costs for such optical devices is device packaging. The GRIN lens architecture results in a compact packaged device resilient to vibrations. However, the architecture can have problems with spherical aberration and problems in achieving the required alignment accuracy. In particular there is often a requirement for precise transverse positioning of the fibres. Also due to manufacturing tolerances in the GRIN lens the focused spot in the reflected beam can be offset significantly in the longitudinal direction from the end face of the output fibre, resulting in an insertion loss penalty. This problem gets worse the longer the GRIN lens. Applying selected non-linear phase modulation to the SLM may compensate for problems such as focus errors, length errors, longitudinal positional errors and spherical aberration. Applying selected linear phase modulation to the SLM and/or using tip-tilt electrodes may compensate for problems such as transverse positional errors.

[0366] Optical systems using SLMs may individually process the channels from an ensemble of channels on different wavelengths, entering the system as a multiplex of signals in a common beam. Given a continuous array of pixels the SLM may also process noise between the channels. Hence the optical system acts as a multiwavelength optical processor. The processing may include measurement of the characteristics of the signals and accompanying noise as well as routing, filtering and attenuation.

[0367] In a first application, the SLMs carry out attenuation, known in this context as channel equalisation. A second application is a channel controller. A third application is an optical monitor. A fourth application is an optical test set. A fifth application is add/drop multiplexing. Further applications are reconfigurable wavelength demultiplexers and finally modular routing nodes. In all of these applications the SLMs may carry out routing and/or power control and/or beam shaping and/or sampling and/or corrective functions as described earlier. The system to be described is not restricted to this set of seven applications but is a general multi-wavelength system architecture for distributing the wavelength spectrum from one or more inputs across an array of devices and recombining the processed spectrum onto one or more selected outputs.

[0368] The inputs and outputs may be to and from optical networking equipment such as transmission systems, transmitter line cards and receiver line cards. Alternatively the inputs may be from one or more local optical sources used as part of a test set: either via an intermediate optical fibre or emitting directly into the optical system. The outputs may be to one or more local photo detectors for use in testing and monitoring. Applications outside the field of communications are also possible such as spectroscopy.

[0369] Such multi-wavelength architectures can be adaptations of optical architectures used for wavelength de-multiplexing. Wavelength demultiplexers typically have a single input port and many output ports. These can use one or more blazed diffraction gratings: either in free-space or in integrated form such as an AWG (Arrayed Waveguide Grating). These devices are reciprocal and hence work in reverse. Hence if a signal of the appropriate wavelength is injected into the output port it will emerge from the input port. The output port usually consists of an optical waveguide or fibre with an accepting end that receives a focused beam from the optical system and a delivery end providing an external connection. Now consider replacing the acceptance end of the output waveguide/fibre with a reflective SLM: all of the processed signals reflected straight back will couple into the input fibre and emerge from the input port. These signals can be separated from the input signal with a circulator. Alternatively the system is adapted so that the reflected signals emerge and are collected together into a different fibre.

[0370] Free-space optical systems performing wavelength de-multiplexing can use diffraction gratings made by ruling, or from a master, or made holographically, or by etching. Usually these work in reflection but some can work in transmission. One or two gratings can be used in the system. The optics used to focus the beams can be based on refractive elements such as lenses or reflective elements such as mirrors or a combination of the two.

[0371] Referring to FIG. 12, a channel equaliser 350 has a single grating 300 used with a refractive focusing element 310 and an SLM 320. To make the diagram clearer, the grating 300 is drawn as working in transmission. Other embodiments use two gratings and/or reflective focusing elements and/or gratings that work in reflection, such as blazed gratings.

[0372] A first input beam 301 from an input port 304 contains an ensemble of channels at different wavelengths entering the equaliser on the same input port 304. As a result of the grating 300 the beam 301 is split into separate beams 301a, 301b, 301c for each wavelength channel, each travelling in a different direction governed by the grating equation. The grating 300 is positioned in the input focal plane of a main routing lens 310 with a reflective SLM 320 at the output focal plane of the routing lens 310. If desired, there may also be a field-flattening lens just in front of the SLM 320.

[0373] If lens 310 were an ideal lens, rays passing through the same point on the focal plane of the lens, regardless of direction provided they are incident on the lens, emerge mutually parallel from the lens. As lens 310 is not a real lens, this is no longer strictly true: however well-known lens design techniques can be applied to make it true over the required spatial window.

[0374] Hence, the beams 301a, 301b, 301c that were incident upon the lens 310 from the same point on the focal plane, but at different angular orientations, emerge mutually parallel from the routing lens 310, but spatially separate. Thus, the lens refracts each beam to a different transverse position 320a, 320b, 320c on the SLM 320. At each position the SLM 320 displays a pixellated hologram and/or has a tip-tilt device for processing the relevant wavelength component of the beam. In the preferred embodiment, the SIM 320 is a continuous pixel array of phase-modulating elements and is polarisation independent. The width of each hologram or tip/tilt device compared to the spot size of the incident beam incident is sufficient to avoid clipping effects. Instead, or additionally, beam shaping may be used. The device may be controlled to deflect or attenuate the beam as described earlier, and provides output processed beams 302a, 302b, 302c. Beams 302a and 302b have moderate channel equalisation applied by a power control hologram and routing towards the output port 305 applied by a routing hologram. As explained previously it is advantageous to use a routing hologram as it deflects the beams from their specular output direction and hence increases the available depth of attenuation. Beam 302c has strong attenuation applied in order to "block" the channel: this is achieved by selecting holograms that direct the light well away from the output port 305 towards, for example, an optical absorber 306. The processed beams are reflected back from the SLM 320 towards the main lens 310 and then refracted back by the main lens towards the diffraction grating 300. Assuming the SLM 320 is flat, all beams subjected to the same deflection at the SLM 320 and entering the system in the same common input beam emerge mutually parallel from the diffraction grating. Curvature of the SLM 320 is compensated by small changes in the deflection angle achieved due to the holograms displayed on the SLM 320. As the light beams 302a, 302b emerge parallel from the SLM 320 they are refracted by the lens 310 to beams 303a, 303b propagating towards a common point in the grating 300, which (having the same grating equation across the whole area of concern) diffracts the beams to provide a single output beam 302. Note that due to the action of the lens, beam 303a is parallel (but in the opposite direction) to beam 301a and beam 303b is parallel (but in the opposite direction) to beam 301b. Therefore all beams subjected to the same eventual output angle from the SLM 320 are collected into the same output port 305. Hence a system may be constructed with a single input port 304 and a single output port 305 that produces independent attenuation or level equalisation for each wavelength channel. Note that to obtain the same deflection angle for all wavelength channels, as required, the effective length of the hologram phase ramp, Ω/m, where m is the mode number of the excited diffraction order and Ω is the hologram period, should be adjusted in proportion to the channel wavelength. That is the wavelength dependence of the beam deflection should be suppressed.

[0375] As described later the channel equalisation can be uniform across each channel so as to provide the required compensation as measured at the centre of each channel. Alternatively the channel equalisation can vary across each channel, so as to compensate for effects such as amplifier gain tilt that become important at higher bit rates such as 40 Gb/s. Channels may be blocked as described earlier so as to apply policing to remote transmitters that renege on their access agreements or whose lasing wavelength has drifted too far. Furthermore the noise between selected channels may be partially or completely filtered out, as described later. Hence in a second application the multiwavelength optical processor acts as a channel controller.

[0376] Although such processing can be applied using conventional optics the multiwavelength optical processor has a number of advantages. Compared to a series of reconfigurable optical filters the multiwavelength processor has the advantage that the channels are processed by independent blocks of pixels. Hence reconfiguration of the processing applied to one or more selected channels does not cause transient effects on the other channels. Compared to a parallel optical architecture that separates the channels onto individual waveguides/fibres before delivery to a processing device (and hence avoids the transient effects) the multiwavelength optical processor has a number of advantages. Firstly it can process the whole spectrum entering the processor (subject to the grating spectral response). Secondly the filter passband width is reconfigurable and can be as much as the entire spectrum, reducing concatenation effects that occur when filtering apart sets of channels routed in the same direction. Thirdly the filter centre frequencies are reconfigurable. Further advantages are discussed later in this application.

[0377] By having a choice of two or more deflection angles at the SLM every input channel may be routed independently to one of two or more output ports. There may also be two or more input ports. It may be shown that for one or more parallel input beams, the action of the grating and main routing lens is such that all channels at the same wavelength but from different input ports are incident at the same transverse position at the SLM. Again this is because "parallel rays converge to the same point". Hence these channels at the same wavelength are incident on the same channel processing hologram and/or tip-tilt device. As every wavelength channel is incident on a different device, the device response may be optimised for that particular wavelength. For example if a pixellated SLM is used the deflection angle is proportional to the wavelength. Hence small adjustments in the phase ramp can be used to adjust the deflection angle to suit the wavelength to be routed. All channels incident on a particular transverse position on the SLM must be reflected from that same position. As this position is in the focal plane of the lens beams from said position will emerge parallel from the lens and travelling towards the grating. After the grating the beams will be diffracted (according to their wavelength). It may be shown that all beams entering the system in a parallel direction will emerge from the system in exactly the opposite direction. It may also be shown that all beams subject to the same output angle from the SLM will emerge coincident from the system and may therefore be collected into the same port.

[0378] Analysis of the beams at the diffraction grating in this architecture shows that the spot size required for a given wavelength channel separation and beam clipping factor C at the hologram depends on the grating dispersion but does not depend on the routing lens focal length nor the number of output ports. The beam centres must be far enough apart to provide adequate crosstalk suppression. Hence the greater the number of output beams the further the beam must be steered by the SLM and lens. As an example consider just routing in 1-D, into the m'th diffraction order with a hologram period , Ω and a routing lens of focal length f. The output beam at the diffraction grating will be offset from its zero order reflection by a distance given approximately by $f.m.\lambda/\Omega$, where λ is the optical wavelength and Ω/m is the effective length of the phase ramp on the hologram (as explained previously). To increase this offset distance the length of the phase ramp can be reduced, which tends to require smaller pixels, or the lens focal length can be increased. In practice there is a lower limit to the pixel size set by the dead space losses and the size of the pixel drive circuits, while increasing the lens focal length makes the overall system longer. This can be a particular problem when there are many output ports, even when close-packing 2-D geometries are used for the output beams.

[0379] Referring to FIG. 14, another method is to put a demagnification stage between the SLM 400 and a routing lens 404. This is positioned so that the SLM 400 is in the object plane of the demagnification stage while the image plane of the demagnification stage 402 is where the SLM would otherwise be, that is in the focal plane of the routing lens 404. What appears in this image plane is a demagnified image of the SLM 400, which therefore acts like a virtual SLM 402 with pixels smaller than those of the real SLM 400 and hence a shorter effective phase ramp length. As an example consider the two lens confocal magnification stage shown in FIG. 14. In FIG. 14 f1 is the focal length of the first lens 401 and f2 is the focal length of the second lens 403 (closer to the virtual SLM). The demagnification is f2/f1 while the beam-steering deflection angle is magnified by f1/f2.

[0380] While this method for increasing the effective beam deflection angle has been described and illustrated in the context of one particular routing architecture it could also be applied to other optical architectures using SLMs to process an optical beam, for routing and other applications. The operating principle is that the virtual SLM 402 has an effective pixel size and hence an effective phase distribution that is smaller in spatial extent than that of the real SLM 400, by an amount equal to the demagnification ratio of the optics. The off-axis aberrations that occur in demagnification stages can be compensated using any of the methods described in this application or known to those skilled in the art.

[0381] In an alternative embodiment the input beam or input beams contain bands of channels, each incident on their own device. In this and the previous embodiment for the channel equaliser the beam deflection or channel equalisation may vary discontinuously with wavelength.

[0382] In a third embodiment the input beam could contain one or more signals spread almost continuously across the wavelength range. The light at a particular wavelength will be incident over a small transverse region of the SLM, with, typically a Gaussian type spatial distribution of energy against position. The position of the peak in the spatial distribution is wavelength dependent and may be calculated from the grating and lens properties. For such a system the beam deflection or channel equalisation varies continuously with wavelength. The pixellated SLM is divided into blocks, each characterised by a 'central wavelength', defined by the wavelength whose spatial peak lands in the middle of the block. A particular channel equalisation or beam deflection is applied uniformly across this block. Light of a wavelength with a spatial peak landing in between the centres of two blocks will see a system response averaged across the two blocks. As the spatial peak moves towards the centre of one block the system response will become closer to that of the central wavelength for the block. Hence a continuous wavelength response is obtained. The block size is selected with respect to the spatial width of each beam in order to optimise the system response. This method is particularly attractive for increasing the wavelength range of a 1 to N switch.

[0383] To achieve this aim the multi-wavelength architecture described earlier, should be configured so as to allow reconfigurable routing from a single input port to one of a set of multiple output ports. The length of the phase ramp used to route the beam to each output port should vary slowly across the SLM such that the wavelength variation in the deflection angle is minimised, or certainly reduced considerably compared to the case for which the phase ramp length is uniform across the SLM. Hence the transverse position of each output beam will vary considerably less with wavelength, with a consequent reduction in the wavelength dependence of the coupling efficiency at the system output. Alternatively, the length of the phase ramp can be varied spatially so as to obtain some desired wavelength dependence in the coupling efficiency.

[0384] The efficiency of a blazed diffraction grating is usually different for light polarised parallel or perpendicular to the grating fringes. In the multi-wavelength systems described above the effect of the quarter-wave plate inside the SLM is such that light initially polarised parallel to the grating fringes before the first reflection from the blazed grating is polarised perpendicular to the grating fringes on the second reflection from the blazed grating. Similarly the light initially polarised perpendicular to the grating fringes before the first reflection from the blazed grating is polarised parallel to the grating fringes on the second reflection from the blazed grating. Hence, in this architecture, the quarter-wave plate substantially removes the polarisation dependence of the double pass from the blazed grating, as well as that of the phase modulation. As is clear to those skilled in the art, this polarisation independence requires the fast and slow axes of the integrated quarter-wave plate to have a particular orientation with respect to the grating fringes. This required orientation is such that the integrated quarter-wave plate exchanges the polarisation components originally parallel and perpendicular to the grating fringes.

[0385] Referring to FIG. 28 a wavelength routing and selection device 600is shown. This device has a multiwavelength input 601 from an input port 611, and provides three outputs 602, 603, 604 at output ports 612-614.

[0386] The device 600, similar to the device of FIG. 12, has a grating 620, a lens 621 and an SLM 622, with the disposition of the devices being such that the grating 620 and SLM 622 are in respective focal planes of the lens 621. Again the grating is shown as transmissive, although a reflective grating 620, such as a blazed grating, would be possible. Equally, the SLM 622 is shown as reflective and instead a transmissive SLM 622 could be used where appropriate.

[0387] The grating 620 splits the incoming beam 601 to provide three single wavelength emergent beams 605, 606, 607 each angularly offset by a different amount, and incident on the lens 621. The lens refracts the beams so that they emerge from the lens mutually parallel as beams 615,616, 617. Each of the beams 615,616,617 is incident upon a respective group of pixels 623,624,625 on the SLM 622. The groups of pixels display respective holograms which each provide a different deviation from the specular direction to provide reflected beams 635, 636 and 637. The beams 635, 636, 637 are incident upon the lens 621 and routed back to the grating 620.

[0388] In the embodiment shown, the beams 605 and 606 are finally routed together to output port 614 and the beam 607 is routed to output port 612. No light is routed to port 613.

[0389] However it will be understood that by careful selection of the holograms, the light can be routed and combined as required. It would be possible to route light of a selected frequency right out of the system if needed so as to extinguish or "block" that wavelength channel. It is also envisaged that holograms be provided which provide only a reduced amount of light to a given output port, the remaining light being "grounded", and that holograms may be provided to multicast particular frequencies into two or more output ports.

[0390] Although the number of output ports shown is three, additional output ports can be included: with appropriate lens design the insertion loss varies weakly with the number of output ports. Although the output ports are shown in the same plane as the input it will be clear to those skilled in the art that a 2-D distribution of output ports is possible.

[0391] Hence the device 600 provides the functions of wavelength demultiplexing, routing, multiplexing, channel equalisation and channel blocking in a single subsystem or module. These operations are carried out independently and in parallel on all channels. Reconfiguration of one channel may be performed without significant long-term or transient effects on other channels, as occurs in serial filter architectures. With most conventional optics (including parallel architectures) separate modules would be required for demultiplexing, routing, multiplexing and the power control functions. This adds the overheads of fibre interconnection between each module, separate power supplies, and a yield that decreases with the number of modules. The device 600 has no internal fibre connections, and a single active element requiring power-the SLM. Each active processing operation (routing, power control, monitoring etc) requires an associated hologram pattern to be applied by the controller but may be carried out by the same SLM, hence the yield does not decrease with increased functionality. Although integrated optical circuits can be made that combine different functions, in general they require a separate device inside the optical chip to perform each function. Again the power (dissipation) and the yield worsen with increased functionality.

[0392] Further applications of the multiwavelength optical processor are as an optical performance monitor, and as a programmable multifunction optical test set. In both applications the SLM may perform two or more different but concurrent monitoring or testing functions on two or more portions of the wavelength spectrum. This may be achieved by applying routing holograms to the pixel block associated with said portions of the wavelength spectrum that connect optically a selected input fibre or input optical source to a selected output fibre or output detector. The routing hologram applied to each portion of the spectrum may be reconfigured as required in order to perform different testing or monitoring functions on said portion of the spectrum. To each output photo detector or to each input optical source is applied control circuitry for carrying out the required tests.

[0393] Considering firstly the performance monitor, the method described later to measure the centre wavelength of a channel may be applied to a selected channel in order to monitor the lasing wavelength. Earlier in this application there is a description of how to measure the second order moments of a beam. Consider orthogonal axes u and v at the SLM. Choose the orientation of these axes such that all wavelength channels entering the system and incident on the grating in the defined parallel direction have the centres of their associated beams along a line of constant v. Hence the position along the u axis increases with wavelength. The second order moment in the v direction is related to the spot size of a monochromatic beam. The second order moment in the u direction is related to this spot size and also the wavelength distribution of the energy in each channel. Hence by measuring second order moments, as described previously, an estimate of the channel bandwidth may be obtained. The noise power between a selected pair of channels may be measured by routing that part of the spectrum between the channels towards a photo detector. Similarly the power of a selected channel may be measured by routing towards a photo detector. One or more photo detectors may be assigned to each type of measurement is allowing many parallel tests to proceed independently on different portions of the spectrum. Alternatively the control circuitry associated with each photo detector output may be designed to be able to perform two or more of the required monitor functions.

[0394] Hence the multiwavelength optical processor acts as an optical spectrum analyser with integrated parallel data processing. Conventional methods for achieving this use either a grating that is rotated mechanically to measure different portions of the spectrum with a photo detector in a fixed position, or a fixed grating with a linear photodiode array. In both cases data acquisition hardware and software and data processing are used to extract the required information from the measured spectrum. Both systems are expensive and require stabilisation against the effects of thermal expansion. The multiwavelength optical processor has no moving parts, can use as few as a single photodiode, and can adapt the holograms to compensate for temperature changes, ageing, aberrations as described previously in this application. The multiwavelength processor also carries out the data processing to measure centre wavelength and channel bandwidth in the optical domain. When used in a communications network the optical performance monitor would pass the processed data from the measurements to a channel controller, such as the one described previously, and also to a network management system. The signal for monitoring would be tapped out from a monitor port at the channel controller or from a routing system or from elsewhere in the network. The monitor processing could be implemented with the same or a different SLM to the channel controller. Monitor processing can also be implemented with the same or different SLMs used to route beams in the add drop routers and routing modules described later in this application. The control electronics for the monitor processing can be integrated with the control electronics for the pixel array.

[0395] With reference to FIG. 30, the programmable multifunction optical test set 900 has a multiwavelength optical processor 928 with one or more inputs 901, 902 from optical sources, 903, 904 each with control circuitry 905, 906 for performing one or more tests of optical performance. The channel equalisation and blocking functions described earlier may be used to adapt the spectrum of the selected source to suit a particular test. The channel filtering functions described later may be used to synthesise a comb or some other complex wavelength spectrum from a selected broadband optical source. A further input 907 from an optical source 910 may be used to exchange data and control information from control and communications software 929 with the same 900 or one or more other optical test sets, allowing remote operation over the fibre under test, or some other fibre. One or more outputs ports 911, 912 from the multiwavelength optical processor are connected to a set of optical fibre transmission systems (or other devices) 913, 914 to be tested. Routing holograms are applied to the pixels associated with the selected parts of the spectrum to direct said parts of the spectrum or said data and control information to the selected output port. A further or the same multiwavelength optical processor has input ports 917, 918 connected to the set of optical fibre transmission systems (or other devices) 915, 916 under test and output ports 919, 920 connected to a set of one or more photo detectors, 921, 922 each with associated control circuitry 925, 926 for carrying out testing functions. A further photo detector 924 connected to a further output port 923 is used to receive data and control information from one or more other test sets. Routing holograms are applied to direct the signals from the selected input port to the required photo detector. The optical monitor functions described above can be applied to the signals. The frequency shaping of the source or spectrum can take place at the transmitting test set or the receiving test set. The control electronics for the test set 927 and control and communications software 929 can be integrated with the control electronics for the pixel array.

[0396] Conventionally, different optical sources would be used to perform different types of test on the wavelength and transmission properties of fibres or devices under test; a separate optical switch would be used to poll the devices under test, and an external communications link would be used for communication of data and control information with a remote test set. However, the multiwavelength optical processor may be used to provide a multifunction programmable optical test set that is capable of remote operation. The test set may include as few as a single source and a single photo detector and performs a wide range of tests on fibres or devices selected from a group of fibres or devices attached to the test ports of the multiwavelength processor.

[0397] A multiwavelength system with two inputs and two outputs can work as an add/drop multiplexer. Add-drop multiplexers are usually used in ring topologies, with the 'main' traffic travelling between the ring nodes, and 'local' traffic being added and dropped at each node. Considering each node, one input (main in) is for the ensemble of channels that has travelled from the 'previous' routing node. The second input (add) is for the ensemble of channels to be added into the ring network at the add/drop node. One output (main out) is for the ensemble of channels travelling to the 'next' routing node while the second output (drop) is for the ensemble of channels to be dropped out of the ring network at the node. If a particular incoming wavelength channel is not to be 'dropped' at the node, then the channel-dedicated device at the SLM should be configured to route the incoming wavelength from the main input to the main output. However, if a particular incoming wavelength channel is to be dropped, then the channel-dedicated device at the SLM should be configured to route the incoming wavelength from the main input to the drop output. In this case the main output now has available capacity for an added channel at that same wavelength. Therefore the channel-dedicated device at the SLM should also be configured to route the incoming wavelength from the add input to the main output.

[0398] The multiwavelength optical processor described in this application distributes wavelength channels across and collects the wavelength channels from a single SLM, allowing the SLM to provide a set of one or more processing operations to each of the channels. However, in most conventional reconfigurable add drop multiplexers, the routing has to be carried out in two successive stages. Usually a first 1*2 switching stage either drops the channel or routes the channel through, while a second 2*1 switching stage either receives the through channel from the first stage or receives an added channel. Fortunately, careful choice of the deflection angles applied by the SLM, and the sharing of the same hologram by input signals at the same wavelength, allows add drop routing to be carried out in a single stage. Hence add drop routing may be conveniently applied in an independent and reconfigurable manner to every wavelength channel in the multiwavelength optical processor.

[0399] An explanatory diagram is shown in FIG. 13a.

[0400] Referring now to FIG. 13a, an SLM 141, used in the context of the multi-wavelength architecture, has a pixel block 140 and/or tip-tilt device upon which a main input beam 130 is incident, at an angle m1 to the normal 142. The main beam has a zero order or specular reflection 130a. Holograms are made available that will cause deflections at $+\theta_1$ to the specular direction and $-\theta_2$ to the specular direction. Due to the display of a first hologram on the pixel block 140, the main output is deflected by $+\theta_1$ from the specular direction to a main output beam 132. An add input 131 is incident at an angle a1 on the block 140, and produces a zero order reflection 131a. The device also has a drop output beam direction 133.

[0401] When the hologram applying the deflection of $+\theta_1$is displayed, light at the relevant wavelength entering in the add direction 131 is not steered into either of the main output beam direction 132 or the drop output beam direction 133. Effectively it is 'grounded'. This feature may be used to help to stop crosstalk passing between and around rings.

[0402] When the hologram applying the alternative deflection of $+\theta_2$ is applied, the add input is routed to the main output beam direction 132 while the main input is routed to the drop output beam direction 133.

[0403] In the interests of clarity, a simplified diagram may be used to explain an add-drop using 1-D routing. This is shown in FIG. 13b in which the point 134 represents the output position of the specular reflection from the add input while the point 135 represents the output position of the specular reflection from the main input. When a first routing hologram is applied the main output beam is deflected by an angle of $+\theta_1$ and therefore the output position of the main beam is deflected by an offset of $f.\theta_1$, compared to the output position 135 of its specular reflection. Here f is the focal length of the routing lens. In FIG. 13b this deflection is represented as a vector 136a and the output beam is routed to the main output 137. The beam from the add input is subject to the same angular deflection with respect to its specular reflection and is thus deflected by a vector of equal length and the same direction 136b with no output port to receive it this beam is "grounded". When a second routing hologram is applied the main output beam is deflected in the opposite direction by a vector 138a to arrive at a drop output 139. The beam from the add input is deflected by an identical vector 138b to arrive at the main output 137.

[0404] The example in FIG. 13a assumes 1-D routing due to the hologram. Given an ability to route in 2-D, either with two orthogonal tip-tilt electrodes or a 2-D pixel array (as described previously) the arrangement of the four ports can be generalised, as shown in FIG. 15. The use of 2-D routing allows closer packing of the input and output beams reducing off-axis aberrations. In FIG. 15 the output positions are shown in 2-D. The point 151 represents the output position of the zero order (specular) reflection from the add input while the point 152 represents the output position of the zero-order reflection from the main input. The hologram deflections are represented as vectors 155a, 155b, 156a and 156b. Vector 155b has the same length and direction as vector 155a and vector 156b has the same length and direction as vector 156a. When a first routing hologram is applied the add input beam is deflected from its specular output position 151 by the vector 155b to the main output 154 while the main input is deflected from its specular output position 152 by the identical vector 155a to the drop output 153. When the alternate routing hologram is applied the main input is deflected from its specular output position 152 by the vector 156a to the main output 154 while the add input is again 'grounded' due to deflection by the identical vector 156b.

[0405] In this general configuration there are six variables. These are the output positions of the main output and drop output, the positions of the zero order reflections from the main input and add input, and the two hologram deflections. Of these six variables only three are mutually independent.

[0406] For example, selection of the input position for the main input with respect to the routing lens axis defines the output position of the zero order reflection, 152. If this is followed by selection of the output positions for the main and drop outputs with respect to the routing lens axis then all three independent variables have been defined. Hence the required hologram deflections are determined as is the input position for the add input with respect to the routing lens axis (which then defines 151).

[0407] FIGS. 13a, 13b and 15 show the hologram deflections required to provide add-drop routing: FIGS. 13a and 13b assume 1-D routing while FIG. 15 assumes 2-D routing. A multiwavelength add-drop architecture using such hologram deflections is shown in FIG. 29. Compared to other methods for achieving add-drop functionality, the advantages are as described previously for FIG. 28.

[0408] Turning now to FIG. 29, an add/drop multiplexer device 700 has two input ports 701, 702 and two output ports 703,704. The first input port 701 is for an input beam 711 termed "add" and the second input port 702 is for a second input beam 712 termed "main in" having two frequencies in this embodiment. The first output port 703 is for a first output beam 713 termed "drop" and the second output port 704 is for a second output beam 714 termed "main out"

[0409] The input beams 711, 712 are incident upon a grating 720 that deflects the beams according to wavelength to provide emergent beams 731, 732 and 733. The emergent beams 731, 732 and 733 are incident upon a lens 722 having its focal plane at the grating 720, and the beams emerge from the lens respectively as beams 741, 742, and 743 to be incident upon an SLM 722 in the other focal plane of the lens 721. As the beams 741, 742 do not originate on the grating 720 from the same location, they are not mutually parallel when emerging from the lens 721. The beam 743 is from a point on the grating 720 common to the origin on the grating 720 of beam742, and hence these beams are mutually parallel. Although the grating is drawn as transmissive and the SLM as reflective, these types are arbitrary.

[0410] The first beam 731 and the third beam 733 are at the same wavelength, hence they emerge parallel from the grating 720 and are refracted by the lens 721 propagating as beams 741 and 743 respectively to a first group or block of pixels 723 on the SLM 722. This pixel block 723 applies the required hologram pattern that routes a channel entering the add port 701 to the main output 704, and also routes a channel entering the main input 702 to the drop port 703. Hence the first group of pixels 723 deflects the first beam 741 to provide first reflected beam 751, and deflects the third beam 743 to provide third reflected beam 753.

[0411] The second beam 732 is at a different wavelength to the first and third beams 731 and 733 and therefore emerges at a different angle from the grating 720. This third beam is refracted by the lens 721 and propagates as beam 742 to a second group of pixels or pixel block 724 on the SLM 722. This second group of pixels applies the hologram pattern that routes a channel entering the main input port 702 to the main output port 704 and "grounds" a channel entering the add port 701. The second group of pixels 724 deflects the second beam 742 to provide the second reflected beam 752. The holograms on the first and second groups of pixels are selected, (examples were described for FIGS. 13a, 13b and 15), so that the first and second reflected beams 751,752 are mutually parallel; the third beam 753 is routed in a different direction. The consequence of this is that the first and second beams 751,752, after passing again through the lens 721 become incident at a common point 726 on the grating 720, and emerge as main out beam 714. The third beam 753 is incident upon a different point on the grating 720 and emerges into as the drop beam 713.

[0412] In most cases ring networks are bi-directional, with separate add/drop nodes for each direction of travel. In some networks a loopback function is required. This allows isolation of one segment of the ring in case of link failure, for example. It also allows the transmission systems for both directions of a link between two nodes to be tested from a single node. This latter function is useful to confirm that a failed link has been repaired. Loop back requires the main input on each add/drop node to be routed to the main output on the other add/drop node, as shown in FIG. 16.

[0413] The figure shows a first module 161a and a second module 161b. The first module 161a has a main input 162a, an add input 166a, a loop back input 165a, a main output 163a, a drop output 167a and a loop back output 164a. The second module 161b has a main input 162b, an add input 166b, a loop back input 165b, a main output 163b, a drop output 167b and a loop back output 164b.

[0414] The node is divided into two sides: a west side 168 and an east side 169. Loop back may be required for one or for both sides of the node. Channels coming from the ring enter the first module 161a on a main input 162a and enter the second module 161b on a main input 162b. In normal operation through channels will be routed from the main input 162a to the main output 163a and from the main input 162b to the main output 163b.

[0415] In loop back operation for the west side 168 the through channels entering the input 162a on the first module 161a are routed to the loop back output 164a. This output 164a is connected to the loop back input 165b of the second module 161b. In loop back operation for the west side all channels entering the input 165b are routed to the main output 163b of the second module 161b.

[0416] In loop back operation for the east side 169 the through channels entering the second module 161b on the main input 162b are routed to the loop back output 164b. This output 164b is connected to the loop back input 165a of the first module 161a. In loop back operation for the east side 169 all channels entering the input 165a are routed to the main output 163a of the first module 161a.

[0417] The function can be implemented in the four port add drop node (explained in FIGS. 13, 13a, 15 and 29) by selecting a further hologram deflection 179a and 179b, as shown in FIG. 17. In the four port architecture both sides of the node loop back at the same time. This is due to the sharing of the same hologram by input signals at the same wavelength. In FIG. 17 the vector 179a deflects the main input from its specular output position 172 to the loop back output 176. The identical vector 179b is applied by the shared hologram to the loop back input such that it is deflected from its specular output position 173 by the identical vector 179b to the main output 175. The other vectors 177a, 177b, 178a and 178b are used for normal add-drop operation: 174 is the drop output and 171 is the specular output position for the add input.

[0418] When such a hologram is applied the main input is routed to the loopback output and the loop back input is routed to the main output. The two add/drop nodes are then connected as in FIG. 16.

[0419] The loop back function can be implemented in other add drop architectures (described later) by reserving drop ports for loop back out and add ports for loop back in. In these other architectures the loop back may be applied to just one side of the node, as well as to both sides.

[0420] The method used to provide loop back ports may also be applied to the multiport add drop (FIG. 18). This method may be used to provide cross connection ports to exchange channels between adjacent add drop nodes.

[0421] It is also possible to devise holograms for multicast, i.e. forwarding an incident light beam to each of several outputs. Such a hologram can be applied to route the main input to two outputs, with vectors 177a and 178a (in FIG. 17). In this case the device is performing a drop and continue function. This is required to provide a duplicated path at nodes connecting two touching ring networks.

[0422] Alternatively, or additionally, additional inputs and outputs can be provided so as to have a separate input for each added channel and a separate output for each dropped channel. This saves the expense and space taken up by additional filtering and/or wavelength multiplexing components that would otherwise be used to combine all added channels onto a common add port, and to separate all dropped channels to individual receivers. An example layout is shown in FIG. 18. In such an implementation care must be taken that sufficient distance is provided between the zero order reflections from each input, and the output positions for each output, so as to control the crosstalk. In FIG. 18 deflection v2 is used to deflect channels entering the main input from the specular output position m0 to the main output position m2. Deflections v4 to v7 are used to route from the four add inputs (with specular output positions a1, a2, a3 and a4) to the main output m2. Identical deflections v4 to v7 are applied by the shared holograms to deflect the main input from its specular output position m0 to the four drop outputs d1 to d4. For example if wavelength channels$\lambda 5$ and $\lambda 7$ enter on add input 2 which has its zero order (specular) reflection at a2, the holograms associated with these wavelength channels are configured to produce deflection v5. Hence these two channels will exit from the main output m2. Any channels entering the main input on these two wavelengths will experience the same hologram deflection, and will then exit from output d2.

[0423] In one implementation of the multiwavelength architecture the optics between any input fibre and the corresponding input beam that arrives at the diffraction grating, is such that the beam spot that arrives at the SLM is an image of the beam spot that leaves the input fibre. Similarly the optics between any output beam and the corresponding output fibre is such that the beam spot that arrives at the output fibre is an image of the beam spot that leaves the SLM. An example embodiment that would achieve this behaviour is to have an individual collimating lens associated with and aligned to every optical fibre.

[0424] Referring to FIG. 27, it is assumed that two adjacent channels are being routed in a different direction to the channel under consideration. Thus the beam under consideration has a first hologram 500, and the two adjacent beams have contiguous holograms 501 and 502 respectively. The beam under consideration has an intensity distribution shown as 510. Hence the energy incident from the beam under consideration on the two adjacent holograms, shown as 511 and 512, is lost. Given a perfect optical system what arrives at the selected output fibre is a demagnified image of the truncated beam. Due to the way that the optical system works, the centre line of the beam incident at the output fibre will be lined up with the centre of the output fibre (indeed the beam deflection angle at the SLM should be adjusted so this is the case).

[0425] To each wavelength channel there is assigned a block of pixels applying the same routing hologram. Preferably this block of pixels should be chosen such that an input light beam exactly at the centre wavelength for the channel arrives at the SLM such that the centre of the beam is within a half pixel's width of the centre of the assigned pixel block. In the presence of thermal expansion of the optomechanical assembly the centre of said beam may arrive at a different point on the pixel block resulting in partial loss of signal as more of the beam tails are lost. This problem can be avoided either by expensive thermally stable optomechanics or by dynamic reassignment of pixels to the blocks associated with each channel. For this to be achievable the pixel array should be continuous. This continuity of the pixel array is advantageous for thermal stability whether or not the imaging criterion used to calculate the filter response is satisfied.

[0426] The way that the architecture behaves is that for all parallel beams incident on the grating, the position at which the beam at a particular wavelength reaches the SLM is independent of the input port. Hence a reference signal of known wavelength will be incident at the same particular point on the SLM, whether it comes in with any of the signals to be routed, or on a separate input. The method to measure the position of the beam centre can be used on one or a pair of such reference signals. Given this information, an interpolation method can be used to measure the wavelength of some other signal entering the system on one of its input ports, given the measurement of the position of the centre of the beam associated with said other signal. This information can be used to monitor the behaviour of the original transmitter lasers, and also to inform the controller for the routing system.

[0427] Furthermore, given the position of said reference beams as they reach the SLM, and also the centre wavelength(s) of (an)other signal(s) entering the system, the position of the beam(s) at said centre wavelength(s) upon the SLM may also be calculated. This information can be used to control the adjustment of the pixel blocks and/or holograms used to route and control said other signal(s). Conversely the position of said reference beams may be used to select a pixel block that provides a given required centre wavelength for a filter. Hence reconfigurable assignment of pixel blocks may be used to tune the centre wavelength of one or more filter pass bands.

[0428] For the purpose of calculating the wavelength filtering response it is assumed that the centre of the beam at the centre wavelength of the channel (shown as 500 in FIG. 27) arrives exactly at the centre of the associated pixel block. With reference to FIG. 31, as the wavelength is increased above the centre wavelength of the channel the centre line 946 of the beam 940 lands at a distance 941 away from the centre 945 of the pixel block or hologram 942. As a result of the offset 941 due to wavelength difference, the beam loses more energy 943 to the adjacent hologram 944. Assuming perfect imaging, what arrives at the output fibre is a demagnified image of this truncated beam.

[0429] An important difference for the multi-wavelength architecture, compared to conventional wavelength demultiplexers, is that a wavelength difference from the centre of a wavelength channel does not (to first order) result in an offset error of the beam at the output. This is because of the way the second pass from the grating 'undoes' the dispersion of the (fixed) diffraction grating, as was shown, for example, in FIG. 12. Hence the original centre line of the truncated beam should be aligned with the peak of the fundamental mode in the output fibre, or, equivalently, aligned with the optical axis of the output fibre. Standard methods for the calculation of coupling efficiency into single-mode fibres have been used to calculate the filter characteristics. Example results are in FIGS. 19 and 20.

[0430] FIG. 19 shows the relative transmission Tlo for in-band wavelengths as a function of the ratio of the wavelength offset u to centre of the wavelength channel separation. Each curve in the Figure is for a different value of the hologram clipping factor (CR) in the range 2 to 4: this factor is defined as the ratio of the hologram width to the beam spot size at the hologram.

[0431] FIG. 20 shows the relative transmission Thi inside the adjacent channel, with u=1 at the centre of the adjacent channel while u-0.5 is at the boundary with the adjacent channel. Again, each curve in the Figure is for a different value of the hologram clipping factor (CR) in the range 2 to 4. FIGS. 19 and 20 also show that a change in the width of the pixel block assigned to the filter passband (that is a change in CR) will change the passband width and extinction rate at the edges of the passband. Hence reconfigurable assignment of pixel blocks may be used to tune the shape and width of the filter pass bands.

[0432] Independently of the clipping factor, the suppression at the edges of the wavelength channel is 6 dB and the full width half maximum (FWHM) filter bandwidth is approximately 80% of the channel separation. Comparison of the different curves in FIG. 19 shows that the flatter the filter passband the steeper the skirts at the edges, leading to greater extinction of the adjacent channel, as shown in FIG. 20.

[0433] This behaviour is advantageous as it avoids the usual tradeoff between adjacent channel extinction and centre flatness. Good centre flatness means that the filters concatenate better, so more routing nodes using such filters can be traversed by a signal before the signal spectrum and hence fidelity starts to deteriorate. Good adjacent channel extinction is also important as it prevents excessive accumulation of crosstalk corrupting the signal.

[0434] For example, in a known conventional wavelength demultiplexer the filter pass bands are Gaussian and the 1 dB and 3 dB filter bandwidths are inversely proportional to the square root of the adjacent channel extinction (in dB), such that the greater the extinction, the narrower the filter passband. For the same FWHM filter bandwidth of 80% a Gaussian filter would have an adjacent channel extinction weaker than 20 dB, leading to crosstalk problems. However for the SLM multi-wavelength architecture the adjacent channel extinction is better than 30 dB, avoiding such problems in most known networks.

[0435] As is well-known to those skilled in the art, an arbitrary beam incident on an optical fibre couples partially into the fundamental mode of the fibre with the rest of the beam energy coupling into a superposition of the higher order modes of the fibre. The higher order modes may be stripped out with a fibre mode stripper. The coupling efficiency into the fundamental mode is given by the modulus squared of the ratio of an overlap integral divided by a normalisation integral. The overlap integrand is the product of the incident field and the fundamental mode. The normalisation integrand is the product of the fundamental mode with itself.

[0436] FIGS. 33 and 34 are included with the aim of explaining the behaviour of the 'imaging filter' as described above. FIG. 32 shows the truncated incident beam profiles 960-964 as the wavelength is increased from the centre of the channel under consideration, 960, to the centre of the adjacent channel, 964. Truncated beams 961, 962 and 963 are for wavelength differences of a quarter, a half and three-quarters, respectively, of the channel separation. In the diagram the truncated beam profiles are offset vertically for clarity. The beam profiles are aligned horizontally as they would be physically at the output fibre; the original centre of each truncated beam is aligned with the centre of the fibre fundamental mode. This is because, as explained above, a wavelength difference from the centre of a wavelength channel does not (to first order) result in an offset error at the output. Beam 965 is the fundamental mode of the fibre. FIG. 33 shows the overlap integrands 970-974 of the truncated incident beams with the fundamental mode of the fibre, as the wavelength is increased from the centre of the channel under consideration, 970, to the centre of the adjacent channel, 974. The normalisation integrand, 975, is also shown. The results in the figures show that the overlap integrand 974 has almost vanished explaining why the adjacent channel extinction is very strong. Overlap integrands 971 and 972 are for wavelength differences of a quarter and a half, respectively, of the channel separation.

* These results explain why the overlap integrand decreases slowly with wavelength difference in this range leading to a flat passband centre. In particular for the halfway case, 972, the overlap integral is exactly half of the normalisation integral (from integrating 975). Hence the amplitude transmission coefficient at this wavelength difference is a half with a power extinction of 6 dB, as was shown in FIG. 19. Therefore two factors are responsible for the excellent filter characteristics. The first factor is that the field incident on the fibre is an image of the field reflected from the SLM. The second factor is that the second pass from the grating undoes the dispersion applied by the first pass from the grating, such that whatever the wavelength offset inside the

collected channel, (to first order), the peak of the reflected truncated beam is aligned with the peak of the fundamental mode of the fibre.

[0437] By way of comparison, FIGS. 34 and 35 illustrate the filtering process for a conventional wavelength demultiplexer. In FIG. 34 the centre of a first beam 984 is aligned with the optical axis 980 of the centre of a first optical fibre or optical waveguide 981. Hence the first beam 984 is at the centre wavelength of the channel collected by the first optical fibre 981. A second optical fibre 9B3, adjacent to the first fibre 981, has an optical axis 982. A second beam 988 is aligned with the optical axis 982 of this second optical fibre. Hence the second beam is at the centre wavelength of the channel collected by the second optical fibre, that is at the centre of the adjacent optical channel to that collected by the first fibre. Beams 985 to 987 are at wavelength differences from the first beam 984 of a quarter, a half, and three-quarters, respectively, of the wavelength separation between the two adjacent channels. The coupling efficiency of each of the beams 985 to 988 into the first optical fibre 981 again depends on the overlap integral of the respective beam with the fundamental mode of the fibre 981. This is mathematically identical to the overlap integral of the respective beam with the first beam 984.

[0438] FIG. 35 shows the overlap integrands 994 to 998 plotted against a vertical axis 990. The spatial width and shape of each curve is identical, as may be shown analytically. Hence the overlap integrand is proportional to the amplitude of the curve, as may be read from the axis 990. Curve 994 is the overlap integrand at the centre of the channel, and is the product of the distribution 984 of FIG. 34 with itself. This curve has an amplitude of 1.0 and hence maximal coupling efficiency. Curves 995 to 997 are the overlap integrands at wavelength differences from the channel centre of a quarter, a half, and three-quarters, respectively, of the wavelength separation between the two adjacent channels. Curve 998 is the overlap integrand at the centre of the adjacent wavelength channel. The coupling efficiency is given by the square of the amplitude of the overlap integrand. The results in FIG. 35 show that the coupling efficiency for the conventional wavelength demultiplexer decreases more quickly around the centre of the filter passband than for the 'imaging' filter discussed in this application. The results also show that the adjacent channel extinction is weaker for the conventional demultiplexer.

[0439] FIGS. 34 and 35 also explain why there is a performance tradeoff for the conventional multiplexer between filter passband flatness and adjacent channel extinction: to increase the width of the filter passband the beams 9B5-986 must be incident closer to the first optical fibre 981. Necessarily the beams 987-988 will also be closer to the first optical fibre, reducing the extinction of the adjacent channel, and requiring the second optical fibre 983 to be moved closer to the first fibre 981.

[0440] FIGS. 32 and 33 explain why the imaging filter behaves in a different way, such that a broader filter passband is associated with a greater extinction of the adjacent channel. Beam 960 in FIG. 32 shows the truncated reflected beam at the centre of the filter passband. The first and second amplitude discontinuities 966a, 966b are due to the two edges of the hologram. An increase in the hologram width relative to the spot size moves these two discontinuities outwards. The significant amplitude discontinuity in the middle beam 962 is exactly at the centre of said beam, whatever the hologram width. This is because said middle beam is associated with a wavelength halfway between the centres of adjacent channels. Hence the coupling efficiency for this halfway point is 6 dB, independently of the hologram width. The significant amplitude discontinuity in the quarterway beam, 961, is exactly halfway between the first amplitude discontinuity, 966a of the centre beam 960 and the significant amplitude discontinuity in the halfway beam, 962. As the first discontinuity 966a moves outwards due to an increased hologram width (in the direction of arrow 967) the significant discontinuity in the quarterway beam must move in the same direction, increasing the overlap integral and improving the filter passband centre flatness. Similarly as the second discontinuity 966b moves outwards (in the direction of arrow 968) the significant discontinuities in the three-quarter way beam 963 and adjacent beam 964 must move in the direction of arrow 968, decreasing the overlap integral and improving the adjacent channel extinction. This explanation reinforces the argument that the two factors described above (imaging and the second 'undoing' pass from the grating) are responsible for the excellent filter characteristics. This explanation also explains how the selection of the width of the block of pixels assigned to a channel may control the filter passband characteristics.

[0441] Analytically it can be shown that the filter response for dropping or adding an isolated channel is purely real. Hence there are no phase distortions with this type of dropping filter. This is advantageous because in many 'flat-top' filters the phase distortions associated with the steep skirts may distort the pulses, particularly in higher bit-rate transmission systems for which the signal bandwidth is broader.

[0442] In these calculations it was assumed that the blocks of pixels assigned to each wavelength channel are contiguous. That is there are no 'guard bands' of pixels between each block. Further analysis showed that introducing such guard bands has the effect of decreasing the channel bandwidth for a given channel separation. Hence, preferably the pixel blocks assigned to each wavelength channel should be contiguous. Alternatively guard bands can be used to route in a third direction to deliberately narrow a channel bandwidth, if required.

[0443] While the above discussion is for the case of an isolated channel, in which both adjacent channels are routed in a different direction to the channel under consideration, there are also filtering effects that can occur when one or both adjacent channels are routed in the same direction. These effects are caused by 'stitching errors' at the adjacent edges of a pair of holograms routing in the same direction. For example a stitching error of pi causes (in theory) complete extinction of a light beam at a wavelength exactly halfway between the centres of two adjacent channels, while for an absence of stitching error at either side of a hologram, the transmission is uniform right across the entire channel. Intermediate stitching errors cause intermediate extinction. This acts as an additional programmable filtering mechanism and can be used to advantage to partially or completely filter out amplifier noise between selected channels, if required. Alternatively when maximally flat passbands are required the stitching error should be minimised.

[0444] As described previously, all channels entering the architecture at the same wavelength are incident on the same hologram. This is because the input beams are arranged to be parallel as they arrive at the diffraction grating, such that all channels at the same wavelength emerge parallel from the diffraction grating. As the diffraction grating is at the focal plane of the lens the beams therefore converge towards the same point in the other focal plane of the routing lens (or equivalent mirror) at which point the SLM is placed.

[0445] Hence for the four port and multiport add/drop devices the channels entering on the main beam (from the main input fibre) share a hologram with those channels at the same wavelength entering on an add port. When configured with one particular routing hologram the channel entering the main input is routed to the (selected) drop port while the channel entering the add port is routed to the main output. Therefore any channel equalisation applied to an added channel will also be unavoidably applied to the dropped channel. Hence it is not possible to carry out independent channel equalisation on added and dropped channels.

[0446] This problem does not occur, however, for the devices with a single input and/or with a single output. This is because in these devices there is no sharing of individual holograms between channels entering or leaving on different ports. Nor does the problem occur for the devices with multiple inputs and multiple outputs, for channels routed from the main input to the main output.

[0447] Another configuration of the multi-wavelength architecture is to have a single input port and a separate output port for every wavelength channel and SLM devices for each channel capable of providing a set of many deflections. When configured so that a single channel leaves on each output port, the device acts as a reconfigurable demultiplexer such that the assignment of a particular wavelength to each output port can be changed dynamically.

[0448] Conventional wavelength demultiplexers are not reconfigurable and are therefore less flexible as a routing component. They also have a Gaussian filtering characteristic, which is inferior to the filter characteristic of the SLM multiwavelength optical processor, as described earlier. A further advantage of the invention, compared to a conventional free-space wavelength demultiplexer, is that the channel filter bandwidth is independent of the physical separation between the output fibres and also independent of the spot size of the output fibre. In contrast, for the conventional demultiplexer, the channel bandwidth is proportional to the ratio of the output waveguide spot size to the physical separation of the output waveguides. Consequently, and in order to obtain sufficient channel bandwidth, microlens arrays are required to increase the effective spot size or waveguide concentrators are used to decrease the waveguide separation.

[0449] When used in reverse the device acts as a reconfigurable multiplexer, allowing the use of, for example, tuneable lasers at each input. In contrast, for a conventional wavelength multiplexer, fixed-tuned lasers must be used at each input.

[0450] A system with a single input port and many output ports can act as a module to form part of a modular routing node. If the system has M output ports and a single input port, then each routing device produces M different deflections, with small adjustments to compensate for wavelength differences and alignment tolerances. All devices (i.e. holograms) producing the same eventual deflection will cause the associated wavelength channel to be routed out of the same output port. Hence such a system can send none, one or many (up to the number of channels entering the input port) channels out from the same output port. The logical function of the module is to sort the incoming channels on the input port according to their required output port, as also illustrated in FIG. 21. Considering firstly the case of the routing architecture shown in FIG. 12. As there is a single input port, every wavelength channel has its own hologram. Hence independent channel equalisation may be applied for all the signals flowing through the module.

[0451] One application of these modules is to use two of them to make an add/drop node, as shown in FIG. 22. FIG. 22 shows a first routing module 660 having one input 661 from a previous node, a through output 662 and three drop outputs 663-5, as well as two spare outputs 666,667. A second routing module 670 has a first input 671 connected to the through output 662 of the first module, three add inputs 672-4 and two spare inputs 675,676. The second module 670 has an output 677 to the next node. The second (output) module can be physically identical to the first (input) module but it is used 'in reverse'.

[0452] The first module routes all the through traffic out on a common through port 662 while providing multiple drop ports: one for each dropped channel. Any single wavelength or any set of wavelengths can be sent to any drop port. Hence each of the drop ports may connect to a local optoelectronic receiver in a local electronic switch, or to a remote customer requiring one or more channels for remote demultiplexing. The reconfigurability of the wavelength assignment means that the module acts like a wavelength demultiplexer combined with a matrix switching function, so may reduce the switching demands placed on the electronics servicing the drop ports. The ability to send a selectable set of wavelengths to the same port reduces the need for additional fibre/multiplexing components and increases flexibility. Furthermore the routing applied to each wavelength channel may be multicast, as well as unicast. Hence drop and continue operation may be provided in which the signal is routed to a drop port and also to the through port. If a transparent optical connection is required through to access and distribution networks this multicasting may also be applied to broadcast signals to a number of drop fibres. In this multicasting operation one or more of the previously described power control methods may be applied to equalise the channels on the through and drop fibres, as required for the transmission systems and receivers to function correctly.

[0453] The first module provides any channel equalisation and monitoring required for the drop ports. Channel equalisation and monitoring for the through channels may take place in the first module, or the second module, or both.

[0454] The second module provides multiple add ports: one for each added channel. Any single wavelength or any set of wavelengths can be received at any of the input ports. This allows each of the add inputs to be a tuneable laser, which would not be possible with a conventional non-reconfigurable wavelength multiplexer. In the conventional case there are two options for providing the added channels. A first option is to use conventional non-reconfigurable wavelength multiplexing to combine the added channels, because this is much more efficient in terms of insertion loss than a non-wavelength-specific multiplexer (such as a 1:N fibre splitter used in reverse, that is a N:1 combiner). However this requires each input port of the wavelength multiplexer to have a transmitter laser at a fixed wavelength. When a particular wavelength channel is added at the node the associated transmitter is in use. However when the network reconfigures its wavelength assignment that laser may no longer be in use. To allow complete reconfigurability a complete set of transmitter lasers must be provided, one for each system wavelength. This makes reconfigurable add drop nodes uneconomic when adding small numbers of channels, due to the large overhead of idle transmitter lasers. A second option is to use tuneable lasers, one for each added channel. With conventional optics this requires a non-wavelength-specific multiplexer, which imposes insertion loss penalties. The multi-wavelength architecture described provides a reconfigurable wavelength multiplexer with lower insertion loss than a N:1 combiner. Furthermore the routing applied to each wavelength channel can be reconfigured without transient effects on other wavelength channels, as occurs in 'serial' multiplexing architectures that have a reconfiguration capability.

[0455] Any add port can receive a reconfigurable set of wavelength channels from a remote customer. The second module also provides any channel equalisation required for the added signals. Finally the second module routes the through channels entering on the port 671 to the output 677.

[0456] The spare ports 666,667,675,676 can be used for routing selected channels to optical regenerators if the signal quality demands it; to wavelength converters to avoid wavelength blocking; to another add/drop node to allow cross-connection between rings, as shown in FIG. 23, or to further modules to allow expansion, as shown in FIG. 24.

[0457] FIG. 23 shows a first to fourth routing modules 720, 730, 740 and 750. The first and fourth modules each have one input 721, 751, a through output 722, 752, a cross-connect output 723,753 and a number of drop outputs721, 754. The second and third modules 730,740 each have respective single output 731,741, a number of add inputs 732,742 a cross-connect input 733,743 and a through input 734, 744. The through output 722 of the first module 720 is connected to the through input 734 of the second module 730, and the through output 752 of the fourth module 750 is connected to the through input 744 of the third module 740. The cross-connect output 723 of the first module 720 is connected to the cross-connect input 743 of the third module 740, and the cross-connect output 753 of the fourth module 750 is connected to the cross-connect input 733 of the second module 730.

[0458] The first and second modules 720, 730 are on one ring and the third and fourth 740, 750 on a second ring. This cross connection capability allows a new ring network to be overlaid on an original ring network when the original ring capacity is becoming exhausted. Channels may be exchanged between the two rings at each node as required. Hence the ring network acts like a ring with two fibres per link (in each direction around the ring). The concept may be extended to three or more overlaid rings, and hence three or more fibres per link (in each direction around the ring). As is well known from many traffic studies, increasing the number of fibres per link reduces significantly a phenomenon known as wavelength blocking, such that more efficient use is made of the capacity of each fibre. Hence cross connection between rings makes better use of the available capacity, allowing more traffic to be carried for the same investment in infrastructure. Cross connection may also be used to exchange signals between diverging rings.

[0459] FIG. 24 shows expansion of a first (input) module 760 having a single input 761, and five outputs 762-6,via an optical amplifier 768 and an intermediate module 770 having four outputs 771-4. The first output 762 of the first module 760 is a through path, the third output 764 is an expansion port and provides an input to the optical amplifier 768, and the output 769 of the optical amplifier is to the intermediate module 770. The intermediate module 770 has an expansion port 771 and three new ports 772-4. Fourth and fifth outputs 765, 766 of the input module 760 form drop outputs. The same principle can also be applied to expansion of a second (output) module. The use of such modules allows extra add and drop ports to be provided without service interruption to the channels flowing through the add drop node. It also allows network operators to apply just in time provisioning, delaying investment in infrastructure until the demand is there to use it. Furthermore it is only the channels dropped or added through the expansion module(s) that are subject to an additional amplification stage. If every node in the ring were upgraded in this manner, the channels should only pass through an additional two amplification stages. This could be reduced to one additional stage by suitable assignment of the added and dropped channels to the original and expansion module.

[0460] Returning to the basic routing module shown in FIG. 21. This type of connectivity would be useful in mesh networks where each node is connected by a multi-fibre link to, typically, each of between two and five nearest neighbour nodes. Each link carries traffic to and from one of the nearest neighbour nodes. Usually individual fibres in the link carry traffic in just one direction but some are bi-directional. For an example where a link has an average of six pairs of external fibres and a node has five links, then there would be thirty external incoming fibres and thirty external outgoing fibres. The function of the node is to route any wavelength channel from any incoming fibre to any outgoing fibre. Each fibre may carry many wavelength channels. Currently up to 160 channel systems are being installed although 40 or 80 channel systems are more usual.

[0461] An ideal node architecture allows the network operator to start with one or more add/drop nodes connected to one or more rings and then allow the individual add/drop nodes to be connected so that the network topology can evolve towards a mesh. The node architecture should also allow extra fibres to be added to each link as required to meet the demand, with the extra parts or modules of the node being installed as and when required. Fibre management and installation between sub-components inside the routing node is also expensive.

[0462] A known architecture for such a routing node uses a separate wavelength demultiplexer for every input fibre. The separated wavelength channels are then carried over optical fibres to N*N optical switches. To avoid internal wavelength blocking then all channels at a particular wavelength must be connected to the same N*N switch. Hence the switch will receive channels at the same wavelength from every single input fibre. The channels leaving the switch are carried over optical fibres to a separate wavelength multiplexer for every output fibre. Hence the switch will route channels at the same wavelength towards every single output fibre.

[0463] These switches have a sufficient number of ports for added and dropped channels, and channels passing to and from wavelength conversion and optical regeneration. This sufficient number is estimated based on traffic analysis as it depends on the instantaneous mapping of channels between nodes and the wavelength and fibre allocation. Each switch may service one or more wavelength channels. In one device, the number of fibres is around b 3000 resulting in significant fibre management and installation costs. Even grouping together different fibres to or from the same link and grouping together the add fibres and regenerator fibres only reduces the number of separate entities to be managed to 560.

[0464] With such a large number of fibres it is not economic to provide optical amplifiers inside the routing node to compensate for insertion losses. Another problem with this architecture is how to add in extra external fibres once the switch capacity has been exhausted with the current number of external fibres. This cannot be done without replacing every single switch. In advance it is difficult to know how large to provision the switch to avoid or delay this problem.

[0465] An alternative node architecture uses one of the multi-wavelength architectures described to provide a separate module for every input fibre and a separate module for every output fibre. Consider first an input module. This should be designed so that none, one, many or all of the input channels may leave any of the output ports (as shown in FIG. 21). These output ports are used to carry channels towards output modules and towards other parts of the node providing wavelength conversion, regeneration and ports to electronic switches, for example. A connection between an input module and an output module carries every wavelength channel mapped between the corresponding input and output fibre. Hence the logical function of an input module is to sort the incoming channels according to their destination output fibre. This logical functionality was illustrated in FIG. 21.

[0466] A particular input module does not have connections to every output module. It does not have connections to output modules going back to the same neighbouring node from which the input channels have travelled, except perhaps for network monitoring and management functions. It might not need to have separate connections to every output module for the output fibres to the other neighbouring nodes. It is however provided with sufficient connectivity to the output channels on every output link to avoid unacceptable levels of wavelength blocking. For example each input module could be connected to a subset of the output modules, with an overflow system used to provide a connection to the other output modules, when required. An output module is designed like an input module but works in the opposite direction. Hence the logical function of the output module is to collect the channels coming from each input module and direct them to a common output port.

[0467] In this architecture, the dropped channels and channels needing wavelength conversion may exit from each module on a common port or a pair of ports. As a result of using the modules it can be shown that satisfactory performance is achieved using fewer than 1000 fibres and fewer than 50 fibre groups.

[0468] Hence the total number of fibres inside the node is reduced by a factor of over 3 while the total number of fibre entities to be installed and managed is reduced by a factor of 10 or more. This represents a significant reduction in cost and complexity.

[0469] An example wavelength-routing crossconnect using the modules is shown in FIG. 25. FIG. 25 shows four input routing modules 790-3, each with a respective input 790i-793i and four outputs 79001-79003 etc. and four output routing modules 794-7 each with four inputs and a respective single output 794o-797o to a respective output fibre. One output of each input module 790-3 forms a drop output. The input and output modules are associated together with input module 790 associated with output module 794, input module 791 associated with output module 795, input module 792 associated with output module 796 and input module 793 associated with output module 797. The remaining three outputs of each input module are cross-connected to the non associated output modules, so that for example the three non-drop outputs of input module 790 are coupled to respective inputs of output modules 795, 796 and 797. Specifically, output 79001 is connected to output module 795. Of the inputs to the four output modules, one per module is an add input and the remainder are connected to outputs of the input modules 790-3.

[0470] In the example the routing function carried out by each input module 790-3 is to sort the incoming channels with respect to the selected output fibre 794o-797o for example, and with reference to the figure, all wavelength channels entering the cross-connect on input 790i that need to leave the cross-connect on 795o are routed by the input module 790 to the output 79001. This output carries these channels to the output module 795 which is collecting frequency channels for output 795o. The output module combines all incoming channels onto a respective single. output.

[0471] In this architecture channel equalisation may be carried out independently for all channels routed through the cross connect.

[0472] The cross connect architecture of FIG. 25 is modular in that it can be used to build a range of nodes of different connectivity and dimension. The modules can be used to assemble a node like that described above, starting with only 1 or 2 fibre pairs per link and adding in extra modules to allow more fibres per link. Extra modules can be added in and connected up as and when required, allowing the network operator to delay investment in infrastructure for as long as possible. When the node has reached, for example, 6 fibre pairs per link and the capacity begins to be exhausted there are three ways to upgrade the node. The first way is to upgrade the numbers of wavelength channels on particular fibres in each link. This requires replacing the associated modules with modules processing more channels. However the other modules (and the fibre interconnections) can remain in service. In contrast for the conventional architecture as well as upgrading the demultiplexers and multiplexers associated with the particular fibres to be upgraded, a whole set of N*N switches must be installed, one for every new system wavelength. These switches will remain under-utilised until all the fibre systems have been upgraded.

[0473] A second way to upgrade the node is to replace selected modules with models providing an increased number of fibre choices per output link allowing more fibres per link. This requires the installation of more fibre groups inside the node. In contrast for the conventional architecture every N*N switch must be replaced meaning the associated system wavelengths would be out of service on every fibre entering or leaving the node.

[0474] A third way to upgrade the node is to upgrade selected modules by cascading another module from a spare, or expansion output port, as shown in FIG. 26.

[0475] FIG. 26 shows a somewhat similar arrangement to FIG. 24, and has an input module 860, with an input 861, five outputs 862-6, an optical amplifier 870 and an intermediate module 880 receiving the output of the optical amplifier 870 and providing four outputs 881-4. The input module has three outputs 862-4 to existing output modules, fourth output 865 to the optical amplifier 870 and fifth output as a drop output. The first to third outputs 881-3 of the intermediate module 880 connect to new or later output modules.

[0476] The advantage of this third way is that service interruption is not required during installation.

[0477] The smallest node can have as few as two modules, which would act as an add/drop node. Several pairs of such modules can service a stacked set of rings, allowing interconnection between different rings. Adjacent rings can also be interconnected. A hybrid ring/mesh network can be created. Hence the same modular system can be used for ring networks, mesh networks and mixes of the two. It can also allow re-use of existing plant and allow an add/drop node to grow and evolve into a wavelength-routing cross-connect.

[0478] It will be clear to those skilled in the art that the use of reflective SLMs may allow optical folding to be accomplished and provide a compact system. Thus folding mirrors which may be found in some systems are replaced by SLMs that serve the dual function of folding and performance management for the system. The performance management may include managing direction change, focus correction, correction of non-focus aberration, power control and sampling. When taken together with the controller and sensors, the SLM can then act as an intelligent mirror.

[0479] As an example, this application of SLMs would be attractive in the context of free-space wavelength demultiplexers as it would help to suppress the problems associated with long path lengths.

[0480] Another example is to provide correction for alignment tolerances and manufacturing tolerances in systems requiring alignment between fibre arrays and lens arrays. In particular focal length errors in the lenses (due to chromatic aberration or manufacturing tolerance) can be compensated by focus correction at the SLM or SLMs, while transverse misalignment between a fibre and lens which leads to an error in the beam direction after the lens, can be compensated by beam deflection at the SLM or

SLMs.

[0481] It will also be clear to those skilled in the art that although the described embodiments refer to routing in the context of one-to-one, it would also be possible to devise holograms for multicast and broadcast, i.e. one-to-many and one-to-all, if desired.

[0482] Although the invention has been described with reference to a number of embodiments, it will be understood that the invention is not limited to the described details. The skilled artisan will be aware that many alternatives may be employed within the general concepts of the invention as defined in the appended claims.

Electronic Patent Application Fee Transmittal

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First Named Inventor/Applicant Name:	Melanie Holmes
Filer:	Timothy J. Meagher/Julie Kertyzak
Attorney Docket Number:	3274.1003-004

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility application filing	1011	1	330	330
Utility Search Fee	1111	1	540	540
Utility Examination Fee	1311	1	220	220
Pages:				
Utility Appl Size fee per 50 sheets >100	1081	1	270	270
Claims:				
Claims in excess of 20	1202	10	52	520
Independent claims in excess of 3	1201	5	220	1100

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous-Filing:				
Late filing fee for oath or declaration	1051	1	130	130
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**3110**

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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Applicant Response to Pre-Exam Formalities Notice	32741003004replymissparts.pdf	83959 56347d78ea3243e034b8b5c28fe4eb7bac4e3492	no	2
Warnings:					
Information:					
2	Transmittal Letter	32741003004feetrans.pdf	135308 580d13bab2eb5f336f889a2b9644721b09b50e73	no	1
Warnings:					
Information:					
3	Oath or Declaration filed	32741003004dec.pdf	78056 55c69cda53a1222d186d5e36a64d01d335064e9e	no	2
Warnings:					
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4	Power of Attorney	32741003004poa.pdf	58178 3ed0328f8a170e8e2bab98c1e201d01140b6183b	no	1
Warnings:					
Information:					
5	Assignee showing of ownership per 37 CFR 3.73(b).	32741003004373b.pdf	154649 78db680e1cd20e7383534a47c5898adb8af695e2	no	3
Warnings:					
Information:					
6	Transmittal Letter	32741003004trans.pdf	45458 81bd05a895247faeca247a9011196c9e1eee1999	no	2
Warnings:					
Information:					
7	Specification	32741003004subspec.pdf	4088349 215860ad1dfe3138c3ef25e3988db5b6255d487b	no	97
Warnings:					
Information:					
8	Fee Worksheet (PTO-875)	fee-info.pdf	41322 9cce644b8fc4497f9f1a2ccaf22cbdcd04472e1a	no	2
Warnings:					
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		Total Files Size (in bytes):	4685279		

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

FEE TRANSMITTAL FOR PATENT APPLICATIONS

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First Named Inventor	Melanie Holmes

CLAIM CALCULATION (includes any preliminary amendment)

CLAIMS	(1) FOR	(2) NUMBER FILED		(3) NUMBER EXTRA	(4) RATE			(5) CALCULATIONS
	TOTAL CLAIMS (37 CFR 1.16(c) or (j))	30	− 20 =	10	X $ 52 =	X $ 26 =	$	520
	INDEPENDENT CLAIMS (37 CFR 1.16(b) or (i))	8	− 3 =	5	X$220 =	X $110 =	$	1100
	MULTIPLE DEPENDENT CLAIMS (if applicable) (37 CFR 1.16(d))				+ $390 =	+ $195 =	$	
				BASIC FEE (37 CFR1.16(a)(1)) Paper or Electronic Filing - Large Entity; Paper Filing - Small Entity; Electronic filing - Small Entity			$	330
	APPLICATION SIZE FEE $270/135 for each add'l 50 sheets exceeding 100 **IF FILED ELECTRONICALLY:** Total No. Pages/Sheets X .75 (If a fraction remains, add 1 page to the total thereby including the fraction). Using the total after calculation, the fee is $270/135 for each additional 50 sheets over 100.			Specification: 104 Pages; Drawings: 36 Sheets; Sequence Listing: 0 pages; Total No. Pages/Sheets **140**			$	270
				SEARCH FEE (37 CFR 1.16(k))			$	540
				EXAMINATION FEE (37 CFR 1.16(o))			$	220
	Surcharge - Late Filing of Declaration or Filing Fees (37 CFR 1.16(f)) =						$	130
	Petition for Extension of Time Fee (37 CFR 1.17) =						$	
	[Other]						$	
	Assignment Recordation Fee (37 CFR 1.21(h)) = (only when filed with application)						$	
	TOTAL =						$	3110

1. Small entity status:
   - a. ☐ A small entity statement is enclosed.
   - b. ☐ A small entity statement was filed in the prior non-provisional application and such status is still proper and desired.
   - c. ☐ Is no longer claimed.
2. ☒ Please charge any deficiency or credit any overpayment in the fees that may be due in this matter to Deposit Account No. 08-0380.
3. ☐ A check is enclosed for **$[ ]**. ☒ Please charge **$3110** to Deposit Account No. 08-0380.
4. ☐ Other:

Signature	[signature]	Date	5/5/10
Submitted by Typed or Printed Name	Timothy J. Meagher	Reg. Number	39,302

980906_1 – September 15, 2008

TS0002292

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
12/710,913	02/23/2010	2872	3110	3274.1003-004	30	8

CONFIRMATION NO. 9661

21005
HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

UPDATED FILING RECEIPT

OC000000041586018

Date Mailed: 05/13/2010

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Melanie Holmes, Suffolk, UNITED KINGDOM;

Assignment For Published Patent Application

Thomas Swan & Co. Ltd.

Power of Attorney: The patent practitioners associated with Customer Number 021005

Domestic Priority data as claimed by applicant

This application is a CON of 11/978,258 10/29/2007
which is a CON of 11/515,389 09/01/2006 PAT 7,612,930
which is a DIV of 10/487,810 09/10/2004 PAT 7,145,710
which is a 371 of PCT/GB02/04011 09/02/2002

Foreign Applications

UNITED KINGDOM 0121308.1 09/03/2001

Request to Retrieve - This application either claims priority to one or more applications filed in an intellectual property Office that participates in the Priority Document Exchange (PDX) program or contains a proper **Request to Retrieve Electronic Priority Application(s)** (PTO/SB/38 or its equivalent). Consequently, the USPTO will attempt to electronically retrieve these priority documents.

If Required, Foreign Filing License Granted: 03/04/2010

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/710,913**

Projected Publication Date: 08/19/2010

Non-Publication Request: No

TS0002293

Early Publication Request: No
Title

OPTICAL PROCESSING

Preliminary Class

359

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004

CONFIRMATION NO. 9661

POA ACCEPTANCE LETTER

OC000000041585933

21005
HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

Date Mailed: 05/13/2010

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 05/05/2010.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/lvongxay/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2872
Filed:	February 23, 2010	Examiner:	Unknown
Confirmation No:	9661		
For:	Optical Processing		

PRELIMINARY AMENDMENT

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Please amend the application as follows:

Amendments to the Specification

Please replace the paragraph at page 1, lines 1 through 9, entitled "RELATED APPLICATIONS" with the following amended paragraph:

This application is a continuation of U.S. Application No. 11/978,258, filed October 29, 2007, which is a continuation of U.S. Application No. 11/515,389, filed September 1, 2006, now issued Patent 7,612,930, which is a divisional of U.S. Application No. 10/487,810, now issued Patent 7,145,710, which is the U.S. National Stage of International Application No. PCT/GB02/04011, filed September 2, 2002, and published in English. This application claims priority under 35 U.S.C. § 119 or 365 to Great Britain Application No. 0121308.1, filed September 3, 2001. The entire teachings of the above application(s) are incorporated herein by reference.

Please replace the paragraph at page 4, lines 25 through 29, through page 5, lines 1 and 2, with the following amended paragraph:

[0022] Clearly in most situations more than one of these control types will be needed-for example in a routing device (such as a switch, filter or add/drop multiplexer) primary changes of direction are likely to be needed to cope with changes of routing as part of the main system but secondary correction will be needed to cope with effects such as temperature and ageing. Additionally, such systems may also need to control power, and to allow sampling (both of which may in some cases be achieved by direction changes).

Please replace the paragraph at page 6, lines 19 through 26, with the following amended paragraph:

[0040] According to a second aspect of the invention, there is provided an optical device comprising an SLM and a control circuit, the SLM having a two-dimensional array of controllable phase-modulating elements and the control circuit having a store constructed and arranged to hold plural items of control data, the control circuit being constructed and arranged to delineate groups of individual phase-modulating elements, to select, from stored control data, control data for each group of phase-modulating elements, and to generate from the respective selected control data a respective hologram at each group of phase-modulating elements, Please replace the paragraph at page 19, lines 4 through 14, with the following amended paragraph:

[0158] Referring to FIG. 1, an integrated SLM 200 for modulating light 201 of a selected wavelength, e.g. 1.5 μm, consists of a pixel electrode array 230 formed of reflective ~~aluminium~~ <u>aluminum</u>. The pixel electrode array 230, as will later be described acts as a mirror, and disposed on it is a quarter-wave plate 221. A liquid crystal layer 222 is disposed on the quarter-wave plate 221 via an alignment layer (not shown) as is known to those skilled in the art of liquid crystal structures. Over (as shown) the liquid crystal layer 222 are disposed in order a second alignment layer 223, a common ITO electrode layer 224 and an upper glass layer 225. The common electrode layer 224 defines an electrode plane. The pixel electrode array 230 is disposed parallel to the common electrode plane 224. It will be understood that alignment layers and other intermediate layers will be provided as usual. They are omitted in FIG. 1 for clarity.

Please replace the paragraph on page 90, lines 13 through 23, with the following amended paragraph:

[0457] FIG. 23 shows a first to fourth routing modules 720, 730, 740 and 750. The first and fourth modules each have one input 721, 751, a through output 722, 752, a cross-connect output 723,753 and a number of drop outputs~~721~~ <u>724</u>, 754. The second and third modules 730,740 each have respective single output 731,741, a number of add inputs 732,742 a cross-connect input 733,743 and a through input 734, 744. The through output 722 of the first module 720 is connected to the through input 734 of the second module 730, and the through output 752 of the fourth module 750 is connected to the through input 744 of the third module 740. The cross-connect output 723 of the first module 720 is connected to the cross-connect input 743 of the third module 740, and the cross-connect output 753 of the fourth module 750 is connected to the cross-connect input 733 of the second module 730.

Amendments to the Drawings

FIG. 23 has been amended to correctly identify the numeral "721", as an input to first module 720 and to identify the drop output from the first module 720 using numeral "724".

Attachment: Replacement Sheet
Annotated Marked-Up Drawings

REMARKS

Specification

The specification has been amended to address certain informalities.

Drawings

Fig. 23 used the numeral "721" to indicate two different elements. Accordingly, Fig. 23 has been amended by replacing one instance of the numeral "721" with the numeral "724".

Supplemental Information Disclosure Statement

A Supplemental Information Disclosure Statement (IDS) is being filed concurrently herewith. Entry of the IDS is respectfully requested.

Entry of the Preliminary Amendment is respectfully requested.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By [signature]

Timothy J. Meagher
Registration No. 39,302
Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133
Date: 6/14/10

989726_1.DOC

Appl'n No.: 12/710,913
Title: Optical Processing
Inventor: Melanie Holmes
Annotated Sheet

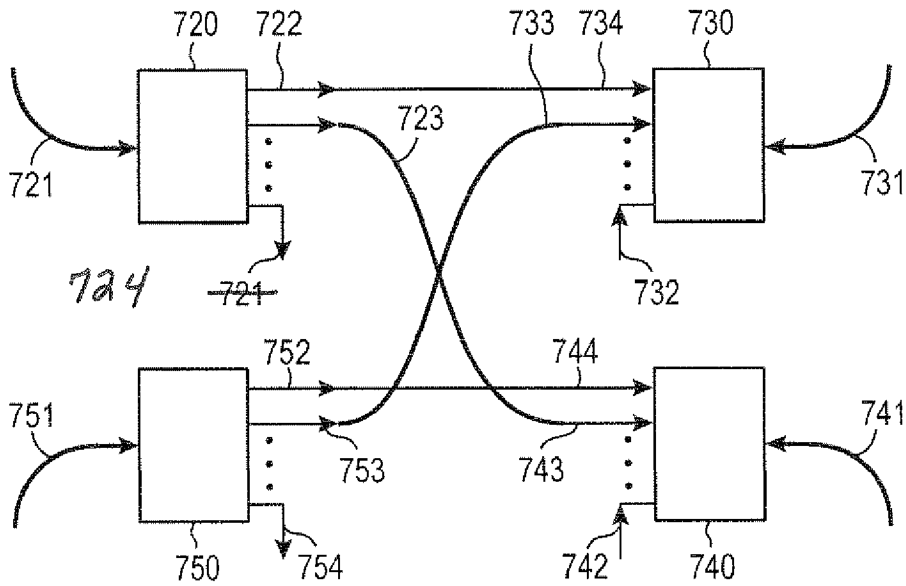

FIG. 23

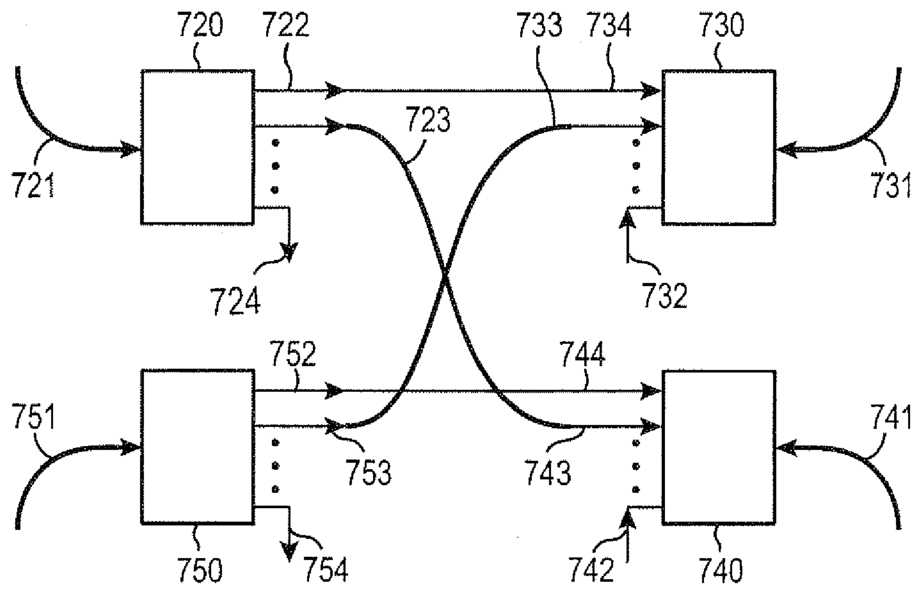
720
722
733
734
730
723
721
731
724
732
752
744
751
741
753
743
750
754
742
740

FIG. 23

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2872
Filed:	February 23, 2010	Examiner:	Unknown
Confirmation No.:	9661		
For:	OPTICAL PROCESSING		

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or is being facsimile transmitted to the United States Patent and Trademark Office on:

Date Signature

Typed or printed name of person signing certificate

TRANSMITTAL LETTER FOR SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Information Disclosure Statement is submitted:

☒ under 37 CFR 1.97(b), or
(Within any one of the following time periods: three months of filing national application (other than a CPA) or date of entry of the national stage in an international application; or before the mailing date of a first office action on the merits; or before the mailing of a first office action after the filing of a Request for Continued Examination).

☐ under 37 CFR 1.97(c) together with either:
- ☐ a Statement under 37 CFR 1.97(e), as checked below, or
- ☐ a $180.00 fee under 37 CFR 1.17(p), or

(After the 37 CFR 1.97(b) time period, but before any of a final action, notice of allowance, or an action that closes prosecution, whichever occurs first)

☐ under 37 CFR 1.97(d) together with:
- ☐ a Statement under 37 CFR 1.97(e), as checked below, and
- ☐ a $180.00 fee under 37 CFR 1.17(p), or

(Filed after final action, notice of allowance, whichever occurs first, or if prosecution otherwise closes, but on or before payment of the issue fee)

☐ under 37 CFR 1.97(i):
Applicant requests that the IDS and cited reference(s) be placed in the application file.
(Filed after payment of issue fee)

Statement Under 37 CFR 1.97(e)

☐ Each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement; or

☐ No item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the undersigned, after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of this Information Disclosure Statement.

Statement Under 37 CFR 1.704(d) (Patent Term Adjustment)
Applies to original applications (other than design) filed on or after May 29, 2000

☐ Each item of information contained in the Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart application and this communication was not received by any individual designated in § 1.56(c) more than thirty days prior to the filing of the Information Disclosure Statement.

☒ Enclosed herewith is a Listing of References:

- ☐ Copies of the cited references are enclosed except as indicated below.
- ☒ Copies of issued U.S. patents and published U.S. applications are not required and are not being provided.
- ☐ Copies of the cited references submitted with an Information Disclosure Statement in prior application, U.S. Application No. [ ], to which priority under 35 U.S.C. 120 is claimed, are not required under 37 CFR 1.98(d)(1) and (2) and are thus not provided.
- ☐ Pending non-published applications are not being provided, since the applications are available to the examiner.

☐ The listed references were cited in the enclosed Search Report in counterpart foreign application [add application number], which is listed in the attached Listing of References.

☐ The "concise explanation" requirement (non-English references) for reference(s) [ ] under 37 CFR 1.98(a)(3) is satisfied by:

- ☐ the explanation provided on the attached sheet.
- ☐ the explanation provided in the Specification.
- ☐ submission of the enclosed International Search Report.
- ☐ submission of the enclosed English-language version of a foreign Search Report and/or foreign Office Action.
- ☐ the enclosed English language abstract.

Method of payment:

☐ Authorization is NOT granted to charge any fees which may be due in this matter to our Deposit Account.

☐ Please charge Deposit Account 08-0380 in the amount of $[ ].

☐ A check for the fee noted above is enclosed, or the fee has been included in the check with the accompanying Reply.

☒ Please charge any deficiency in fees and credit any overpayment to Deposit Account 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By [signature]
Timothy J. Meagher
Registration No. 39,302
Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133
Dated: 6/14/10

Substitute for form 1449B/PTO **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **June 14, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		APPLICATION NO. 12/710,913
	FIRST NAMED INVENTOR Melanie Holmes		FILING DATE February 23, 2010
	EXAMINER Unknown	CONFIRMATION NO. 9661	GROUP 2872

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
	A31	6,879,426 B1	04-12-2005	Weiner
	A32	6,950,609 B2	09-27-2005	Marom
	A33	6,738,540 B2	05-18-2004	Marom
	A34	6,657,770 B2	12-02-2003	Marom, et al.
	A35	6,795,182 B2	09-21-2004	Rakuljic, et al.
	A36	6,804,428 B1	12-14-2001	Garrett, et al.
	A37	7,177,496 B1	12-27-2001	Polynkin, et al.
	A38	6,275,623	07-12-1999	Brophy, et al.

We are not listing separately any prior U.S. Patent Office communications regarding the cited application(s) because the Examiner has access to any such actions through PAIR.

EXAMINER	DATE CONSIDERED

989678_1

Electronic Acknowledgement Receipt

EFS ID:	7803527
Application Number:	12710913
International Application Number:	
Confirmation Number:	9661
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Customer Number:	21005
Filer:	Timothy J. Meagher/Julie Kertyzak
Filer Authorized By:	Timothy J. Meagher
Attorney Docket Number:	3274.1003-004
Receipt Date:	14-JUN-2010
Filing Date:	23-FEB-2010
Time Stamp:	12:13:28
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	32741003004trans.pdf	76382 ceaab1692bfe4f154a25b8a472b62b166c56daec	no	3

Warnings:

Information:

2		32741003004prelamd.pdf	121763 b684e44cb4dde1fcd96ae2fa3ec3fd48ee379239	yes	5

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Preliminary Amendment	1	1
	Specification	2	3
	Drawings-only black and white line drawings	4	4
	Applicant Arguments/Remarks Made in an Amendment	5	5

Warnings:

Information:

3	Drawings-only black and white line drawings	32741003004draw.pdf	21270 8523928bb34f78c6cf64869e95461e7ddf696d8a	no	2

Warnings:

Information:

4	Transmittal Letter	32741003004sids.pdf	97996 eaf27346f9eb79714e6ea853c6a0841fbc33f8f2	no	3

Warnings:

Information:

5	Information Disclosure Statement (IDS) Filed (SB/08)	32741003-0041449.pdf	45319 fa0ee43a3e11f3ebee03d66bc0137a1d360b50e8	no	1

Warnings:

Information:

This is not an USPTO supplied IDS fillable form

Total Files Size (in bytes):	362730

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2872
Filed:	February 23, 2010	Examiner:	Unknown
Confirmation No.:	9661		
For:	Optical Processing		

CERTIFICATE OF MAILING OR TRANSMISSION
I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or is being facsimile transmitted to the United States Patent and Trademark Office on:

Date Signature

Typed or printed name of person signing certificate

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Transmitted herewith is a Preliminary Amendment for filing in the above-identified application.

☐ Small entity status of this application under 37 CFR 1.9 and 1.27 has been established by a Small Entity Statement previously submitted.

☐ A Small Entity Statement to establish small entity status under 37 CFR 1.9 and 1.27 is enclosed.

The claims fee has been calculated as shown below:

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NO. PREVIOUSLY PAID FOR	PRESENT EXTRA	SMALL ENTITY RATE	SMALL ENTITY ADDIT. FEE	OR	OTHER THAN SMALL ENTITY RATE	OTHER THAN SMALL ENTITY ADDIT. FEE
TOTAL	30	MINUS	* 30	0	X $ 26	$		X $52	$ 0
INDEP	8	MINUS	** 8	0	X $110	$		X $220	$ 0
☐ FIRST PRESENTATION OF MULTIPLE DEP. CLAIM					+ $195	$		+ $390	$
			* not fewer than 20 ** not fewer than 3		TOTAL =	$ 0		TOTAL =	$ 0

The Application Size Fee has been calculated as shown below:
(Effective for cases filed on or after December 8, 2004)

Actual Sheets (Including current amendment)	Highest No. of Sheets Paid For (At least 100)	No. of Additional Units Required (Increments of 50 sheets)	SMALL ENTITY Rate	SMALL ENTITY Total Amount Owed	OTHER THAN SMALL ENTITY Rate	OTHER THAN SMALL ENTITY Total Amount Owed	Payment Sufficient for up to
143	150	0	X $135	$[ ]	X $270	$[ ]	150 Sheets

Petition for Extension of Time

☐ Applicant hereby petitions to extend the time to respond to the [ ] dated [ ] for [ ] month(s) from [ ] to [ ]. The appropriate fee is set forth below.

☐ *[For action-specific language in an extension of time, select the appropriate option from the Firm Templates]*

Please charge Deposit Account No. 08-0380 for the following fees:

☐ Petition for [ ] month Extension of Time $ ______

☐ Claims Fee $ ______

☐ Application Size Fee $ ______

☐ Other Fees:

______ $ ______

______ $ ______

TOTAL: $ ______

A check is enclosed in payment of the following fees:

☐ Petition for [ ] month Extension of Time $ ______

☐ Claims Fee $ ______

☐ Application Size Fee $ ______

☐ Other Fees:

______ $ ______

______ $ ______

TOTAL: $ ______

☒ Please charge any deficiency or credit any overpayment in the fees that may be due in this matter to Deposit Account No. 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By ______
Timothy J. Meagher
Registration No.: 39,302
Telephone (978) 341-0036
Facsimile (978) 341-0136

Concord, Massachusetts 01742-9133
Dated: 6/14/10

Substitute for form 1449B/PTO **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **June 24, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		APPLICATION NO. 12/710,913
	FIRST NAMED INVENTOR Melanie Holmes		FILING DATE February 23, 2010
	EXAMINER Unknown	CONFIRMATION NO. 9661	GROUP 2872

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
	A39	5,917,625	06-29-1999	Ogusu, *et al.*
	A40	5,802,222	09-01-1998	Rasch, *et al.*
	A41	6,559,986 B1	05-06-2003	Sauer, *et al.*
	A42	6,583,901 B1	06-24-2003	Hung
	A43	6,577,417 B1	06-10-2003	Khoury
	A44	5,832,155	11-03-1998	Rasch, *et al.*
	A45	5,285,308	02-081994	Jenkins, *et al.*
	A46	7,127,168 B2	10-24-2006	Kani, *et al.*
	A47	7,113,702 B2	09-26-2006	Yamada, *et al.*
	A48	7,436,588 B2	10-14-2008	Rothenberg, *et al.*
	A49	5,121,231	06-091992	Jenkins, *et al.*

We are not listing separately any prior U.S. Patent Office communications regarding the cited application(s) because the Examiner has access to any such actions through PAIR.

EXAMINER	DATE CONSIDERED

995670_1

Electronic Acknowledgement Receipt

EFS ID:	7884994
Application Number:	12710913
International Application Number:	
Confirmation Number:	9661
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Customer Number:	21005
Filer:	Timothy J. Meagher/Katie Norris
Filer Authorized By:	Timothy J. Meagher
Attorney Docket Number:	3274.1003-004
Receipt Date:	24-JUN-2010
Filing Date:	23-FEB-2010
Time Stamp:	16:17:50
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	32741003004SIDS.pdf	157100 8df6f8e87a7acc1e8f3c3fc13222919dda7a13b6	no	3

Warnings:

Information:

TS0002315

2	Information Disclosure Statement (IDS) Filed (SB/08)	32741003004ListofRefs.pdf	74558 61df54d08c238173dae3386eb7ab1b2979efb355	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
			Total Files Size (in bytes):	231658	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2872
Filed:	February 23, 2010	Examiner:	Unknown
Confirmation No.:	9661		
For:	OPTICAL PROCESSING		

CERTIFICATE OF MAILING OR TRANSMISSION
I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or is being facsimile transmitted to the United States Patent and Trademark Office on:

Date ______ Signature ______

______
Typed or printed name of person signing certificate

TRANSMITTAL LETTER FOR SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Information Disclosure Statement is submitted:

☒ under 37 CFR 1.97(b), or
(Within any one of the following time periods: three months of filing national application (other than a CPA) or date of entry of the national stage in an international application; or before the mailing date of a first office action on the merits; or before the mailing of a first office action after the filing of a Request for Continued Examination).

☐ under 37 CFR 1.97(c) together with either:
- ☐ a Statement under 37 CFR 1.97(e), as checked below, or
- ☐ a $180.00 fee under 37 CFR 1.17(p), or

(After the 37 CFR 1.97(b) time period, but before any of a final action, notice of allowance, or an action that closes prosecution, whichever occurs first)

☐ under 37 CFR 1.97(d) together with:
- ☐ a Statement under 37 CFR 1.97(e), as checked below, and
- ☐ a $180.00 fee under 37 CFR 1.17(p), or

(Filed after final action, notice of allowance, whichever occurs first, or if prosecution otherwise closes, but on or before payment of the issue fee)

☐ under 37 CFR 1.97(i):
Applicant requests that the IDS and cited reference(s) be placed in the application file.
(Filed after payment of issue fee)

Statement Under 37 CFR 1.97(e)

☐ Each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement; or

☐ No item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the undersigned, after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of this Information Disclosure Statement.

Statement Under 37 CFR 1.704(d) (Patent Term Adjustment)
Applies to original applications (other than design) filed on or after May 29, 2000

☐ Each item of information contained in the Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart application and this communication was not received by any individual designated in § 1.56(c) more than thirty days prior to the filing of the Information Disclosure Statement.

☒ Enclosed herewith is a Listing of References:

- ☐ Copies of the cited references are enclosed except as indicated below.
- ☒ Copies of issued U.S. patents and published U.S. applications are not required and are not being provided.
- ☐ Copies of the cited references submitted with an Information Disclosure Statement in prior application, U.S. Application No. [ ], to which priority under 35 U.S.C. 120 is claimed, are not required under 37 CFR 1.98(d)(1) and (2) and are thus not provided.
- ☐ Pending non-published applications are not being provided, since the applications are available to the examiner.

☐ The listed references were cited in the enclosed Search Report in counterpart foreign application [add application number], which is listed in the attached Listing of References.

☐ The "concise explanation" requirement (non-English references) for reference(s) [ ] under 37 CFR 1.98(a)(3) is satisfied by:

- ☐ the explanation provided on the attached sheet.
- ☐ the explanation provided in the Specification.
- ☐ submission of the enclosed International Search Report.
- ☐ submission of the enclosed English-language version of a foreign Search Report and/or foreign Office Action.
- ☐ the enclosed English language abstract.

Method of payment:

☐ Authorization is NOT granted to charge any fees which may be due in this matter to our Deposit Account.

☐ Please charge Deposit Account 08-0380 in the amount of $[ ].

☐ A check for the fee noted above is enclosed, or the fee has been included in the check with the accompanying Reply.

☒ Please charge any deficiency in fees and credit any overpayment to Deposit Account 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By [signature]
Timothy J. Meagher
Registration No. 39,302
Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133
Dated: 6/24/10

995675_1

Substitute for form 1449B/PTO **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **July 29, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		APPLICATION NO. 12/710,913
	FIRST NAMED INVENTOR Melanie Holmes		FILING DATE February 23, 2010
	EXAMINER Loha Ben	CONFIRMATION NO. 9661	GROUP 2873

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
	A50	6,141,361	10-31-2000	Mears, *et al.*

We are not listing separately any prior U.S. Patent Office communications regarding the cited application(s) because the Examiner has access to any such actions through PAIR.

EXAMINER	DATE CONSIDERED

1004888_1

Electronic Acknowledgement Receipt

EFS ID:	8114815
Application Number:	12710913
International Application Number:	
Confirmation Number:	9661
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Customer Number:	21005
Filer:	Timothy J. Meagher/Wendy Morrissey
Filer Authorized By:	Timothy J. Meagher
Attorney Docket Number:	3274.1003-004
Receipt Date:	29-JUL-2010
Filing Date:	23-FEB-2010
Time Stamp:	15:29:15
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	32741003004SIDS.PDF	132120 2bff01ab4a9cdd5d575d72dd3da7a606198c5028	no	3

Warnings:

Information:

2	Information Disclosure Statement (IDS) Filed (SB/08)	32741003004ListingofReferences.PDF	49784 6c5edc0e5eee7ac88c9f1ad77ebdaea19db6c4c3	no	1

Warnings:

Information:

This is not an USPTO supplied IDS fillable form

Total Files Size (in bytes):	181904

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2873
Filed:	February 23, 2010	Examiner:	Loha Ben
Confirmation No.:	9661		
For:	OPTICAL PROCESSING		

CERTIFICATE OF MAILING OR TRANSMISSION
I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or is being facsimile transmitted to the United States Patent and Trademark Office on:

______________ ______________________________
Date Signature

____
Typed or printed name of person signing certificate

TRANSMITTAL LETTER FOR SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Information Disclosure Statement is submitted:

☒ under 37 CFR 1.97(b), or
(Within any one of the following time periods: three months of filing national application (other than a CPA) or date of entry of the national stage in an international application; or before the mailing date of a first office action on the merits; or before the mailing of a first office action after the filing of a Request for Continued Examination).

☐ under 37 CFR 1.97(c) together with either:
- ☐ a Statement under 37 CFR 1.97(e), as checked below, or
- ☐ a $180.00 fee under 37 CFR 1.17(p), or

(After the 37 CFR 1.97(b) time period, but before any of a final action, notice of allowance, or an action that closes prosecution, whichever occurs first)

☐ under 37 CFR 1.97(d) together with:
- ☐ a Statement under 37 CFR 1.97(e), as checked below, and
- ☐ a $180.00 fee under 37 CFR 1.17(p), or

(Filed after final action, notice of allowance, whichever occurs first, or if prosecution otherwise closes, but on or before payment of the issue fee)

☐ under 37 CFR 1.97(i):
Applicant requests that the IDS and cited reference(s) be placed in the application file.
(Filed after payment of issue fee)

Statement Under 37 CFR 1.97(e)

☐ Each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement; or

☐ No item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the undersigned, after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of this Information Disclosure Statement.

Statement Under 37 CFR 1.704(d) (Patent Term Adjustment)
Applies to original applications (other than design) filed on or after May 29, 2000

☐ Each item of information contained in the Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart application and this communication was not received by any individual designated in § 1.56(c) more than thirty days prior to the filing of the Information Disclosure Statement.

☒ Enclosed herewith is a Listing of References:

- ☐ Copies of the cited references are enclosed except as indicated below.
- ☒ Copies of issued U.S. patents and published U.S. applications are not required and are not being provided.
- ☐ Copies of the cited references submitted with an Information Disclosure Statement in prior application, U.S. Application No. [ ], to which priority under 35 U.S.C. 120 is claimed, are not required under 37 CFR 1.98(d)(1) and (2) and are thus not provided.
- ☐ Pending non-published applications are not being provided, since the applications are available to the examiner.

☐ The listed references were cited in the enclosed Search Report in counterpart foreign application [add application number], which is listed in the attached Listing of References.

☐ The "concise explanation" requirement (non-English references) for reference(s) [ ] under 37 CFR 1.98(a)(3) is satisfied by:

- ☐ the explanation provided on the attached sheet.
- ☐ the explanation provided in the Specification.
- ☐ submission of the enclosed International Search Report.
- ☐ submission of the enclosed English-language version of a foreign Search Report and/or foreign Office Action.
- ☐ the enclosed English language abstract.

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☐ Authorization is NOT granted to charge any fees which may be due in this matter to our Deposit Account.

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☐ A check for the fee noted above is enclosed, or the fee has been included in the check with the accompanying Reply.

☒ Please charge any deficiency in fees and credit any overpayment to Deposit Account 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By__________________________

Timothy J. Meagher
Registration No. 39,302
Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133

Dated: 7/29/10

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004

CONFIRMATION NO. 9661

PUBLICATION NOTICE

OC000000043115891

21005
HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

Title:OPTICAL PROCESSING

Publication No.US-2010-0209109-A1
Publication Date:08/19/2010

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

21005 7590 08/24/2010

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

EXAMINER	
BEN, LOHA	

ART UNIT	PAPER NUMBER
2873	

NOTIFICATION DATE	DELIVERY MODE
08/24/2010	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

pwatson@hbsr.com
helpdesk@hbsr.com

Office Action Summary	Application No.	Applicant(s)	
	12/710,913	HOLMES, MELANIE	
	Examiner	Art Unit	
	LOHA BEN	2873	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *1* MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *23 February 2010*.

2a)☐ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-30* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☐ Claim(s) _____ is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☒ Claim(s) *1-30* are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Election/Restrictions

Restriction is required under 35 U.S.C. 121 and 372.

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1.

In accordance with 37 CFR 1.499, applicant is required, in reply to this action, to elect a single invention to which the claims must be restricted.

Group I, claim(s) 1-13 and 23-30, drawn to light wave directional modulation device having reflective SLM.

Group II, claim(s) 14-22, drawn to optical processor comprising beam combining or dividing devices.

The groups of inventions listed above do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

For the invention of Group I, the device uses **specifically reflective SLM** along with other elements in the combination to carry out the light wave directional modulation, whereas for that of Group II, the beam combining or beam dividing has no association with light reflection whatsoever.

Applicant is advised that the reply to this requirement to be complete must include (i) an election of a species or invention to be examined even though the requirement may be traversed (37 CFR 1.143) and (ii) identification of the claims encompassing the elected invention.

The election of an invention or species may be made with or without traverse. To preserve a right to petition, the election must be made with traverse. If the reply does not distinctly and specifically point out supposed errors in the restriction requirement, the election shall be treated as an election without traverse. Traversal must be presented at the time of election in order to be considered timely. Failure to timely traverse the requirement will result in the loss of right to petition under 37 CFR 1.144. If claims are added after the election, applicant must indicate which of these claims are readable on the elected invention or species.

Should applicant traverse on the ground that the inventions have unity of invention (37 CFR 1.475(a)), applicant must provide reasons in support thereof. Applicant may submit evidence or identify such evidence now of record showing the inventions to be obvious variants or clearly admit on the record that this is the case. Where such evidence or admission is provided by applicant, if the examiner finds one of the inventions unpatentable over the prior art, the evidence or admission may be used in a rejection under 35 U.S.C. 103(a) of the other invention.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to LOHA BEN whose telephone number is (571)272-2323. The examiner can normally be reached on M-SAT, generally between 12:01 p.m. to 8:00 p.m.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Ricky Mack, can be reached on M-F, at (571) 272-2333. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

August 17, 2010

/Loha Ben/
Primary Examiner, Art Unit 2873

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
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BIB DATA SHEET

CONFIRMATION NO. 9661

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
12/710,913	02/23/2010 **RULE**	359	2873	3274.1003-004

APPLICANTS
Melanie Holmes, Suffolk, UNITED KINGDOM;

** **CONTINUING DATA** *************************
This application is a CON of 11/978,258 10/29/2007
which is a CON of 11/515,389 09/01/2006 PAT 7,612,930
which is a DIV of 10/487,810 09/10/2004 PAT 7,145,710
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	Examiner LOHA BEN	Art Unit 2873

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

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Application Serial No: 12/710,913

Attorney Docket No: 3274.1003-004
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Substitute for form 1449B/PTO **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **September 23, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		APPLICATION NO. 12/710,913
	FIRST NAMED INVENTOR Melanie Holmes		FILING DATE February 23, 2010
	EXAMINER Ben, Loha	CONFIRMATION NO. 9661	GROUP 2873

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	EXAMINER Ben, Loha	CONFIRMATION NO. 9661	GROUP 2873

Examiner's Initials	Ref. No.	**OTHER DOCUMENTS** *(Including Author, Title, Date, Pertinent Pages, Etc.)*
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EXAMINER	DATE CONSIDERED

LOW CROSSTALK DEVICES FOR WAVELENGTH-ROUTED NETWORKS.

M.J. Holmes* (now #), F.P. Payne*, P. Dainty#, T.J. Hall# and W.A. Crossland*.

Abstract: Over the last year, homodyne beat noise and bandwidth narrowing due to filter concatenation have been identified as major problems for large wavelength-routed networks. These problems will become more acute and will interact at the design stage, as wavelength channel spacings are decreased and as the channel bit rate is increased, leading to the requirement for devices with high fractional bandwidth per channel and with very low (<-50 dB) crosstalk. We explore the fundamental limits to crosstalk in optical routing components, and propose new design concepts for wavelength demultiplexers/multiplexers and space switches that have the potential to meet these strict performance requirements.

1 Introduction.

Wavelength division multiplexing (WDM) is an attractive technique for providing the high aggregate capacities into optical routing nodes because, with appropriate network design, the routing can be transparent to the bit-rate per channel and to the transport mechanism (PDH/SDH/ATM), and the routing does not require any form of synchronisation between channels [1]. In the next section we outline two of the current major problems in wavelength-routed networks, and describe how these problems lead to the demand for wavelength-routing devices with high fractional bandwidth per channel and very low crosstalk, typically - 50 dB. The purpose of the work presented in this paper was to investigate the design of wavelength-routing components with such properties.

It is an aim of the POETS project to investigate free-space implementations of optical routing, based on the use of fixed and dynamic holographic components. In the context of a colloquium on guided-wave devices, we were interested in answering the following questions: what sort of crosstalk (and bandwidth) performance might we be able to achieve with holographic (free-space) optical components, how does the likely crosstalk performance of the holographic devices compare with that of guided-wave devices, and how can we take advantage of recent advances in microengineering techniques [2], and exploit the potential for 2-D fan-out with free-space optics, in order to design compact devices.

In section 3 we discuss how the various choices made during the design of a space-switch will influence the final crosstalk, and compare the fundamental limits to the crosstalk in guided-wave and free-space optical switching: we predict that for semiconductor integrated guided-wave devices there is a 'background' level of crosstalk, induced by scattering from surface roughness, even for switches with infinite extinction ratio. For 'free-space' optical switching we show that the 'background' crosstalk may be suppressed by exploiting the coupling behaviour of Gaussian beams into single-mode fibres.

In section 4 we present a new holographic implementation for optical switching with spatial light modulators, that has been designed to eliminate the crosstalk from higher diffraction orders. In section 5 we show that guided-wave wavelength demultiplexing and remultiplexing devices are unlikely to provide the combination of high fractional bandwidth and low crosstalk that will be required in wavelength-routed networks. We also discuss the problems that arise for a blazed-grating wavelength demultiplexer when narrow channel spacings are required. Finally, in section 6 we present a new design of wavelength demultiplexer, designed to overcome the problems of a blazed grating approach.

2 Current problems in wavelength-routed networks.

One of the first applications of optical routing is likely to be an evolutionary one: not a fully transparent optical network but a transparent optical transport layer, overlaid on the electronic transport layer [3,4]. The function of the optical crossconnects would be to route high capacity tandem traffic, bypassing the electronics, and 'adding (dropping)' the lower capacity channels and the originating (terminating) traffic from (to) an electronic cross-connect. The function of a WDM crossconnect is to set up semi-permanent routes for each wavelength channel: this may be achieved with three optical stages: a wavelength demultiplexer on every input fibre, followed by a reconfigurable space-switch, followed by a wavelength multiplexer on every output fibre (figure 1).

As a result of recent demonstrator projects on

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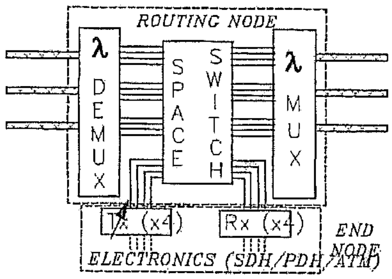
wavelength-routing nodes [5], two major problems have been discovered to afflict wavelength-routing networks. The problems are bandwidth narrowing and homodyne beat noise, and they interact at the design stage. Wavelength routing necessarily involves a wavelength selection process (in the demux stage and perhaps the mux stage): every wavelength selection process has a finite filter bandwidth, and each subsequent filtering operation leads to a narrowing of the net bandwidth perceived by a routed channel. For a large wavelength-routed network the net end-to-end bandwidth can become very narrow, leading to the demand for tight control on the transmitter wavelengths: good wavelength stability can be achieved with fibre gratings [6]. In a large network we would then have many transmitter lasers at almost (within the wavelength referencing tolerance) the same wavelength. As a signal traverses the network, crosstalk in the routing optics will lead to the accumulation of in-band crosstalk, originating from other transmitters at the same (nominal) system wavelength. Because the receiver is a square-law device, the crosstalk will beat with the signal. If the frequency difference between the signal and crosstalk is within the receiver bandwidth, the crosstalk will corrupt the data.

Figure 1: Transparent Optical Cross-Connect



Even without tight wavelength referencing, homodyne beat noise will still arise due to crosstalk originating from the same transmitter as the signal itself: this occurs due to non-perfect wavelength demultiplexing and remultiplexing [7], and depends on the routing configuration.

The net crosstalk amplitude can be reduced by making the multiplexer wavelength dependent [8], but this requires an extra filtering operation per routing node, and so will exacerbate the bandwidth narrowing problem. Reducing the device crosstalk will very often lead to a reduction in the allowed filter bandwidth, again making the bandwidth narrowing worse. A narrower end-to-end bandwidth requires tighter wavelength referencing, leading to worse homodyne beat noise.

The conclusion from this cycle, is that for the wavelength filtering devices we should seek to maximise the bandwidth we can achieve for a given crosstalk, and for the space-switches we should seek to minimise the crosstalk.

We have used a statistical approach to simulate the accumulation of beat-noise terms for an optical transport network with as many nodes as the current UK inner-core network, and have found that (for a maximum receiver penalty of 2 dB at error rates of 1 in 10^9), the crosstalk requirements vary between -43 dB and -50 dB, depending on the network architecture.

3 Space switch design for low crosstalk.

For wavelength-routing the space-switches need reasonable fan-out, e.g. 4 or 8, rather than fast switching speed: for example the reconfiguration time for an electronic (SDH) crossconnect is 20 mS [9]. The routing configuration is controlled by electronic signals sent by the local element management centre: all-optical switching is not necessary. Therefore very fast nonlinear 'all-optical' switches are outside the scope of this study, although they may have other roles to play in WDM networks for use as wavelength converters, for example.

The design of a space-switching component breaks down into 3 stages: the first is the choice of a process or method for performing a space-switching function; the second is the choice of a particular architecture or arrangement of the sub-switch components; the third stage is the choice of a particular implementation: that is the device technology and the details of the device design. Decisions made at all 3 stages of the design process have implications for the final crosstalk levels.

3.1 Switch method.

(i) Guided-wave switches: Guided-wave switches fall into two classes: those based on interferometers, and those performing a more digital, 'gating' function. The interferometer-based switches are operated by adjusting the effective indices of parallel waveguides. This process will inevitably be prone to high crosstalk, because small changes in the effective index of one guide can lead to large changes in the power coupled across. Possibly the best crosstalk results that have been obtained with an interferometer method are - 24 dB crosstalk in a 4 by 4 matrix switch using electro-optic effects in a directional coupler [10].

The 'gating' class of guided-wave switches is less crosstalk-prone: one method involves splitting the input power so as to take several 'copies' of the input signal. The passage of one copy of the signal in a particular direction is controlled by turning gain blocks on and off: in the 'on' state the gain compensates for the splitting loss, and in the 'off' state the signal is blocked by the attenuation of the gain block. Both semiconductor laser amplifiers and rare-earth doped fibre amplifiers have been used as gain blocks to perform a switching function. Another 'gating' switch is based on the 'digital optical' Y switch. The crosstalk for this class of switch depends on the extinction ratio of each individual switch element. For 'gating' switches implemented into integrated semiconductor devices, reported extinction ratios for the SLA are 40 dB [11], and for the Y-switch are 40 dB [12].

(ii) Free-space switches: 'Shadow-routing' switches are the free-space equivalent of the semiconductor laser amplifier guided-wave switch, except that the shadow-routing uses attenuation instead of gain to control the routing. For the shadow-routing, a fixed hologram acts as a splitter to take many copies of the input signal. All but the chosen copy are blocked with an (amplitude) spatial light modulator: at present typical modulator contrast ratios are in the range 150 to 200, but experimental studies indicate that an order of magnitude increase in the contrast ratio is possible with refined substrate properties. The shadow routing switches can have very high fan-out: for example a 64 by 64 crossbar switch has been demonstrated as part of the OCPM project [13]. However, to achieve such high fan-out requires the use of multimode fibre in the output plane, and this would preclude the use of such switches in a transparent optical network.

The second free-space switching method for performing a switching function is to 'beam-steer' the input signal to the required output waveguide. This method is perhaps the least prone to crosstalk out of all four (guided-wave+free-space) methods discussed in this paper: assuming we have steered the beam to the correct output, the resulting crosstalk will come from the evanescent tails of beams steered to an adjacent output port. For Gaussian output beams of spot size 'x', matched into output waveguides spaced distance 's' apart, the theoretical crosstalk is $-4.34\,(s/x)^2$ (using [14]). For 'standard' type telecomms fibres spaced 250 um apart, and planar silica waveguides spaced 50 um apart, this theoretical crosstalk is only -10,400 dB and - 940 dB, respectively (!). This is far too small to be measured and would not contribute to homodyne beat noise problems in even the largest of networks. Examples of beam-steering switches include 'Start' fibres, acousto-optic beam deflectors and liquid-crystal holograms.

3.2 Switch architecture.

It is well-known that dilated switch architectures will reduce the net crosstalk for a space-switch. For example, a logical N by N (crossbar) switch can be formed from a 1:N switch at every input port, fibre 'wired' to N:1 switches at every outport port. For this architecture, 2 'crosstalk events' must occur for crosstalk to appear at the output. Hence the net crosstalk is second-order: a net crosstalk of -60 dB for a space-switching stage can be achieved with 1:N and N:1 switches with crosstalk between ports of -30 dB.

A secondary advantage of a dilated architecture is that it is easily upgraded: a dilated N by N switch can be progressively upgraded to a MN by MN switch by placing 1:M switches at each of the o/p's of the 1:N switch.

3.3 Switch implementation.

The choice of device technology can also influence the crosstalk.

(i) Guided wave switches: The lowest crosstalk guided-wave switches are those using semiconductor 'gating' elements. These are integrated into a planar semiconductor device, with connection between the gain/loss blocks in waveguide form. The semiconductor device fabrication process can introduce imperfections in the waveguide walls. The typical feature size for these imperfections is close to the carrier wavelength for optical signals. We were interested to see whether scattering from these surfaces would lead to a significant 'background' level to the crosstalk, that would occur even for switch elements with infinite extinction ratio.

In this technology, significant attenuation in the waveguides occurs as a result of mode coupling from the fundamental waveguide mode(s) to radiation and substrate modes, where the mode coupling is excited by the surface roughness of the waveguide walls. Typical loss coefficients for this scattering mechanism are between 3 cm^{-1} and 5 cm^{-1}. The coupling can be interpreted as being equivalent to a given probability (per unit length) of a photon being coupled out of the waveguide. On reaching an adjacent waveguide, the photon will have the same probability of being coupled into this waveguide. Hence the mode coupling will lead to a 'background' level of crosstalk, even for switch blocks with infinite extinction ratios. Earlier theory developed to calculate the attenuation due to this surface roughness [15], has been adapted to calculate the crosstalk. It was found that the ratio of the (absolute) crosstalk, C, to the square of the loss coefficient due to this scattering mechanism is given by:

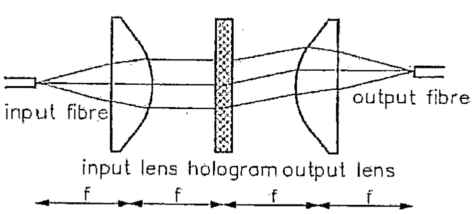
$$C/\alpha^2 \propto L^2/D \qquad (1)$$

where L is the length of parallel waveguides, D their separation, and the constant of proportionality depends strongly on the correlation length of the surface roughness, but is insensitive to all other parameters. The maximum crosstalk occurs at short correlation lengths of the order of 0.05 um: with a loss coefficient of 5 cm^{-1}, and a 1 mm length of parallel waveguides separated by 250 um, we estimate the crosstalk to be - 50 dB.

(ii) Free-space switches: Reflections in a free-space optical system can lead to two distinct crosstalk mechanisms: reflection into the wrong o/p port (not the intended o/p), leading to a crosstalk of say, -C dB per switch, can be reduced to a net crosstalk level of - 2C dB, given a dilated switch architecture. However, coherent (unwanted) reflections into the intended o/p port, cannot be removed with a dilated architecture. The coherent scattering should therefore be less than - 50 dB, while the adjacent channel crosstalk can be -25 dB with a dilated architecture. Unwanted diffraction orders in a holographic system can also lead to crosstalk.

In a free-space holographic optical system, unwanted reflections will occur from the input and output lenses, the hologram surfaces, the cleaved fibre ends, and the fibre mounts. High-quality commercial AR coatings on the lens surfaces will bring these reflectances down to less than 0.12 % (equivalent to - 29 dB) over a 40 nm window [16]. For Fresnel reflection off the fibre end we assume an effective fibre index of 1.445, giving a net reflectance of 3.3 % or -14.8 dB. One side of the hologram will be rough, due to the devices/pixels used to form the hologram: it would be difficult to AR coat this surface so we assume a reflectance of around 4 % (- 14 dB). The other side of the hologram could be AR coated with a reflectance of - 29 dB (as for the lens surfaces).

Figure 2: Hologram used in transmission.



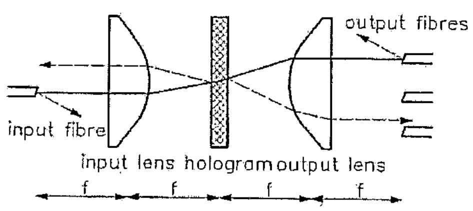
For a holographic system used in transmission (figure 2), two reflections must occur for coherent scattering or crosstalk to be coupled into the o/p fibres, so that the net effect is a second-order function of the reflection from a single surface. In order to maximise transmitted power and minimise spherical aberrations we assume the use of precision-moulded plano-aspheric lenses for the i/p lenses, with the planar surfaces closest to the fibre ends. We have estimated the size of the reflections from each possible pair of surfaces. Single-mode fibres will only accept light from i/p beams that are well-focused, at near-normal incidence, and with a beam centre close to the fibre core: we have also estimated how much of the reflected power is coupled into the input and output fibres, using the standard formulae [14] for the coupling efficiency of Gaussian beams into standard telecomms fibres.

Beams reflecting from a lens surface will diffract and be defocused on the fibre ends: the resulting phase-front curvature leads to very weak coupling into the fibre, therefore most reflection pairs including a reflection from a lens surface will cause negligible coherent scattering. The strongest event in this set occurs for light that is initially reflected from the cleaved end of the output fibre, then again reflected from the near surface of the output lens. After reflection from a plane lens surface and coupling back into the o/p fibre, the net crosstalk level is estimated to be - 80 dB, for a lens surface 5 mm from the fibre end.

Beams reflecting from the rough hologram surface: normal reflections from the hologram surfaces will be refocused by the lenses and can therefore be strongly coupled into the i/p and o/p fibres. We assume that the rough surface of the hologram is facing towards the i/p fibre. Reflection from this hologram surface, followed by transmission through the i/p lens, will lead to a significant back-reflection into the i/p fibre. In a dilated switch architecture, two such scattering events will lead to coherent scattering levels of - 28 dB or more, depending on the roughness of the hologram surface, leading to significant beat-noise. Reflection from the rough hologram surface, followed by reflection from the cleaved end of the input fibre would also lead to - 28 dB coherent scattering in the output fibre. However, we can avoid these crosstalk mechanisms by placing the i/p fibre slightly off-axis (figure 3). For an i/p fibre offset by 'o' um, the reflected beam would be offset by 2'o' um, and the fraction of backscattered power coupled into the i/p fibre would be $-4.343(2o/x)^2$ dB [14] : an offset of 11 um is sufficient to suppress the backscattered power by 80 dB.

Figure 3:

Reflected beam paths with angle-polished fibre ends and i/p beam in off-normal incidence to the hologram.



Beams reflecting from the cleaved end of both fibres: the estimated crosstalk for this mechanism would be - 50 dB. This effect can be suppressed by polishing the face of the input fibre: an angle of 8 degrees is known to give the best compromise between (out)coupling loss and suppression of backscatter.

Reflection off the cleaved end of the o/p fibre, followed by reflection from the smooth (and AR coated) surface of the hologram (figure 3) may lead to crosstalk into other o/p fibres, depending on their position. With worst-case positioning, the crosstalk would be -43 dB.

With careful choice of the position of the o/p fibres, this crosstalk could be reduced considerably. A 15 um separation between the centre of the crosstalk beam, and the nearest o/p fibre, would reduce the crosstalk to below - 80 dB. Alternatively we could polish the end of the output fibres to suppress the reflection.

Crosstalk from unwanted diffraction orders.

The crosstalk and coherent scattering due to reflections will occur in any implementation of a beam-steering hologram. The crosstalk from unwanted diffraction orders depends on the specific details of the hologram technology and design.

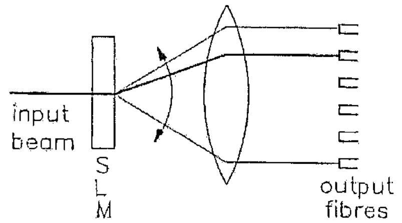
Holographic beam-steering can be implemented with phase modulation of a spatial light modulator (SLM) [17]. Polarisation-independent operation [18] can be achieved with a binary phase hologram, formed from a 2-D pixellated array of ferroelectric liquid-crystal, embedded in, and controlled by, a VLSI silicon backplane consisting of 2 um CMOS. Binary-phase holograms are so-called because they can induce two different values of path difference in light passing through the pixels. The relative phases are usually 0 and pi, and are controlled by rotating the liquid-crystal molecules, so as to adjust the refractive index experienced by light passing through the liquid crystal. The fraction of incident power diffracted by the hologram varies as $\sin^2(2t)$, where t is half the angle through which the molecule is rotated. Half-angles of 36 degrees have recently been achieved [19], with a switching time of 80 us: such devices will allow diffraction of 90 % of the power incident on the pixels. These devices are an attractive component for future telecomms networks because they are potentially very cheap, they require only standard 10V digital supply voltages, and the 2-D operation allows a large fan-out per switch. Other examples of beam-steering switches are acousto-optic beam deflectors, which require RF supply, and 'Start' switches, which are limited to 2:2 (crossbar) operation, although bigger switches can be made by cascading many 2 by 2 crossbars.

An SLM is used as a beam-steerer by changing (electronically) the phase of chosen pixels in order to construct a phase diffraction grating with a tuneable period and pattern. For pure beam-steering we require a perfect sawtooth phase diffraction grating: for this case we would get diffraction into a single grating order, and the output angle of the switched light would then be given by:

$$\sin\theta = \lambda / Q \qquad (2)$$

where Q is the grating (sawtooth) period. By changing the sawtooth period we change the output angle, and switch the output between different waveguides (fig 4).

Figure 4: Principle of holographic beam steering



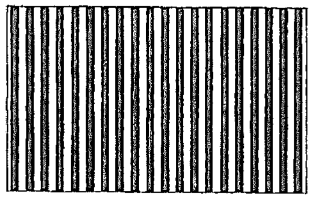
SLM acts as diffraction grating with a digitally tuneable grating period.

For binary-phase operation we are limited to 2 discrete phase levels, so we cannot form a sawtooth phase variation. The closest binary-phase approximation to a sawtooth is a 'square wave', as shown in figure 5, with equal width stripes inducing alternate phase shifts of 0 and pi. For this case (and with 1-D fanout) 80% of the input power is diffracted into two (equal) main orders, positioned symmetrically about the optical axis. The rest of the power goes into higher-order grating modes: the relative amplitude of each mode is shown in figure 6, where the output angle of the m'th grating order is given by:

$$\sin\theta = m\lambda / Q \qquad (3)$$

Figure 5:

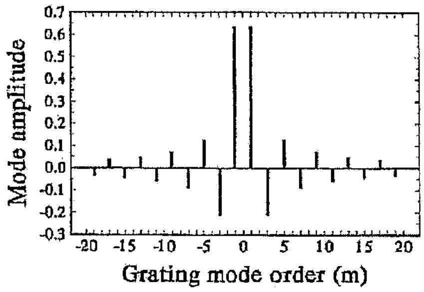
a square wave grating.



For a square-wave SLM, we choose the grating period such that the light diffracted into one of the first-order grating modes is coupled into the selected output fibre. Unfortunately, the higher-order grating modes will then lead to severe crosstalk whenever the light diffracted into these orders is coupled into another (NOT selected) output waveguide. One method to suppress this crosstalk is to change the grating pattern: from a square wave to a more complex (computer-optimised) structure, designed to suppress the higher-orders. Crosstalk levels of -35 dB have been achieved by this method, but the penalty is that a large number of pixels are required in each period, leading to a small output angle for a fixed pixel pitch, and consequently long devices.

Acousto-optic beam deflectors can also be used to implement a free-space optical switch. We have not calculated the crosstalk levels in these devices but note that the acoustic wave is usually at around 100 MHz. Hence at room temperature we would expect 50,000

Figure 6: binary phase o/p amplitudes for 1-D fanout from a 'square-wave' grating.



thermally-excited acoustic phonons per acoustic mode. The modes would be in an almost continuous spectrum, leading to a continuous angular distribution of crosstalk diffracted from the thermally excited acoustic waves, which cannot be avoided by appropriate positioning of the o/p fibres. By contrast, the unwanted diffraction orders from a hologram form a discrete spectrum, such that the crosstalk can be avoided by appropriate fibre positioning.

In the following section we investigate a new implementation of beam-steering liquid-crystal holograms: we present a very simple technique for suppressing the crosstalk from higher grating orders, and show that the potential for 2-D fan-out can lead to compact and low loss devices.

4 Beam-steering switches with very low crosstalk.

To see how to avoid the crosstalk from higher diffraction orders we return to the simple square-wave SLM. The minimum period of such a binary phase grating is twice the pixel pitch, and in general the grating period must be an integer multiple of twice the pixel pitch (to minimise the power lost to the zeroth grating order), such that the possible output angles are given by:

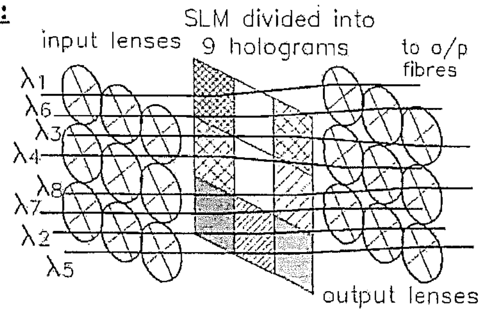
$$\sin\theta_Z = m\lambda/(2Zp) \qquad (4)$$

where Z is the integer multiple, and p is the pixel pitch. For any pair of integers, Z_1 and Z_2, a higher-order grating output will be coupled perfectly into the wrong fibre, whenever the following condition holds, for some integer m:

$$m\lambda/(2Z_1 p) = \lambda/(2Z_2 p) \qquad (5)$$

Rearranging this expression we find that $Z_1 = m.Z_2$, in other words we may avoid perfect coupling of the crosstalk if we ensure that we never select a grating period that is an integer multiple of another grating period that we are intending to use: a simple way to achieve this is to use only prime values of Z. We also wish to use the lowest possible values of Z so as to maximise the output angle from the SLM. If we use Z=1, then any other Z is a multiple of this case, so we exclude Z=1. The lowest possible value of Z is then 2.

Figure 7:

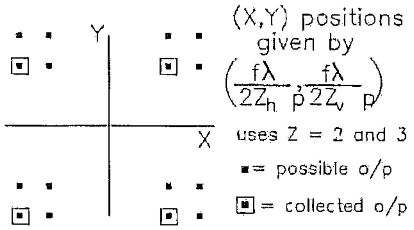


We now investigate specific designs for 'prime number' holographic switches. By making use of both horizontal and vertical directions, we may design the switches such that a single transmissive SLM can perform 1:N switching for every WDM channel on a specific i/p fibre into the routing node. To service an 8-channel WDM system, we divide the SLM into 9 equal area holograms (figure 7). We arrange the wavelength allocation of each hologram, such that crosstalk from an adjacent hologram will be two or more wavelength channels away. Hence we may render insignificant this crosstalk by using wavelength-dependent multiplexing at the routing node output fibres [8].

We may define periodic gratings in both the horizontal and vertical directions. For any pair of (horizontal and vertical) integer multiples of twice the pixel pitch, Z_h and Z_v, and with binary phase operation, 64 % of the diffracted power will be directed to 4 equal o/p's, at o/p positions, (relative to the input fibre), given by:

$$(x, y)_{out} = \left(\pm\frac{f\lambda}{2Z_h p}, \pm\frac{f\lambda}{2Z_v p}\right) \qquad (6)$$

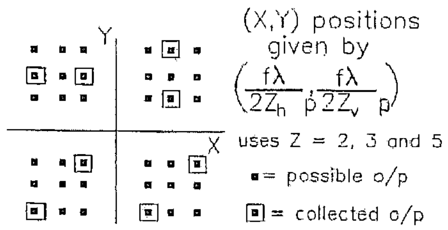
Figure 8: Output positions for the 1:4 switch



We may form a 1:4 switch using the first two prime numbers for Z_h and Z_v. The resulting o/p positions are shown in figure 8. We may collect the o/p light from any of the 4 positions for each (Z_h, Z_v) pair. Our choice of collected orders is that which minimises the required o/p lens focal length for a given separation between o/p waveguides. For the o/p choice shown in figure 8, and a separation, s, between o/p waveguides, the o/p focal length, f_{out}, is given by:

$$f_{out} = 2.4sp/\lambda \qquad (7)$$

Figure 9: Output positions for the 1:8 switch



For a 1:8 switch we use the first three prime numbers (2,3 and 5) for Z_h and Z_v. All o/p positions are as shown in figure 9. For a minimum separation, s_{min}, between o/p waveguides, f_{out} is given by:

$$f_{out} = 6.67 s p / \lambda \qquad (8)$$

The choice of o/p lens focal length, i/p lens focal length and pixel pitch depends on a tradeoff between 3 loss mechanisms.

Dead space loss: the 'dead space' between the active pixel blocks has a width of between 1 and 5 um. The effect of the dead space is to modify the amplitude of each grating order, but the hologram periodicity is not changed by the dead space, so the position of each grating order remains the same. For a dead space of width d, the power diffracted into each switch output is reduced to a fraction T_{ds} of the o/p power with no dead space, independently of the transmission properties of the dead space. The smaller the pixel pitch, the greater the dead space loss. For a holgram with a 'square-wave' pattern in both horizontal and vertical directions, T_{ds} is given by:

$$T_{ds} = \left(1 - \frac{d}{p}\left\{\frac{\pi}{2Z}\sum_{n=1}^{Z-1}\sin\left(\frac{\pi n}{Z}\right)\right\}\right)^4 \qquad (9)$$

For Z = 2, 3 and 5, the value of the {} term is 0.785, 0.907 and 0.967 respectively.

Input loss: A typical SLM silicon backplane device is 14 mm square. When divided into 9 blocks, each hologram is 4.67 mm square. Any of the incident light that falls outside of this hologram area cannot be switched to the correct output. Using a Gaussian beam approximation for the fibre mode, and approximating the hologram to a disk of diameter w, the fraction of input power reaching the hologram is given by (for std telecomms fibre of $1/e^2$ angle 11 degrees):

$$T_{input} = 1 - \exp\{-(w/(0.136 f_{in}))^2\} \qquad (10)$$

where f_{in} is focal length of the i/p lens.

Output loss: On reaching the output fibre, the beam spot-size is magnified by a fraction f_{out}/f_{in}. Assuming the modes of the i/p and o/p fibres to have the same spot-size, the mismatch at the o/p fibre leads to a transmission loss. The fraction of incident power coupled into the o/p fibre is given by:

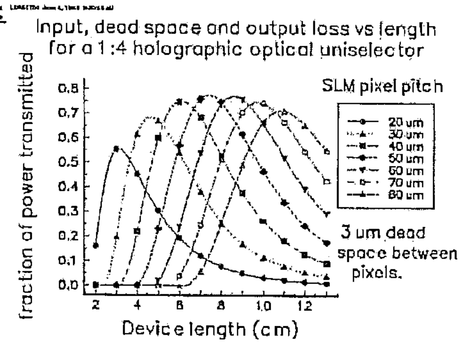
$$T_{out} = \left(\frac{2 f_{out}/f_{in}}{1 + (f_{out}/f_{in})^2}\right)^2 \qquad (11)$$

The overall switch transmission is given by (for a 1.55 um optimised SLM):

$$T_{switch} = 0.16\sin^2(2\theta)\{T_{in}T_{ds}T_{out}\} \qquad (12)$$

For rotation angles of 36 degrees, the term outside the {} brackets is 0.148 (-8.3 dB), and the term inside the {} brackets has been calculated as a function of the pixel pitch and device length, $L=2(f_{out}+f_{in})$, for 8 parallel 1:8 and 1:4 switches from a single SLM. The results are shown in figures 10 and 11, assuming a dead-space of 3 um, and for o/p waveguides separated by at least 250 um. For 1:4 switching the {} term has a maximum value of 0.77, at a fibre to fibre device length of 8 cm and pixel pitch of between 50 and 60 um. For such a 1:4 switch the overall transmission loss should be -9.5 dB. For 1:8 switching the {} term has a maximum value of 0.55 at a device length of 11 cm and pixel pitch of 25 um. For such a 1:8 switch the overall transmission loss would be - 11 dB. The guided-wave equivalent switch block would require 64 semiconductor amplifiers to perform the same function. Hence the insertion loss is irrelevant, compared to the cost savings by using a free-space switch. By reducing the width of the dead space to 1 um, the {} term is increased to 0.77 and 0.90 for the 1:8 and 1:4 switches respectively, leading to a net transmission loss of -9.4 dB and -8.8 dB respectively. The use of prime-only grating periods together with 2-D fanout has lead to an order of magnitude reduction in the switch length, compared to earlier implementations of holographic beam-steering switches [17].

Figure 10:



We will also get crosstalk from the higher grating orders and the non-collected switch orders, if the output position of these orders is close to the output waveguide for another switch position. For the 1:4 switch the closest diffraction order is from a non-collected switch output, and is 50 um away, with a theoretical crosstalk level of under - 400 dB. For the 1:8 switch the closest diffraction order (neglecting the effect of the dead space) is 111 um away. If the dead space excites the m=2 orders, the closest distance to a collected switch output

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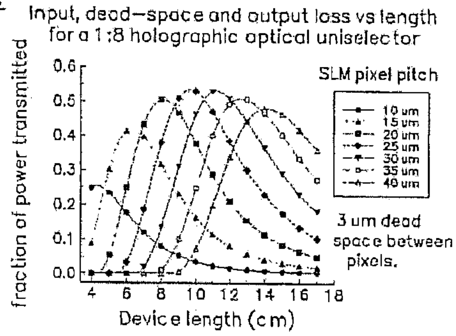
is 55 um. In either case the crosstalk is vanishingly small.

Figure 11:



5 Wavelength demultiplexer design for low crosstalk and high bandwidth.

As for the space-switch, the net crosstalk for the wavelength demultiplexing and multiplexing depends on the method, architecture and implementation used to perform the demux/mux operations. Diffraction-based separation of the wavelength channels followed by spatial filtering with a single-mode waveguide is an excellent method, because the resulting Gaussian wavelength filtering characteristic gives a large bandwidth per channel for a given adjacent channel crosstalk. Cross-channel crosstalk in the space-switch will be eliminated by using a wavelength-dependent multiplexer. Hence we use a dilated wavelength filtering architecture: the crosstalk requirement for the demultiplexer and multiplexer is < - 25 dB each, to achieve a net crosstalk of < - 50 dB.

Guided wave devices: Planar silica devices are frequently used for wavelength demux/mux operations: we were interested in investigating any 'background' crosstalk that might occur in such technology. The dominant manufacturing defect in glasses is inhomogeneities in the refractive index: any initial ripples in the waveguide walls can be removed by the reflow process. The index inhomogeneities lead to Rayleigh scattering losses: photons are coupled from the fundamental mode to the substrate and radiation modes of the planar device. This scattering can be interpreted as being equivalent to a given probability (per unit length) of a photon being coupled out of the waveguide. On reaching an adjacent waveguide, the photon will have the same probability of being coupled into this waveguide. Hence the Rayleigh scattering can lead to a 'background' level of crosstalk, even for waveguides far enough apart to suppress evanescent coupling. Detailed analysis shows that the absolute crosstalk, C, between two parallel waveguides is given by:

$$C = \lambda (L\alpha)^2 / (4\pi^2 N D) \qquad (13)$$

where L is the length of waveguides, D their separation, N is the substrate index and all other symbols have their usual meaning. For a 1 cm length of 2 parallel waveguides, 50 um apart, the theoretical crosstalk is - 65 dB and -45 dB, for waveguide losses of 0.1 dB/cm and 1 dB/cm respectively.

The dominant crosstalk therefore will depend on the wavelength filtering characteristics of the chosen filter method. For a diffraction-based device, the crosstalk, X, for a given channel FWHM bandwidth and wavelength channel separation (H) is given by:

$$X(\mathrm{dB}) \sim -12(H/FWHM)^2 \qquad (14)$$

For a crosstalk level of - 30 dB, the bandwidth is 63.4 % of the channel separation. If all channels are collected from the same diffraction order in a confocal system, the o/p waveguide separation for a given bandwidth is given by:

$$s = 2x\sqrt{\ln 2}.(H/FWHM) \qquad (15)$$

For a guided-wave device we find that the required o/p separation between planar silica waveguides would be 9 um. For such close spacings there would be significant evanescent crosstalk between the waveguides. Therefore it seems unlikely that guided-wave devices will be able to supply high bandwidth and low crosstalk.

Free-space devices: For blazed gratings, we can achieve the required bandwidth even for o/p fibres 125 um apart by using a separate (converging) microlens for each output fibre [20]. However, for narrow channel spacings the required device lengths become prohibitively long and lead to thermal stability problems. In order to reduce the device length we may reduce the grating period. However, as the grating period approaches the optical wavelength, the boundary conditions feel very different for electric fields parallel to, and perpendicular to the grating lines: for given polarisation directions all but the zeroth grating order can become evanescent, such that the diffracted power drops dramatically for all useful grating orders. Hence the devices become very polarisation sensitive. In addition, blazed gratings are used in reflection so that the background scattering will be much higher than for a holographic transmission grating. In the next section we show that we may overcome these problems by using a binary-phase hologram.

6 Circular wavelength demultiplexer using binary-phase gratings.

While dynamic binary-phase holograms can be synthesised with an SLM, fixed binary-phase holograms are made by a lithographic process, and for feature sizes of the order of a micron, they can be stamped out from a master grating.

In general, (fixed) binary-phase holograms can be designed to produce any number of equal amplitude diffraction orders. For an M-channel system, a binary-phase output with M equal diffraction orders will act as a combined power splitter and diffraction-based filter: so we may collect ANY M channels from an incoming WDM ensemble. Because we no longer need to collect several wavelength channels from the same grating order, the channel bandwidth is not constrained by the o/p waveguide separation [21]. We then find that the device length becomes independent of the channel separation, so we can build compact and stable free-space demultiplexers. The bandwidth per channel is given by:

$$FWHM = \frac{x2\sqrt{\ln 2}(1-(m/Q)^2\lambda^2)^{3/2}}{f(m/Q)} \quad (16)$$

The result shows that for a 40 nm optical window the bandwidth depends only weakly on the optical wavelength: for a given lens focal length (f) the bandwidth depends mainly on (m/Q), where (m/Q) defines the output angle for a given wavelength (as in (3)). Therefore we may collect M channels of almost exactly equal bandwidth, by designing a binary-phase hologram to produce M equal-sized diffraction orders on the perimeter of a circle in (m/Q) space.

We have used computer optimisation techiques to design a binary-phase hologram to give us 8 main diffraction orders on a circle. The symmetry of the design (figure 12) is such that the whole hologram will not be changed by rotation through 90 degrees. Hence the diffraction efficiency should be polarisation independent, even for very narrow channel spacings.

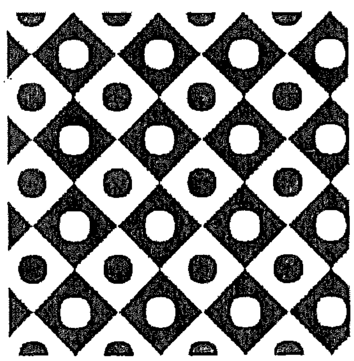
The diffraction orders are shown in figure 13: the output angle for the 8 main orders is given by

$$\sin\theta = \sqrt{5}\lambda/Q \qquad (17)$$

where Q is the grating period. The minimum feature size on the hologram is estimated to be 17 % of the grating period. The estimated diffraction efficiency into these 8 orders is between 60 % and 64 % : therefore the maximum holographic insertion loss is -11.2 dB.

Figure 12:

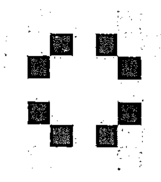
hologram design



A circular binary-phase demultiplexer allows us to have channel spacings defined in terms of either frequency or wavelength difference. For a crosstalk level of - 30 dB the FWHM bandwidth must not exceed 64 % of the channel separation. We have calculated the device length and mean output radius necessary to provide this performance, for postulated channel separations of 25 GHz, 100 GHz, 2 nm and 4 nm, and for minimum feature sizes that are

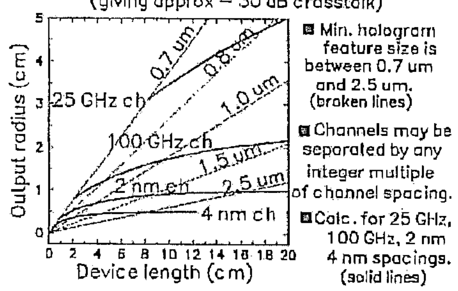
Figure 13:

2-D diffraction orders in the hologram output



no less than 0.7 um, allowing mass-production from a master grating. The results (figure 14), show that for 4 nm channel spacing, the device length can be below 1 cm, while even for 25 GHz channel spacing the device length can be as short as 8 cm. Such short lengths should help improve the device thermal stability.

Figure 14: Circular wavelength demultiplexer with 8 outputs
Parameters for bandwidth=64% of channel spacing
(giving approx – 30 dB crosstalk)



The centre wavelength for each channel may be adjusted by small changes in the radial position of the output fibre, according to:

$$(\delta r) = (\delta\lambda)x2\sqrt{\ln 2}/FWHM \quad (18)$$

7 Conclusions.

Future optical routing networks using high density wavelength division multiplexing will require optical space switches and wavelength demultiplexers with very low crosstalk and high fractional bandwidth, in order to avoid severe problems due to homodyne beat noise.

Comparing different guided-wave and free-space switching methods, we identify free-space beam-steering as the method most suited for providing low crosstalk. Comparing different switch implementations, we predict a background level to the crosstalk in integrated semiconductor guided-wave devices, even for switch elements with infinite extinction ratio. The background level varies with the square of the device length, and could be as high as - 50 dB for a 1 mm long device. For free-space switching with direct output into single-mode fibres, we show that the 'background' crosstalk may be suppressed to - 80 dB, by using the natural coupling properties of Gaussian beams to single-mode fibres. We present a novel implementation for beam-steering devices based on phase-only spatial light modulators. Our new design uses the properties of prime numbers to eliminate crosstalk from higher diffraction orders, and makes use of 2-D fanout to design compact devices with low insertion loss.

We also consider the design of low crosstalk and high bandwidth wavelength demultiplexers: we show that it may be difficult to combine both properties in a guided-wave implementation. We present a new design for a free-space wavelength demultiplexer based on a fixed binary phase hologram. Our new design acts as a combined power splitter and diffraction-based filter, to collect any 8 channels from an incoming WDM ensemble with channel spacings as low as 25 GHz. The device design makes use of 2-D fanout to avoid the polarisation sensitivity of a blazed-grating approach and leads to very compact devices: for a minimum hologram feature size of 0.7 um, large enough to allow mass-production from a 'master' grating, the device lengths vary from 8 cm for channels 25 GHz apart, down to 1 cm for channels 4 nm apart.

8 Acknowledgements.

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Variable Passband Optical Add-Drop Multiplexer Using Wavelength Selective Switch

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Abstract: We propose a novel application of a liquid-crystal based wavelength selective switch that offers user configurable, variable passband optical add-drop multiplex for 10 and 40 Gbps DWDM network systems.

Introduction

A wavelength selective switch (WSS) based on free space optics and a liquid-crystal spatial light modulator (LC-SLM) /1/ offers flexible applications as optical add drop multiplexers (OADM) /2-3/, with the benefits of a broad flat top passband profile and continuous filter function between adjacent channels. A WSS switch in general can be configured with 1x1 or 2x2 port arrangements. For example, a 2x2 WSS can be independently configured either for the 'bar' state or for the 'cross' state on individual channel basis. When the adjacent channels are in the same state, the filter function shows a nearly continuous spectrum between the two channel passbands.

For a WSS switch with the LC-SLM technology, the channel filter functions are defined by the pixels widths and positions on the SLM, where the spectrum of the DWDM signal coincides. In conventional applications, there is usually a one-to-one relationship between the DWDM channels and the pixels. In our new approach, we consider grouping two or more adjacent pixels in the same states, allowing the filter bandwidth to be adjusted in a quasi-continuous fashion. By grouping the pixels in this manner, the filter function can accommodate wider signal spectra, increased transmitter wavelength tolerances, and/or flexible channel plans. Further, groups of adjacent wavelengths can be added and dropped with essentially flat filter characteristics across the add/drop range. The net benefit is to add unprecedented flexibility to OADM functionality, enabling new methods to be employed in the design of DWDM systems.

The WSS used in our study has granularity of 50 GHz with 80 pixels. In our example, two-pixel or three-pixel groups can offer a 75-GHz or 125-GHz passband width, respectively, whereas the single-pixel passband width is 25 GHz. A broader passband width is a critical requirement for transmission at higher data rates or with a highly chirped transmitter such as directly modulated laser diodes. In this paper, we discuss variable channel-width OADM applications of WSS for 10- and 40-Gbps externally modulated optical transmissions, to allow flexible channel spaces and passband widths in a DWDM network system.

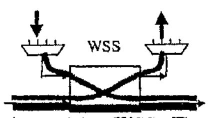

Fig.1 OADM node model a WSS. The dark gray curve illustrates the express signal path, and the light green curve illustrates the add/drop signal path.

WSS OADM Model

Utilizing the functionality of a 2x2 switch, WSS OADM is achieved as shown in Fig.1. Both add and drop ports require terminal DWDM multiplexer and demultiplexer to combine and separate the individual channels on the single fibers. One of the design challenges related to OADM equipment in long-haul systems is to achieve flexibility of add/drop channels, while at the same time avoiding narrowing or degrading the spectral passband for express (non-dropped) channels. Applying the grouped pixel operation of WSS, we can achieve a flexible channel plan with arbitrary channel spacing and passband width for optically transparent network systems. The benefits of such applications can potentially maximize the use of available fiber bandwidth under non-linear fiber impairment constraints and offer OADM flexibility for applications with multi line rate and transmitter types.

Results and discussions

An 80-pixel WSS with 50 GHz center-to-center pixel spacing is used to study the transport performance of the grouped-pixel OADM. This particular device has a 25-GHz single-pixel passband width with 0.2 dB insertion loss ripples and the same isolation bandwidth with better than 35 dB isolation, in the worst case where the adjacent pixels are in the opposite states. Fig.2 shows the insertion loss measurements of single pixel and two-pixel group filter functions, with a wavelength-scanning continuous-wave laser source. Because there is a gap between the pixels, the insertion loss data show approximately 0.3-dB insertion loss ripple in this inter-pixel region. The main focus of our study is to understand the system penalty in this inter-pixel region for grouped pixel channel assignments.

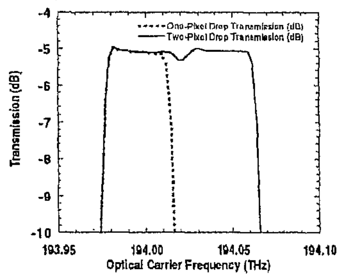

Fig.2 Typical transmission spectra of one-pixel and two-pixel group with the 'cross' state. The adjacent pixels are set to the 'bar' state for express traffic. The effect from terminal DWDM demultiplexer filter function is not included. A two-pixel group drop shows a 75-GHz continuous passband filter function.

We experimentally measure the system penalty of 10 Gbps externally modulated laser transmission. The set-up consists of a tunable laser source, an NRZ lithium niobate modulator, and an optically pre-amplified receiver. The bit-error-rate measurements with a (2^{31}-1) word-length pseudo-random bit sequence (PRBS) is conducted to measure the Q

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factor of the system performance. The back-to-back performance of this system is 11.4 dBQ, where $dBQ \equiv 10 \log Q$. In order to determine the penalty in the inter-pixel region, we set two adjacent pixels to the cross state, and measure Q factors as a function of fine transmitter wavelength steps. The result is presented in Fig. 3 that shows the Q penalties less than 0.3 dBQ in the inter-pixel region, and a passband width of approximately 75 GHz.

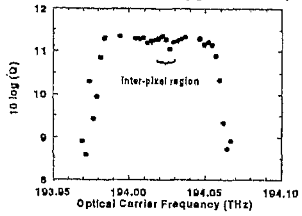


Fig. 3 Q factor performance of 10 Gbps OADM versus optical carrier frequency over a two-pixel group drop state.

The same two-pixel drop state can handle 40-Gbps transmission. In order to generate 40-Gbps optical data, we use an optical time division multiplex (OTDM) and demultiplex technology by use of electro-absorption modulators (EAM). In the transmitter, an EAM generates 20-GHz RZ pulse train with a 40% duty ratio. The pulses are then modulated by a lithium niobate modulator driven by a 20-Gbps PRBS with a (2^{23}-1) word length. The resulting RZ signal is then multiplexed coherently in the same polarization by a 3-dB coupler with phase-stabilized relative time delays to create a 40-Gbps pseudo-NRZ optical signal. At the receiver, an EAM is used to demultiplex 40 Gbps to 10 Gbps for BER measurements. One of the OTDM channels is chosen arbitrarily at the receiver as we maintain nearly the same performance in all channels. The back-to-back performance of the system is 12.6 dBQ. Fig. 4 shows the result of a two-pixel drop applications. This data shows the capability of handling 40 Gbps traffic with two 50-GHz pixels and no pronounced penalty when the carrier frequency coincides with the inter-pixel region.

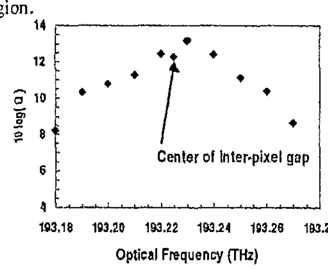


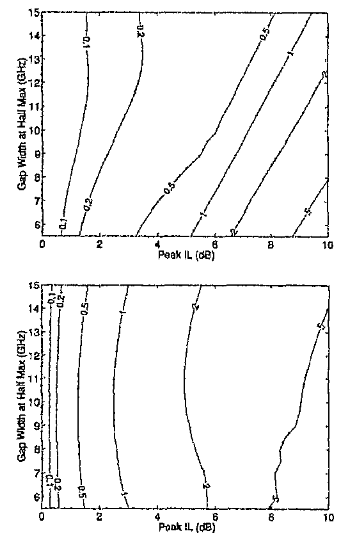
Fig. 4 Q factor performance of 40 Gbps OADM versus optical carrier frequency over a two-pixel group drop state.

The impact of the inter-pixel insertion loss penalty is further analyzed with numerical simulations to assess the requirement for 25-GHz pixel group channel OADM applications. The inter-pixel insertion loss or the transfer function T is modeled by

$$T = 1 - \beta \sum_i \exp\left(-(f - f_i)^2 / f_a^2\right)$$

where f_i's are the frequency positions of centers of inter-pixel gaps, and f_a defines the width of an inter-pixel gap. Parameter f_a can be derived from a 50% full width f_H by a simple equation of $f_a = f_H / \sqrt{2\ln(2)}$. Note that this does not appear as a 3-dB change in the insertion loss measurement in the dB scale. Parameter β defined the depth of insertion loss modulation at the center of the inter-pixel region. The frequency-domain optical signal at the receiver is obtained by the product of transmission spectrum and the transfer function. The corresponding time domain signal is calculated with inverse discrete Fourier transform to obtain an eye-pattern. The eye penalty is then estimated with respect to the eye opening in the absence of the WSS transfer function. In this analysis, we exclude the penalty from power loss. The penalty is, of course, a function of optical carrier frequency (wavelength). In the following results, we search for the worst case penalty by changing optical carrier frequency with a 2-GHz step.

The results of the numerical simulation are shown in Figs. 5(a) and 5(b) for 10- and 40-Gbps transmissions, respectively. In the plots, the eye penalties in dB are shown as contours as a function of the excess insertion loss and the width of the inter-pixel region. The penalty in a practical WSS design space is a weak function of the gap spacing, but a strong function of insertion loss depth. The data shows the insertion loss tolerance in the inter-pixel region is as large as 1 dB within a 0.5-dB eye penalty budget for both 10- and 40-Gbps transmissions.



(a)

(b)

Fig. 5 Contour plot of 10-Gbps, (a), and 40-Gbps, (b), eye penalty in dB as a function of insertion loss peak and width of inter pixel region with 25 GHz pixel WSS.

Conclusions

We propose a novel application of wavelength selective switch for variable passband OADM. The channel width and spacing is flexibly configured by operating multiple pixels in groups to expand passband width of a channel. Experimental demonstration of such application is achieved with a 50-GHz, 80-pixel WSS for 10- and 40- Gbps traffic transmission.

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Wavelength-selective 1×4 switch for 128 WDM channels at 50 GHz spacing

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Abstract: We present a reconfigurable wavelength-selective switch that independently distributes 128 input WDM channels to four output ports. The switch is based on bulk optics and MEMS micro-mirrors, exhibits <5 dB insertion loss and flat-top pass-bands, and is well suited for transparent switching of 10 Gb/s signals.

OCIS codes: (060.1810) Couplers, switches, and multiplexers, (230.3990) Microstructure devices, (060.2330) fiber optics communications

The evolution towards transparent optical transport systems, with the use of enabling technologies as fiber amplifiers and WDM transmission, affords cost reduction and performance enhancements over legacy systems. Expensive electronic equipment, such as SONET ADM, is being replaced by optical add-drop multiplexers (OADM), which eliminate the unnecessary regeneration of express traffic channels. The dropped channels are typically detected locally for access or retransmitted onto another line system. Enabling the direct transfer of wavelengths from one line system to another without regeneration will extend the transparency region and reduce the overall network cost.

Transparent switching in today's multi-channel optical communication systems is often accomplished by first demultiplexing (Demux) the ingress WDM channels into separate ports, traversing through a high-port-count optical switch fabric,[1-3] and re-multiplexing (Mux) the channels into common egress fibers for transmission downstream. However, as the channel count and complexity of WDM networks increases, management of the multiple interconnecting fibers between the Demux, switching fabric, and Mux becomes more difficult. This solution also requires a high start-up cost. Integrating the Mux and Demux functionality into the switching device eliminates the need for these interconnecting fibers, as has been demonstrated for reconfigurable wavelength add-drop switches with free-space[4,5] or arrayed waveguide grating[6] (AWG) Mux/Demux technology, as well as optical cross connects with embedded AWG.[7] In this paper, we demonstrate a new transparent switch fabric that distributes any optical wavelengths from an input port to one of four output ports — wavelength-selective 1×4 switch — implemented with free-space optics and micro-electro-mechanical-system (MEMS) mirrors.

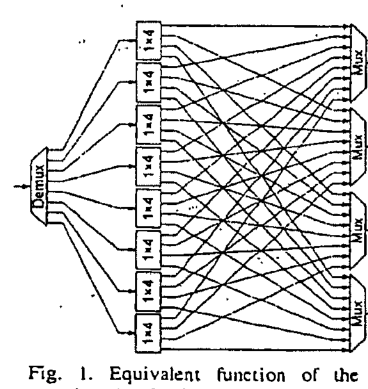

Fig. 1. Equivalent function of the wavelength-selective 1x4 switch using discrete multiplexers and switches.

The multi-port wavelength-selective switch accepts an optical signal comprised of 128 WDM channels at its input port and can independently switch every input optical channel to one of the 4 multiplexed output ports. Thus, every output port carries a subset of the input channels and cumulatively the 4 output ports contain all 128 WDM channels. The functionality provided by the wavelength-selective 1×4 switch could be implemented using discrete components, see Fig. 1 (drawn for simplicity with only 8 wavelength channels), however, as the figure illustrates, this

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solution requires a large fiber count to interconnect the 128 port Demux, the 128 1×4 switches, and the 4 Muxes with 128 ports.

The wavelength-selective 1×4 switch architecture is comprised of two major sub-assemblies (see Fig. 2). The first sub-assembly comprises: a linear array of 5 fibers, 5 collimator lenses each aligned to a fiber in the array, and a high NA condenser lens whose aperture subtends all the collimator lenses. One fiber in the array carries the input WDM channels and the remaining four serve as the output fibers of the switch. This first sub-assembly images all the fiber end-faces onto a single small spot (whose size depends on the magnification ratio of the imaging system), such that the distinct fibers are now separated in angle space only (i.e., propagation direction). The second sub-assembly consists of a resolution lens, a diffraction grating, and a 128 MEMS micro-mirror array. This second sub-assembly disperses the optical channels onto the MEMS mirror array, such that each wavelength channel is incident upon a unique mirror in the array for independent addressing. The switch operates as follows: an input WDM channel from the ingress fiber (see A in Fig. 2) is imaged via the collimator and condenser in the first sub-assembly onto the common spot (B). The channel is subsequently imaged onto a particular micro-mirror (D) via the resolution lens and grating in the second sub-assembly. The mirror is tilted to a prescribed angle (one of 4 possible angles), such that the reflected beam is propagating in a different direction. The reflected beam passes through the same resolution lens and grating, ensuring that the reflected beam will be imaged back to the same common spot (B), yet with a different propagation direction that depends on the angle of the MEMS mirror (D). The beam continues to propagate through the first sub-assembly, which images the reflected beam at the distinct propagation direction onto one of the output fibers (F). Hence, the choice of output port is determined by the tilt angle of the MEMS mirror. The channel pass bands are determined by the amount of spatial dispersion (a function of the resolution lens and grating of the second sub-assembly) and the beam spot size at the output of the first sub-assembly, and can be designed to meet necessary bandwidth requirement.

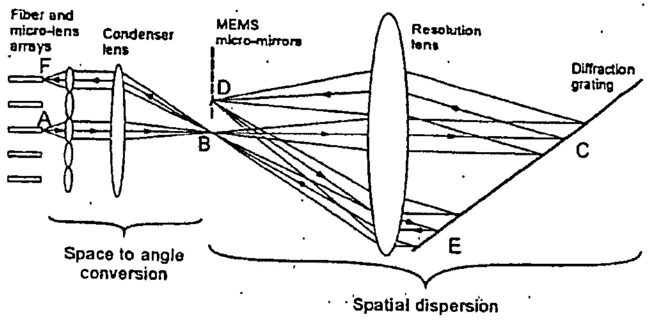

Fig. 2. Schematic of the optical system for the wavelength-selective 1x4 switch.

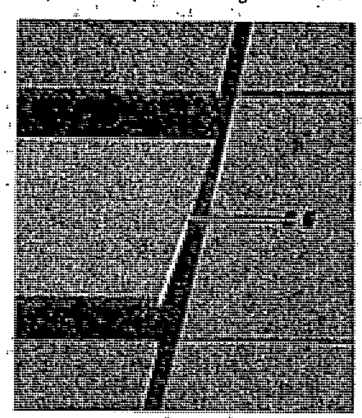

Fig. 3. SEM of actuated MEMS micro-mirror in the array.

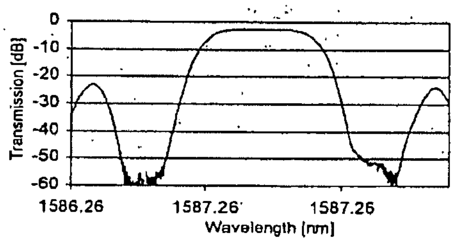

Fig. 4a. Typical passed channel when adjacent channels dropped. Pass band exhibits a broad flat top.

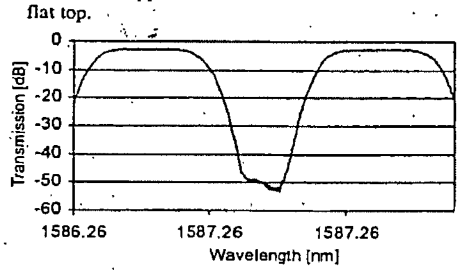

Fig. 4b. Typical rejection of a channel that was diverted to another output port when adjacent channels are transmitted.

We implemented a 128 channel, 50 GHz channel spacing, wavelength-selective 1×4 switch, to match the needs of next-generation transparent transport systems. A custom 100 mm focal length resolution lens and an 1100 gr/mm grating provide the necessary spatial dispersion. We also employ polarization diversity to offset the diffraction grating's polarization dependence. The fibers are imaged onto the common spot (position "B" in Fig. 2) by a magnification ratio of ×3. The MEMS mirrors are etched from a silicon-on-insulator (SOI) wafer, and have two support rods which define a rotation axis and allow for rotation about the axis (see Fig. 3). The mirrors are actuated by an electrostatic attractive force imposed by one of two electrodes per mirror on either side of the axis. The mirrors in our arrangement can rotate up to ±8°, at a max voltage of 115 VDC applied to either mirror electrode. The mirror size in the dispersion direction varies across the spectrum, due to the nonlinear angular dispersion that the high frequency grating exhibits over the 55 nm of bandwidth. The mirror gap is minimized to ensure that the channel pass bands are maximized, resulting in a very high mirror fill ratio of 98%. Typical pass-band widths for a single isolated channel are: -1 dB level @ 35.6 GHz, -3 dB level @ 44.5 GHz (see Fig. 4a). The broad flat-top region enables the switch to be cascaded in transparent systems carrying 10Gbps data. The two peaks at –25 dB level that are visible beyond the nulls of the switched adjacent channels is light scattering from the mirror edges, which couples to all the output ports due to its large angular spectrum. Fortunately, in a real transmission system there is no illumination on the mirror edges, as each WDM channel signal is contained within the mirror area. These peaks are a consequence of the measurement technique. The directivity of the switch, measured when the adjacent channels are switched to a particular port (see Fig. 4b), is better than -30 dB across 27.1 GHz and better than -40 dB across 21.5 GHz.

We found insertion loss (IL) variation across the four output ports. The causes for these port losses are still under investigation, but we suspect that the system alignment can be improved further, as we can optimize the system to any particular port. When fully optimized to a particular port, the IL value is better than 3 dB. When we attempt to minimize the losses on all ports simultaneously, we find a worst case IL of 5 dB (inclusive of one connector loss). The switch does not exhibit any wavelength dependent loss across the wide optical bandwidth (see Fig. 5).

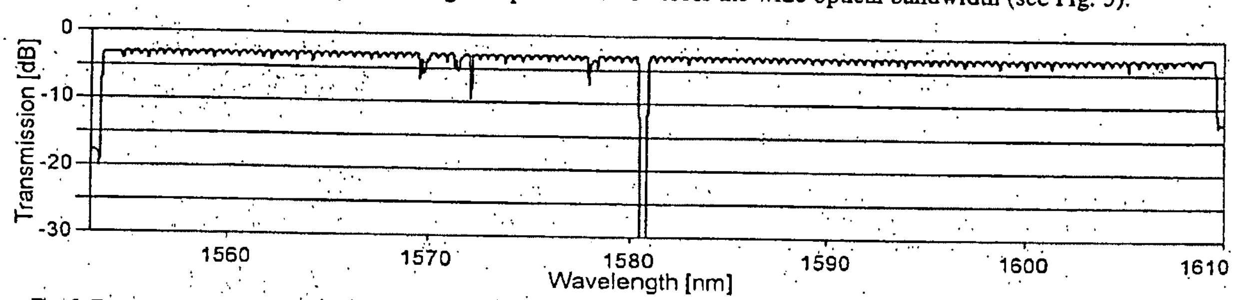

Fig. 5. Transmitted spectrum of all 128 wavelength channels through switch, showing negligible wavelength dependent loss. Few mirrors from the array are non-functioning on this early prototype.

The filter shape effect for a particular single switched wavelength channel was experimentally evaluated by transmitting 10 Gb/s, 33% RZ pseudorandom data through the channel located at 1566.3nm and detuning the optical carrier center frequency from the filter's ITU grid. The power penalty was less than 1 dB for frequency detuning as large as ±15 GHz (see Fig. 6), measured with a 2^{31} length sequence. The power penalty rises quickly beyond ±15 GHz as one of the 10 GHz side tones crosses over the border to the adjacent channel pass band (border, and mirror edge, are at 25 GHz for a 50 GHz based device). This translates to a ±30% channel margin for the transmitter, leading to increased robustness in optical transport systems.

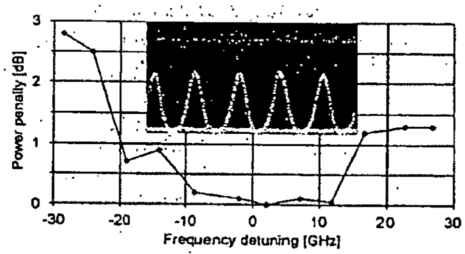

Fig. 6. Power penalty induced by filter shape as a function of detuning the optical carrier frequency. Inset: eye diagram at zero offset.

In summary, we presented a new multi-port wavelength-selective switch fabric based on free-space optics and MEMS micro-mirrors technologies. This free-space arrangement integrated Demux, switch and Mux functionality into one compact, low loss unit with very high channel count and flat-top pass band characteristics. 10 Gb/s RZ data transmission through the switch showed negligible channel degradation and a large channel margin as required for next-generation transparent transport systems.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2873
Filed:	February 23, 2010	Examiner:	Ben, Loha
Confirmation No.:	9661		
For:	Optical Processing		

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Concord, MA 01742-9133
Dated: 9/23/10

Electronic Acknowledgement Receipt

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Application Number:	12710913
International Application Number:	
Confirmation Number:	9661
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Customer Number:	21005
Filer:	Timothy J. Meagher/Katie Norris
Filer Authorized By:	Timothy J. Meagher
Attorney Docket Number:	3274.1003-004
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TJM/jtk(cef)
February 23, 2011

PATENT APPLICATION
Docket No.: 3274.1003-004

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Melanie Holmes

Application No.: 12/710,913 Group: 2873

Filed: February 23, 2010 Examiner: Ben, Loha

Confirmation No.: 9661

For: Optical Processing

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Responsive to the Restriction Requirement dated August 24, 2010, the claims of Group I (Claims 1-13 and 23-30) drawn to light wave directional modulation device having reflection SLM are provisionally elected for prosecution. Applicant reserves the right to file a continuing application or take such other appropriate action as deemed necessary to protect the non-elected inventions. Applicant does not hereby abandon or waive any rights in the non-elected inventions.

The requirement is being traversed for the reasons set forth in detail below.

An extension of time to respond to the Restriction Requirement is respectfully requested. A Petition for an Extension of Time and the appropriate fee are being filed concurrently.

Please amend the application as follows:

Amendments to the Claims

Please amend Claims 14-16 and 19. The Claim Listing below will replace all prior versions of the claims in the application:

Claim Listing

1. (Original) An optical processor having a reflective SLM, a dispersion device and a focussing device, wherein the SLM has an array of controllable elements; wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over at least part of the SLM, and wherein the processor is configured such that the controllable elements display different holograms at chosen locations of the SLM where said light is incident, for controlling directions at which light from respective said locations emerges.

2. (Original) The optical processor of claim 1, having control circuitry adapted to provide plural different holograms to the SLM.

3. (Original)The optical processor of claim 2, wherein said plural different holograms include respective holograms each for performing a different function, whereby controllable elements at respective chosen locations of the SLM may operate as selected ones of the group comprising: an optical add/drop multiplexer, an optical monitoring device, a channel equaliser, a channel controller, a programmable optical source, a programmable optical filter, an optical spectrum analyser, an evaluation device, a reconfigurable wavelength demultiplexer, and a reconfigurable wavelength multiplexer.

4. (Original) The optical processor of claim 1, having a single SLM.

5. (Original)The optical processor of claim 1, having more than one SLM, each having a respective array of controllable elements wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over at least part of each SLM.

6. (Original) The optical processor of claim 1, configured so that said light from a common point on the dispersion device is substantially collimated when incident upon the SLM.

7. (Original) The optical processor of claim 1, further comprising at least one light sensor arranged to provide signals indicative of emergent light.

8. (Original) The optical processor of claim 7, having at least one light sensor arranged to provide signals indicative of light specularly reflected at the SLM.

9. (Original) The optical processor of claim 1, wherein the SLM is a Liquid Crystal on Silicon SLM.

10. (Original) The optical device of claim 1, wherein the SLM incorporates a quarter wave-plate.

11. (Original) The optical processor of claim 1, wherein each hologram occupies an array of controllable elements that has between 10 and 50 controllable elements in at least one dimension.

12. (Original) The optical processor of claim 1, wherein each hologram occupies an array of controllable elements that has a size in at least one dimension that is at least 2 times the 1/e spot half-width of the amplitude distribution of an incident beam in the corresponding direction.

13 (Original) The optical processor of claim 1, wherein the controllable elements are phase-modulating elements

14. (Currently Amended) An optical processor having at least one input and at least two outputs and operable to select between the outputs, the module comprising a reflective [[an]] SLM having an array of pixels, with circuitry constructed and arranged to display holograms on the pixels to route light of different frequencies to respective outputs.

15. (Currently Amended) A method of controlling light comprising

applying an input light beam having plural wavelengths to a reflective SLM ~~controllable optical device~~;

controlling the controllable optical device thereby to select desired wavelengths from the input light beam; and

directing the desired wavelengths to respective output directions.

16. (Currently Amended) The method of claim 15, comprising varying the control of the reflective SLM ~~controllable optical device~~ whereby a subset of the plural wavelengths to a respective output direction is varied.

17. (Original) The method of claim 15, wherein at least two of the output directions contain at least one common wavelength.

18. (Original) The method of claim 17, adapted for multicasting.

19. (Currently Amended) An optical processor having plural inputs and an output, comprising a reflective SLM ~~controllable device~~ for combining wavelengths from the inputs to appear at the output, wherein each input signal may contain any desired set of the plural wavelengths of the output.

20. (Original) The optical processor of claim 19, wherein the or each input signal is at least one broadband optical source.

21. (Original) The optical processor of claim 20, arranged to perform at least one of the group of functions comprising: production of a desired output spectrum and synthesising a comb spectrum.

22. (Original) The optical processor of claim 21, having a controller for varying control of the controllable device whereby an output spectrum may be varied.

23. (Original) A method of operating an optical processor having a reflective SLM having an array of controllable elements, a dispersion device and a focussing device wherein light beams from a common point on the dispersion device are spatially separate when incident upon the SLM, and wherein the SLM is configured to display holograms at respective locations of incidence of light to provide emergent beams having controllable directions, the method comprising delineating groups of individual controllable elements; selecting, from stored control data, control data for each group of - controllable elements of the SLM; generating from the respective selected control data a respective hologram at each group of controllable elements; and varying the delineation of the groups and/or the selection of control data whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

24. (Original) A method of operating an optical device according to claim 23, comprising selecting control of said light beams from the group comprising: control of direction, control of power, focussing, aberration compensation, sampling and beam shaping.

25. (Original) A method according to claim 23, comprising determining, by means of a control device, selection of the groups, selection of control data and delineation of the group boundaries in response to signals from sensors arranged to provide signals indicative of said emerging light.

26. (Original) A method of controlling light comprising:

causing said light to become angularly dispersed by a dispersion device;

focussing, by a focussing device, angularly dispersed light from the dispersion device to provide focussed light;

making said focussed light incident upon a reflective SLM, whereby the light is spatially distributed across at least a part of the SLM, wherein the SLM has an array of controllable elements; and

displaying respective holograms at respective locations of incidence of light to provide emergent light whose direction is controlled by respective holograms.

27. (Original) A method of directing light using a reflective SLM, a dispersion device and a focussing device, wherein the reflective SLM has an array of controllable elements and wherein the arrangement is such that light from a common point on the dispersion device is spatially distributed over the reflective SLM, the method comprising:

causing the - controllable elements to display different holograms at chosen locations whereon light is incident, whereby light from said locations emerges in controllable directions.

28. (Original) The method of claim 27, wherein the controllable elements are phase-modulating elements

29. (Original) A method of measuring at least one spectral property selected from: channel power, channel centre wavelength, channel bandwidth occupied and noise power between channels, the method comprising the method of directing light of claim 26.

30. (Original) An optical processor arranged to function as at least one of the following: an optical add/drop multiplexer, an optical monitoring device, a channel equaliser, a channel controller, a programmable optical source, a programmable optical filter, an optical spectrum analyser, an evaluation device, a reconfigurable wavelength demultiplexer, and a reconfigurable wavelength multiplexer, the processor having a reflective SLM,, a dispersion device and a focussing device, wherein the SLM has an array of controllable elements; wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over the SLM, and wherein the processor is

configured such that the controllable elements display different holograms at chosen locations, whereby light from said locations emerges in respective directions, the directions deviating from a direction of specular reflection.

TJM/jtk(cef)
February 17, 2011

PATENT APPLICATION
DOCKET NO. 3274.1003-004

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Melanie Holmes

Application No.: 12/710,913 Group: 2873

Filed: February 23, 2010 Examiner: Ben, Loha

Confirmation No.: 9661

For: Optical Processing

CERTIFICATE OF MAILING OR TRANSMISSION
I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or is being facsimile transmitted to the United States Patent and Trademark Office on:

_______________ _______________________________
Date Signature

____
Typed or printed name of person signing certificate

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Transmitted herewith is Reply to Restriction Requirement and Amendment for filing in the above-identified application.

☐ Small entity status of this application under 37 CFR 1.9 and 1.27 has been established by a Small Entity Statement previously submitted.

☐ A Small Entity Statement to establish small entity status under 37 CFR 1.9 and 1.27 is enclosed.

The claims fee has been calculated as shown below:

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NO. PREVIOUSLY PAID FOR	PRESENT EXTRA	SMALL ENTITY RATE	SMALL ENTITY ADDIT. FEE	OR	OTHER THAN SMALL ENTITY RATE	OTHER THAN SMALL ENTITY ADDIT. FEE
TOTAL	30	MINUS	* 30		X $ 26	$		X $52	$ 0
INDEP	8	MINUS	** 8		X $110	$		X $220	$ 0
☐ FIRST PRESENTATION OF MULTIPLE DEP. CLAIM					+ $195	$		+ $390	$

* not fewer than 20
** not fewer than 3

TOTAL = $ 0 TOTAL = $ 0

The Application Size Fee has been calculated as shown below:
(Effective for cases filed on or after December 8, 2004)

Actual Sheets (Including current amendment)	Highest No. of Sheets Paid For (At least 100)	No. of Additional Units Required (Increments of 50 sheets)	SMALL ENTITY Rate	SMALL ENTITY Total Amount Owed	OTHER THAN SMALL ENTITY Rate	OTHER THAN SMALL ENTITY Total Amount Owed	Payment Sufficient for up to
143	150		X $135	$[ ]	X $270	$[ ]	150 Sheets

Petition for Extension of Time

☒ Applicant hereby petitions to extend the time to respond to the Restriction Requirement dated August 24, 2010 for 5 months from September 24, 2010 to February 24, 2011. The appropriate fee is set forth below.

☐ *[For action-specific language in an extension of time, select the appropriate option from the Firm Templates]*

Please charge Deposit Account No. 08-0380 for the following fees:

☒	Petition for 5 month Extension of Time	$	2,350.00
☐	Claims Fee	$	
☐	Application Size Fee	$	
☐	Other Fees:		
		$	
		$	
	TOTAL:	$	2,350.00

A check is enclosed in payment of the following fees:

☐	Petition for [ ] month Extension of Time	$	
☐	Claims Fee	$	
☐	Application Size Fee	$	
☐	Other Fees:		
		$	
		$	
	TOTAL:	$	

☒ Please charge any deficiency or credit any overpayment in the fees that may be due in this matter to Deposit Account No. 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By ______________________

Timothy J. Meagher
Registration No.: 39,302
Telephone (978) 341-0036
Facsimile (978) 341-0136

Concord, Massachusetts 01742-9133
Dated: 2/23/11

1062036.1

Electronic Acknowledgement Receipt

EFS ID:	9515228
Application Number:	12710913
International Application Number:	
Confirmation Number:	9661
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Customer Number:	21005
Filer:	Timothy J. Meagher/Julie Kertyzak
Filer Authorized By:	Timothy J. Meagher
Attorney Docket Number:	3274.1003-004
Receipt Date:	23-FEB-2011
Filing Date:	23-FEB-2010
Time Stamp:	16:18:53
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$2350
RAM confirmation Number	4207
Deposit Account	080380
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	32741003004feetrans.PDF	186154 29fb7f9e1980e1cd8034133e995f7fe1544a29c9	no	3
Warnings:					
Information:					
2		32741003004RRamd.PDF	585075 e1d14a0485fcc32f7eaf1a2f919080f7b14bc660	yes	9

Multipart Description/PDF files in .zip description

Document Description	Start	End
Response to Election / Restriction Filed	1	1
Claims	2	7
Drawings-only black and white line drawings	8	8
Applicant Arguments/Remarks Made in an Amendment	9	9

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
Warnings:					
Information:					
3	Drawings-only black and white line drawings	32741003004draw.PDF	58168 0c9960dd44ce4f6783fb069a90adabea67177341	no	2
Warnings:					
Information:					
4	Fee Worksheet (PTO-875)	fee-info.pdf	30268 78ff43ea754e25abe42b97d3d475107608476667	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	859665		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Electronic Patent Application Fee Transmittal

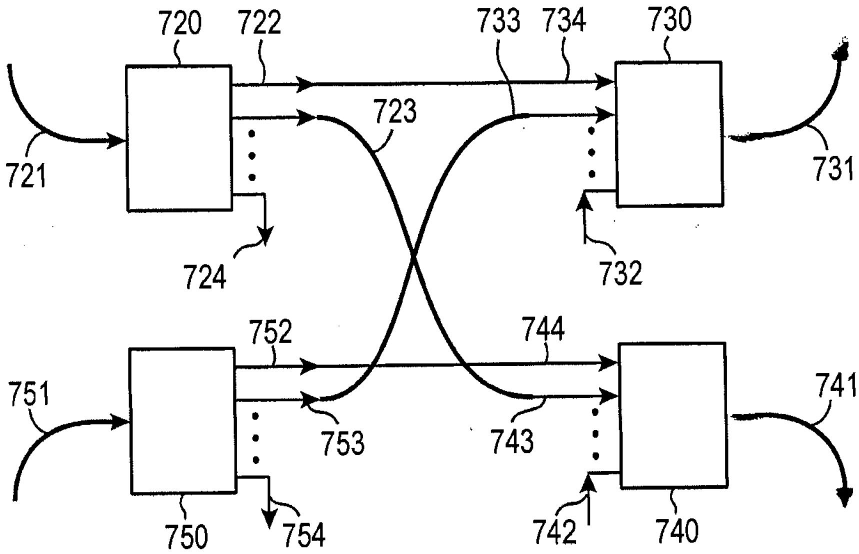
Application Number:	12710913
Filing Date:	23-Feb-2010
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Filer:	Timothy J. Meagher/Julie Kertyzak
Attorney Docket Number:	3274.1003-004

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Extension - 5 months with $0 paid	1255	1	2350	2350

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
		Total in USD ($)		**2350**


720
722
733
734
730
723
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731
724
732
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750
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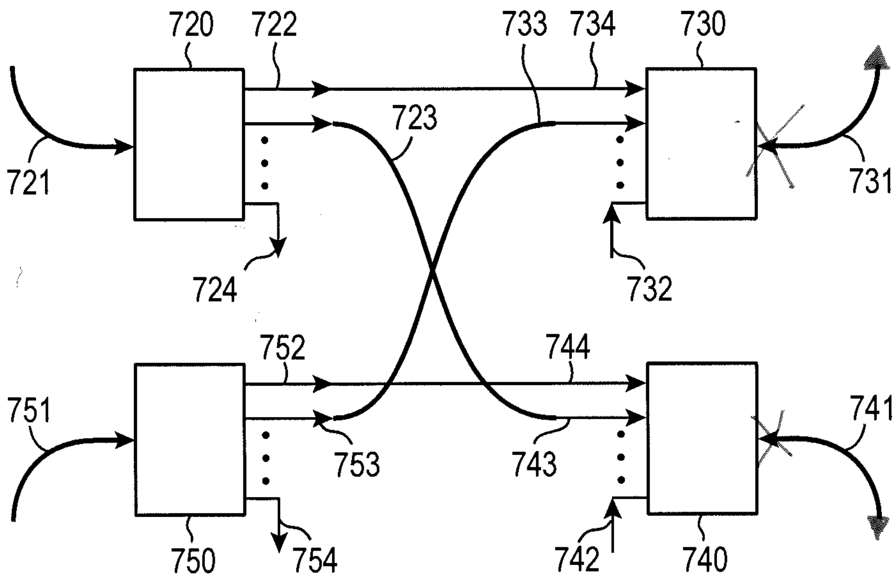
740

FIG. 23


720
722
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742
740

FIG. 23

Amendments to the Drawings

Fig. 23 has been amended to correct output arrows 731 and 741 by reversing the arrows.

Attachment: Replacement Sheet
Annotated Marked-Up Drawings

REMARKS

Claims 1-30 are pending in this application. Claims 14-16 and 19 have been amended to recite a reflective SLM.

The Office Action dated August 24, 2010 required restriction between Claims 1-13 and 23-30 in Group I and Claims 14-22 in Group II. The reason given for the restriction is that the device in claims of Group I use specifically reflective SLM, whereas for Group II, the beam combining or dividing has no association with light reflection.

With the amendment to Claims 14-16 and 19 to recite a reflective SLM, Applicant believes the claims of both Groups I and II relate to a single general inventive concept under PCT Rule 13.1 Therefore, Applicant respectfully requests withdrawal of the restriction requirement under 35 USC Sections121 and 372.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By ____________________
Timothy J. Meagher
Registration No. 39,302
Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133
Dated: 2/23/11

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number	Filing Date	
12/710,913	02/23/2010	☐ To be Mailed

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY ☐ RATE ($)	FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
			TOTAL			TOTAL	

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

AMENDMENT

02/23/2011	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 30	Minus	** 30	= 0	X $ =		OR	X $52=	0
Independent (37 CFR 1.16(h))	* 8	Minus	***8	= 0	X $ =		OR	X $220=	0
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	**0**

AMENDMENT

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)	OR	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/DALE HALL/

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

21005 7590 05/06/2011

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

EXAMINER	
BEN, LOHA	
ART UNIT	PAPER NUMBER
2873	
MAIL DATE	DELIVERY MODE
05/06/2011	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

PTOL-90A (Rev. 04/07)

Office Action Summary	Application No. 12/710,913	Applicant(s) HOLMES, MELANIE	
	Examiner LOHA BEN	Art Unit 2873	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on 23 February 2011.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) 1-30 is/are pending in the application.

4a) Of the above claim(s) 14-22 is/are withdrawn from consideration.

5)☒ Claim(s) 1-13,23,24,26-28 and 30 is/are allowed.

6)☒ Claim(s) 25 and 29 is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☒ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on 23 February 2010 and 23 February 2011 is/are: a)☐ accepted or b)☒ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☒ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date 0210;0610(2);0710;0910.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☒ Other: See Continuation Sheet.

Continuation of Attachment(s) 6). Other: A copy of (corrected) disapproved Fig. 23.

DETAILED ACTION

Applicant's election with traverse of claims 1-13 and 23-30 in the reply filed on February 23, 2011 is acknowledged. The traversal is on the ground(s) that is based on **only a portion of the indication given by the Examiner** that is associated with the difference between “**reflective** SLM" of Group I and “SLM” of Group II. This is not found persuasive because the mere insert of the word “reflective” in front of the word "SLM" in claims of Group II would not create a single general inventive concept under PCT Rule 13.1 without considering the fact that claims of Group II do not have any “dispersion device” and “focusing device”. The latter two devices would require different fields of searches.

The requirement is still deemed proper and is therefore made FINAL.

Claims 14-22 are withdrawn from further consideration pursuant to 37 CFR 1.142(b), as being drawn to a nonelected claims, there being no allowable generic or linking claim. Applicant timely traversed the restriction (election) requirement in the reply filed on February 23, 2011.

Specification

The disclosure is objected to because of the following informalities:

In the Specification

In paragraph [0408]: on line 1, numeral “700” is not seen in Fig. 29.

In paragraph [0409]: on line 3, “722” should be – 721 --.

In paragraphs [0409]-[0411](pages 75-76): numerals 720-724, 731-733 and 741-743 of Fig. 29 appear to indicate elements different than those represented by numerals 720-724, 731-733 and 741-743 of Fig. 23.

In paragraphs [0447]-[0458](pages 90-91): numerals 720-724, 731-733 and 741-743 of Fig. 23 appear to indicate elements different than those represented by the same numerals 720-724, 731-733 and 741-743 of Fig. 29.

In the Claims

In claim 1: on line 2, after “elements”, “;” should be replaced with -- , -- (comma).

In claims 13 and 28: on line 2, after “elements”, -- . – (period) should be inserted.

In claim 23: on line 2, after “device”(second occurrence), -- , -- (comma) should be inserted; and on line 7, before “controllable”, “-“ should be deleted.

In claim 24: on line 1, “device” should be – processor --.

In claim 26: on bottom line, after “by”, -- the – should be inserted.

In claim 27: on line 5, before “controllable”, “-“ should be deleted.

In claim 30: on line 5, after “SLM”, “,,” should be replaced with -- , --; and on line 7, “;” should be replaced with -- , --.

In the Drawings

As pointed out above, numerals 720-724, 731-733 and 741-743 of Fig. 23 appear to indicate elements different than those represented by the same numerals 720-724, 731-733 and 741-743 of Fig. 29.

Numeral “700” disclosed on line 1 of paragraph [0408] is not seen illustrated in Fig. 29.

Appropriate correction is required.

Remarks: The drawing Fig. 23 filed on February 23, 2011 has been disapproved pending correction reflecting indications given above relating to Figs. 23 and 29.

INFORMATION ON HOW TO EFFECT DRAWING CHANGES

Replacement Drawing Sheets

Drawing changes must be made by presenting replacement sheets which incorporate the desired changes and which comply with 37 CFR 1.84. An explanation of the changes made must be presented either in the drawing amendments section, or remarks, section of the amendment paper. Each drawing sheet submitted after the filing date of an application must be labeled in the top margin as either “Replacement Sheet” or “New Sheet” pursuant to 37 CFR 1.121(d). A replacement sheet must include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. The figure or figure number of the amended drawing(s) must not be labeled as “amended.” If the changes to the drawing figure(s) are not accepted by the examiner, applicant will be notified of any required corrective action in the next Office action. No further drawing submission will be required, unless applicant is notified.

Identifying indicia, if provided, should include the title of the invention, inventor’s name, and application number, or docket number (if any) if an application number has not been assigned to the application. If this information is provided, it must be placed on the front of each sheet and within the top margin.

Annotated Drawing Sheets

A marked-up copy of any amended drawing figure, including annotations indicating the changes made, may be submitted or required by the examiner. The annotated drawing sheet(s) must be clearly labeled as “Annotated Sheet” and must be presented in the amendment or remarks section that explains the change(s) to the drawings.

Timing of Corrections

Applicant is required to submit acceptable corrected drawings within the time period set in the Office action. See 37 CFR 1.85(a). Failure to take corrective action within the set period will result in ABANDONMENT of the application.

If corrected drawings are required in a Notice of Allowability (PTOL-37), the new drawings MUST be filed within the THREE MONTH shortened statutory period set for reply in the "Notice of Allowability." Extensions of time may NOT be obtained under the provisions of 37 CFR 1.136 for filing the corrected drawings after the mailing of a Notice of Allowability.

Claim Rejections - 35 USC § 112

The following is a quotation of the second paragraph of 35 U.S.C. 112:

> The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

Claims 25 and 29 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

In claim 25: on line 4, "said emerging light" has no antecedent basis.

In claim 29: in the preamble, the method called for is "a method of measuring at least one spectral property . . ." wherein on line 3 of the claim, the method comprises "the method of directing light of claim 26". In the context, the connection between "measuring" and "directing" cannot be seen. Further, on line 3, it is not clear what king of "light" of claim 26 is being directed. Is it "an incident light", a focused light", "an emergent light", or "a dispersed light"?

Allowable Subject Matter

Claims 1-13, 23, 24, 26-28 and 30 are allowable.

Claims 25 and 29 would be allowable if rewritten to overcome the rejection(s) under 35 U.S.C. 112, 2nd paragraph, set forth in this Office action and to include all of the limitations of the base claim and any intervening claims.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to LOHA BEN whose telephone number is (571)272-2323. The examiner can normally be reached on M-SAT, generally between 12:01 p.m. to 8:00 p.m.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Ricky Mack, can be reached on M-F, at (571) 272-2333. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

May 4, 2011

/Loha Ben/
Primary Examiner, Art Unit 2873

Notice of References Cited	Application/Control No. 12/710,913	Applicant(s)/Patent Under Reexamination HOLMES, MELANIE	
	Examiner LOHA BEN	Art Unit 2873	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-7,796,319 B2	09-2010	MacKinnon et al.	359/239
*	B	US-7,151,601 B2	12-2006	MacKinnon et al.	356/326
*	C	US-6,781,691 B2	08-2004	MacKinnon et al.	356/326
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Index of Claims	Application/Control No. 12710913	Applicant(s)/Patent Under Reexamination HOLMES, MELANIE
	Examiner LOHA BEN	Art Unit 2873

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	08/17/2010	05/04/2011							
	1	÷	=							
	2	÷	=							
	3	÷	=							
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	26	÷	=							
	27	÷	=							
	28	÷	=							
	29	÷	✓							
	30	÷	=							

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BIB DATA SHEET

CONFIRMATION NO. 9661

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
12/710,913	02/23/2010 **RULE**	359	2873	3274.1003-004

APPLICANTS
Melanie Holmes, Suffolk, UNITED KINGDOM;

** **CONTINUING DATA** *************************
This application is a CON of 11/978,258 10/29/2007
which is a CON of 11/515,389 09/01/2006 PAT 7,612,930
which is a DIV of 10/487,810 09/10/2004 PAT 7,145,710
which is a 371 of PCT/GB02/04011 09/02/2002

** **FOREIGN APPLICATIONS** *************************
UNITED KINGDOM 0121308.1 09/03/2001

** **IF REQUIRED, FOREIGN FILING LICENSE GRANTED** **
03/04/2010

		STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
Foreign Priority claimed ☑ Yes ☐ No 35 USC 119(a-d) conditions met ☑ Yes ☐ No Verified and Acknowledged /LOHA BEN/ Examiner's Signature	☐ Met after Allowance Initials	UNITED KINGDOM	36	30	8

ADDRESS

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530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133
UNITED STATES

TITLE

OPTICAL PROCESSING

FILING FEE RECEIVED	FEES	
3110	FEES: Authority has been given in Paper No.____________ to charge/credit DEPOSIT ACCOUNT No.____________ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other ________________ ☐ Credit

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	56	((reflect$5 or mirror$2) WITH ((spatial$2 NEAR5 modulat$3) or SLM$1)) SAME (dispers$5 or grating$1 or diffract$5) SAME (focus$4 or condens$3 or converg$3) SAME control$4	USPAT; EPO; DERWENT	OR	OFF	2011/05/04 14:26
L2	226	((reflect$5 or mirror$2) WITH ((spatial$2 NEAR5 modulat$3) or SLM$1)) SAME (dispers$5 or grating$1 or diffract$5) SAME (focus$4 or condens$3 or converg$3)	USPAT; EPO; DERWENT	OR	OFF	2011/05/04 14:27
L3	195	L2 and control$4	USPAT; EPO; DERWENT	OR	OFF	2011/05/04 14:27
L4	121	L3 and holygra$8	USPAT; EPO; DERWENT	OR	OFF	2011/05/04 14:28
L5	12	359/3,9,11,237-239,279,556,558,559,566.CCLS. and L4	USPAT; EPO; DERWENT	OR	OFF	2011/05/04 14:29
L6	11	356/326,328.CCLS. and L4	USPAT; EPO; DERWENT	OR	OFF	2011/05/04 14:29
L7	0	362/26,602.CCLS. and L4	USPAT; EPO; DERWENT	OR	OFF	2011/05/04 14:30
L8	12	369/103.CCLS. and L4	USPAT; EPO; DERWENT	OR	OFF	2011/05/04 14:30
L9	13	385/15-18,22,31,43,129,133,146,147,901.CCLS. and L4	USPAT; EPO; DERWENT	OR	OFF	2011/05/04 14:31

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Disapproved

/L.B./

05/04/2011

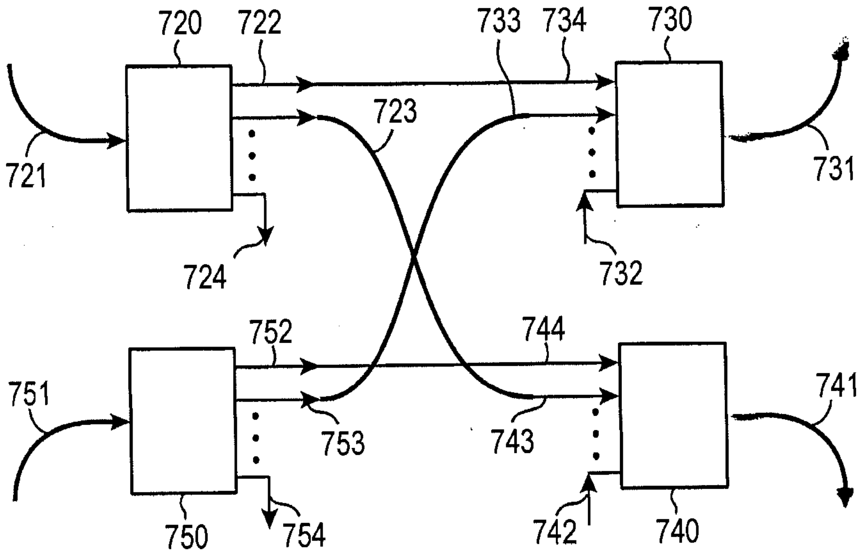

FIG. 23

Mail room date: 02/23/2010

Substitute for form 1449B/PTO

INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION

LISTING OF REFERENCES

February 23, 2010

(Use several sheets if necessary)

ATTORNEY DOCKET NO. 3274.1003-004	APPLICATION NO. 12/710,913	
FIRST NAMED INVENTOR Melanie Holmes	FILING DATE 02/23/2010	
EXAMINER Loha Ben	CONFIRMATION NO. 9661	GROUP 2873

U.S. PATENT DOCUMENTS				
Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
/L.B./	A1	2002/0060760	05-23-2002	Weiner
	A2	6,954,252	10-11-2005	Crossland, et al.
	A3	5,315,423	05-24-1994	Hong
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/L.B./	A21	4,952,010	08-1990	Healey, et al.

EXAMINER /Loha Ben/	DATE CONSIDERED 05/04/2011

961592_1

Substitute for form 1449B/PTO **INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **February 23, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		XXXXXXXXXXXXX APPLICATION NO. XXXXXXXX 12/710,913
	FIRST NAMED INVENTOR Melanie Holmes		XXXXXXXXXXXXX FILING DATE 02/23/2010 XXXXXXXXXXXXX
	EXAMINER Loha Ben	CONFIRMATION NO. XXXX 9661	GROUP 2873

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EXAMINER /Loha Ben/	DATE CONSIDERED 05/04/2011

961592_1

Substitute for form 1449B/PTO **INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **February 23, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004	XXXXXXXXXXXXXX APPLICATION NO. XXXXXXX 12/710,913	
	FIRST NAMED INVENTOR Melanie Holmes	XXXXXXXXXXXXX FILING DATE 02/23/2010 XXXXXXXXXXXXXX	
	EXAMINER Loha Ben	CONFIRMATION NO. XXXX 9661	GROUP 2873

FOREIGN PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Country Code-Number-Kind Code (if known)	DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT	TRANSLATION YES	NO
/L.B./	B1	EP 1 207 418 A1	05/22/2002	Alcatel		
	B2	WO 01 90823 A1	11-29-01	Intelligent Pixels, Inc.		
	B3	WO 01 25848 A2	04-12-01	Thomas Swan & Co., Ltd.		
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	B6	WO 02 079870 A2	10-10-02	Thomas Swan & Co., Ltd.		
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/L.B./	B8	EP 1 053 501 B1	07-23-03	Thomas Swan & Co., Ltd.		

EXAMINER /Loha Ben/	DATE CONSIDERED 05/04/2011

961592_1

Substitute for form 1449B/PTO **INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **February 23, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		XXXXXXXXXXXX APPLICATION NO. XXXXXXX 12/710,913
	FIRST NAMED INVENTOR Melanie Holmes		XXXXXXXXXXXX FILING DATE 02/23/2010 XXXXXXXXXXXX
	EXAMINER Loha Ben	CONFIRMATION NO. XXXX 9661	GROUP 2873

Examiner's Initials	Ref. No.	**OTHER DOCUMENTS** *(Including Author, Title, Date, Pertinent Pages, Etc.)*
/L.B./	C1	Yamazaki, H., *et al.*, "4 x 4 Free Space Optical Switching Using Real-Time Binary Phase-Only Holograms Generated by a Liquid-Crystal Display," *Optical Society of America*, 16(18):1415-1417 (1991).
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/L.B./	C5	Marom, D.M., *et al.*, "Wavelength-Selective 1x4 Switch for 128 WDM Channels at 50 Ghz Spacing," *OFC Postdeadline Paper*, pp. FB7-1-FB7-3 (2002).
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EXAMINER	DATE CONSIDERED
/Loha Ben/	05/04/2011

961592_1

CONSIDERED: /L.B./

Mail room date: 06/14/2010

Substitute for form 1449B/PTO

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION

LISTING OF REFERENCES

June 14, 2010

(Use several sheets if necessary)

ATTORNEY DOCKET NO.	APPLICATION NO.	
3274.1003-004	12/710,913	
FIRST NAMED INVENTOR	FILING DATE	
Melanie Holmes	February 23, 2010	
EXAMINER	CONFIRMATION NO.	GROUP
XXXXXXXX LOHA BEN	9661	XXXX 2873

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
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We are not listing separately any prior U.S. Patent Office communications regarding the cited application(s) because the Examiner has access to any such actions through PAIR.

EXAMINER	DATE CONSIDERED
/Loha Ben/	05/04/2011

989678_1

CONSIDERED: /L.B./

TS0002396

Substitute for form 1449B/PTO **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **June 24, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		APPLICATION NO. 12/710,913
	FIRST NAMED INVENTOR Melanie Holmes		FILING DATE February 23, 2010
	EXAMINER XXXXXXX LOHA BEN	CONFIRMATION NO. 9661	GROUP XXXX 2873

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
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We are not listing separately any prior U.S. Patent Office communications regarding the cited application(s) because the Examiner has access to any such actions through PAIR.

EXAMINER	DATE CONSIDERED
/Loha Ben/	05/04/2011

995670_1

CONSIDERED: /L.B./

Substitute for form 1449B/PTO **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **July 29, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		APPLICATION NO. 12/710,913
	FIRST NAMED INVENTOR Melanie Holmes		FILING DATE February 23, 2010
	EXAMINER Loha Ben	CONFIRMATION NO. 9661	GROUP 2873

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
/L.B./	A50	6,141,361	10-31-2000	Mears, *et al.*

We are not listing separately any prior U.S. Patent Office communications regarding the cited application(s) because the Examiner has access to any such actions through PAIR.

EXAMINER /Loha Ben/	DATE CONSIDERED 05/04/2011

1004888_1

CONSIDERED: /L.B./

Mail room date: 09/23/2010

Substitute for form 1449B/PTO **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **September 23, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004	APPLICATION NO. 12/710,913	
	FIRST NAMED INVENTOR Melanie Holmes	FILING DATE February 23, 2010	
	EXAMINER Ben, Loha	CONFIRMATION NO. 9661	GROUP 2873

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
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	A59	6,603,894 B1	08-05-2003	Pu
	A60	6,654,516 B2	11-25-2003	So
	A61	6,707,959 B2	03-16-2004	Ducellier *et al.*
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	A64	6,920,261 B2	07-19-2005	Inada *et al.*
/L.B./	A65	7,536,108 B2	05-19-2009	Hirano *et al.*

We are not listing separately any prior U.S. Patent Office communications regarding the cited documents because the Examiner has access to any such actions through PAIR.

EXAMINER /Loha Ben/	DATE CONSIDERED 05/04/2011

1019906.1

TS0002399

Substitute for form 1449B/PTO **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **September 23, 2010** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		APPLICATION NO. 12/710,913
	FIRST NAMED INVENTOR Melanie Holmes		FILING DATE February 23, 2010
	EXAMINER Ben, Loha	CONFIRMATION NO. 9661	GROUP 2873

Examiner's Initials	Ref. No.	**OTHER DOCUMENTS** *(Including Author, Title, Date, Pertinent Pages, Etc.)*
/L.B./	C7	Holmes, M.J. *et al.*, "Low Crosstalk Devices for Wavelength-Routed Networks," *IEEE Colloquium on Guided Wave Optical Signal Processing*, pages 1-10 (June 8, 1995).
/L.B./	C8	Rhee, J.-K. *et al.*, "Variable Passband Optical Add-Drop Multiplexer Using Wavelength Selective Switch," *Proc. 27th Eur. Conf. on Opt. Comm. (ECOC'01 – Amersterdam)*, pp. 550-551 (9/30/2001 through 10/4/2001).
/L.B./	C9	Marom, D.M., *et al.*, "Wavelength-Selective 1x4 Switch for 128 WDM Channels at 50 Ghz Spacing," *OFC Postdeadline Paper*, pp. FB7-1-FB7-3 (Mar. 2002).

***Copies of any U.S. Office Communications or non-published U.S. Patent Applications are not being provided because the examiner has access to such documents through PAIR.**

EXAMINER /Loha Ben/	DATE CONSIDERED 05/04/2011

1019906.1

CONSIDERED: /L.B./

TS0002400

WEST Search History for Application 12710913

Creation Date: 2011050316:39

Prior Art Searches

Query	DB	Op.	Plur.	Thes.	Date
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME hologra$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME hologra$8 SAME display$3 SAME control$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME hologra$8 SAME display$3 SAME control$4.CLM.	PGPB	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME hologra$8 SAME (display$3 or delineat$3) SAME control$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME hologra$8 SAME (display$3 or delineat$3) SAME control$4.CLM.	PGPB	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
(((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4) and (display$3 or comput$3 or process$3 or delineat$3) SAME hologra$8 SAME control$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12710913	HOLMES, MELANIE
	Examiner	**Art Unit**
	LOHA BEN	2873

SEARCHED

Class	Subclass	Date	Examiner
359	3,9,11,237-239,279,556,558,559,566	05/04/2011	LB
385	15-18,22,31,43,129,133,146,147,901	05/04/2011	LB
356	326,328	05/04/2011	LB
362	26,602	05/04/2011	LB
369	103	05/04/2011	LB

SEARCH NOTES

Search Notes	Date	Examiner
WEST & EAST	05/04/2011	LB

INTERFERENCE SEARCH

Class	Subclass	Date	Examiner
See WEST	See WEST	05/04/2011	LB

Amendments to the Drawings

Fig. 29 is amended to replace numerals "7xx" with "17xx".

Attachment: Replacement Sheet

Annotated Marked-Up Drawings

REMARKS

Claims 1-30 are pending in the application. Claims 14-22 are withdrawn from consideration. With entry of the amendment, Claims 1, 13, 23-30 are amended.

Claim Amendments

Claim 25 is amended to recite "emergent beams" in place of "emerging light." Claim 26 is amended to recite "input" in line 1. Claim 29 is amended to independent form with certain features of claim 27. Claims 1, 13, 23, 24, 26-28 and 30 have been amended to correct typographical errors objected to by the Examiner.

Objections to Specification

The disclosure is objected to because of several informalities. In particular, the Examiner notes the following:

Paragraph [0408]: line 1, numeral "700" is not seen illustrated in Fig. 29.

Paragraph [0409]: line 3, "722" should be --721--.

Paragraphs [0409]-[0411] (pages 75-77): numerals 720-724, 731-733 and 741-743 of Fig. 29 appear to indicate elements different than those represented by the same numerals 720-724, 731-733 and 741-743 of Fig. 23.

Paragraphs [0457]-[0458] (pages 90-91): numerals 720-724, 731-733 and 741-743 of Fig. 23 appear to indicate elements different than those represented by the same numerals 720-724, 731-733 and 741-743 of Fig. 29.

To address the objections to the specification, the numerals referenced in paragraphs [0408]-[0411] have been amended from "7xx" to "17xx" in reference to Fig. 29. In addition, "722" has been amended to "1721" at paragraph [0409], line 3.

Reconsideration of the objections is respectfully requested in view of the amendments to the specification made herein.

Objections to Drawings

The Examiner objects to Figs. 23 and 29 for reasons noted above with respect to the specification. To address the objections to the drawings, the numerals in Fig. 29 have been amended from "7xx" to "17xx", and numeral "1700" has been added. In view of these amendments to Fig. 29, acceptance of amended Fig. 29 and previously amended Fig. 23 is respectfully requested.

Claim Rejections Under 35 USC 112

Claims 25 and 29 are rejected under 35 USC 112, second paragraph, as being indefinite. The rejections are respectfully traversed.

Regarding claim 25, the Examiner notes that the phrase "said emerging light" has no antecedent basis. Accordingly, claim 25 is amended to recite "said emergent beams."

Regarding claim 29, the Examiner notes that a connection between "measuring" and "directing," as recited in the claim, cannot be seen. To address the rejection, claim 29 is amended to independent form and now incorporates features of claim 27 and "at least one sensor."

In view of the foregoing amendments, reconsideration of the rejection of claims 25 and 29 is respectfully requested.

Information Disclosure Statement

An Information Disclosure Statement (IDS) is being filed concurrently herewith. Entry of the IDS is respectfully requested.

CONCLUSION

In view of the above amendments and remarks, it is believed that all claims are in condition for allowance, and it is respectfully requested that the application be passed to issue. If the Examiner feels that a telephone conference would expedite prosecution of this case, the Examiner is invited to call the undersigned.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By ______________________
Timothy J. Meagher
Registration No. 39,302
Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133

Date: 8/8/11

Amendments to the Claims

Please amend claims 1, 13, 23-30. The Claim Listing below will replace all prior versions of the claims in the application:

Claim Listing

1. (Currently Amended) An optical processor having a reflective SLM, a dispersion device and a focussing device, wherein the SLM has an array of controllable elements[[;]], wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over at least part of the SLM, and wherein the processor is configured such that the controllable elements display different holograms at chosen locations of the SLM where said light is incident, for controlling directions at which light from respective said locations emerges.

2. (Original) The optical processor of claim 1, having control circuitry adapted to provide plural different holograms to the SLM.

3. (Original) The optical processor of claim 2, wherein said plural different holograms include respective holograms each for performing a different function, whereby controllable elements at respective chosen locations of the SLM may operate as selected ones of the group comprising: an optical add/drop multiplexer, an optical monitoring device, a channel equaliser, a channel controller, a programmable optical source, a programmable optical filter, an optical spectrum analyser, an evaluation device, a reconfigurable wavelength demultiplexer, and a reconfigurable wavelength multiplexer.

4. (Original) The optical processor of claim 1, having a single SLM.

5. (Original) The optical processor of claim 1, having more than one SLM, each having a respective array of controllable elements wherein the processor is configured such that

light from a common point on the dispersion device is spatially distributed over at least part of each SLM.

6. (Original) The optical processor of claim 1, configured so that said light from a common point on the dispersion device is substantially collimated when incident upon the SLM.

7. (Original) The optical processor of claim 1, further comprising at least one light sensor arranged to provide signals indicative of emergent light.

8. (Original) The optical processor of claim 7, having at least one light sensor arranged to provide signals indicative of light specularly reflected at the SLM.

9. (Original) The optical processor of claim 1, wherein the SLM is a Liquid Crystal on Silicon SLM.

10. (Original) The optical device of claim 1, wherein the SLM incorporates a quarter wave-plate.

11. (Original) The optical processor of claim 1, wherein each hologram occupies an array of controllable elements that has between 10 and 50 controllable elements in at least one dimension.

12. (Original) The optical processor of claim 1, wherein each hologram occupies an array of controllable elements that has a size in at least one dimension that is at least 2 times the 1/e spot half-width of the amplitude distribution of an incident beam in the corresponding direction.

13. (Currently Amended) The optical processor of claim 1, wherein the controllable elements are phase-modulating elements.

14. (Withdrawn) An optical processor having at least one input and at least two outputs and operable to select between the outputs, the module comprising a reflective SLM having an array of pixels, with circuitry constructed and arranged to display holograms on the pixels to route light of different frequencies to respective outputs.

15. (Withdrawn) A method of controlling light comprising

applying an input light beam having plural wavelengths to a reflective SLM;

controlling the controllable optical device thereby to select desired wavelengths from the input light beam; and

directing the desired wavelengths to respective output directions.

16. (Withdrawn) The method of claim 15, comprising varying the control of the reflective SLM whereby a subset of the plural wavelengths to a respective output direction is varied.

17. (Withdrawn) The method of claim 15, wherein at least two of the output directions contain at least one common wavelength.

18. (Withdrawn) The method of claim 17, adapted for multicasting.

19. (Withdrawn) An optical processor having plural inputs and an output, comprising a reflective SLM for combining wavelengths from the inputs to appear at the output, wherein each input signal may contain any desired set of the plural wavelengths of the output.

20. (Withdrawn) The optical processor of claim 19, wherein the or each input signal is at least one broadband optical source.

21. (Withdrawn) The optical processor of claim 20, arranged to perform at least one of the group of functions comprising: production of a desired output spectrum and synthesising a comb spectrum.

22. (Withdrawn) The optical processor of claim 21, having a controller for varying control of the controllable device whereby an output spectrum may be varied.

23. (Currently Amended) A method of operating an optical processor having a reflective SLM having an array of controllable elements, a dispersion device and a focussing device, wherein light beams from a common point on the dispersion device are spatially separate when incident upon the SLM, and wherein the SLM is configured to display holograms at respective locations of incidence of light to provide emergent beams having controllable directions, the method comprising delineating groups of individual controllable elements; selecting, from stored control data, control data for each group of [[-]] controllable elements of the SLM; generating from the respective selected control data a respective hologram at each group of controllable elements; and varying the delineation of the groups and/or the selection of control data whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

24. (Currently Amended) A method of operating an optical ~~device~~ processor according to claim 23, comprising selecting control of said light beams from the group comprising: control of direction, control of power, focussing, aberration compensation, sampling and beam shaping.

25. (Currently Amended) A method according to claim 23, comprising determining, by means of a control device, selection of the groups, selection of control data and delineation of the group boundaries in response to signals from sensors arranged to provide signals indicative of said emergent beams ~~emerging light~~.

26. (Currently Amended) A method of controlling input light comprising:

causing said light to become angularly dispersed by a dispersion device;

focussing, by a focussing device, angularly dispersed light from the dispersion device to provide focussed light;

making said focussed light incident upon a reflective SLM, whereby the light is spatially distributed across at least a part of the SLM, wherein the SLM has an array of controllable elements; and

displaying respective holograms at respective locations of incidence of light to provide emergent light whose direction is controlled by the respective holograms.

27. (Currently Amended) A method of directing light using a reflective SLM, a dispersion device and a focussing device, wherein the reflective SLM has an array of controllable elements and wherein the arrangement is such that light from a common point on the dispersion device is spatially distributed over the reflective SLM, the method comprising:

causing the [[-]] controllable elements to display different holograms at chosen locations whereon light is incident, whereby light from said locations emerges in controllable directions.

28. (Currently Amended) The method of claim 27, wherein the controllable elements are phase-modulating elements.

29. (Currently Amended) A method, using a reflective SLM, a dispersion device and a focussing device, wherein the reflective SLM has an array of controllable elements and wherein the arrangement is such that light from a common point on the dispersion device is spatially distributed over the reflective SLM, of measuring at least one spectral property selected from: channel power, channel centre wavelength, channel bandwidth occupied and noise power between channels, the method comprising causing the controllable elements to display different holograms at chosen locations whereon light is

incident, whereby light from said locations emerges in controllable directions to at least one sensor ~~the method of directing light of claim 26~~.

30. (Currently Amended) An optical processor arranged to function as at least one of the following: an optical add/drop multiplexer, an optical monitoring device, a channel equaliser, a channel controller, a programmable optical source, a programmable optical filter, an optical spectrum analyser, an evaluation device, a reconfigurable wavelength demultiplexer, and a reconfigurable wavelength multiplexer, the processor having a reflective SLM[[,,]], a dispersion device and a focussing device, wherein the SLM has an array of controllable elements[[;]], wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over the SLM, and wherein the processor is configured such that the controllable elements display different holograms at chosen locations, whereby light from said locations emerges in respective directions, the directions deviating from a direction of specular reflection.

Amendments to the Specification

Please replace the paragraph at page 75, line 26 through page 76, line 1 with the following amended paragraph:

[0408] Turning now to FIG. 29, an add/drop multiplexer device ~~700~~ 1700 has two input ports ~~701, 702~~ 1701, 1702 and two output ports ~~703,704~~ 1703, 1704. The first input port ~~701~~ 1701 is for an input beam ~~711~~ 1711 termed "add" and the second input port ~~702~~ 1702 is for a second input beam ~~712~~ 1712 termed "main in" having two frequencies in this embodiment. The first output port ~~703~~ 1703 is for a first output beam ~~713~~ 1713 termed "drop" and the second output port ~~704~~ 1704 is for a second output beam ~~714~~ 1714 termed "main out"

Please replace the paragraph at page 76, lines 2-11 with the following amended paragraph:

[0409] The input beams ~~711, 712~~ 1711, 1712 are incident upon a grating ~~720~~ 1720 that deflects the beams according to wavelength to provide emergent beams ~~731, 732 and 733~~ 1731, 1732 and 1733. The emergent beams ~~731, 732 and 733~~ 1731, 1732 and 1733 are incident upon a lens ~~722~~ 1721 having its focal plane at the grating ~~720~~ 1720, and the beams emerge from the lens respectively as beams ~~741, 742, and 743~~ 1741, 1742 and 1743 to be incident upon an SLM ~~722~~ 1722 in the other focal plane of the lens ~~721~~ 1721. As the beams ~~741, 742~~ 1741, 1742 do not originate on the grating ~~720~~ 1720 from the same location, they are not mutually parallel when emerging from the lens ~~721~~ 1721. The beam ~~743~~ 1743 is from a point on the grating ~~720~~ 1720 common to the origin on the grating ~~720~~ 1720 of beam ~~742~~ 1742, and hence these beams are mutually parallel. Although the grating is drawn as transmissive and the SLM as reflective, these types are arbitrary.

Please replace the paragraph at page 76, lines 12-19 with the following amended paragraph:

[0410] The first beam ~~731~~ 1731 and the third beam ~~733~~ 1733 are at the same wavelength, hence they emerge parallel from the grating ~~720~~ 1720 and are refracted by the lens ~~721~~ 1721 propagating as beams ~~741 and 743~~ 1741 and 1743 respectively to a first group or block of pixels ~~723~~ 1723 on the SLM ~~722~~ 1722. This pixel block ~~723~~ 1723 applies the required hologram pattern that routes a channel entering the add port ~~701~~ 1701 to the main output ~~704~~ 1704, and also routes a channel entering the main input ~~702~~ 1702 to the drop port ~~703~~ 1703. Hence the first group of pixels ~~723~~ 1723 deflects the first beam ~~741~~ 1741 to provide first reflected beam ~~751~~ 1751, and deflects the third beam ~~743~~ 1743 to provide third reflected beam ~~753~~ 1753.

Please replace the paragraph at page 76, line 20 through page 77, line 3 with the following amended paragraph:

[0411] The second beam ~~732~~ 1732 is at a different wavelength to the first and third beams ~~731 and 733~~ 1731 and 1733 and therefore emerges at a different angle from the grating ~~720~~ 1720. This third beam is refracted by the lens ~~721~~ 1721 and propagates as beam ~~742~~ 1742 to a second group of pixels or pixel block ~~724~~ 1724 on the SLM ~~722~~ 1722. This second group of pixels applies the hologram pattern that routes a channel entering the main input port ~~702~~ 1702 to the main output port ~~704~~ 1704 and "grounds" a channel entering the add port ~~701~~ 1701. The second group of pixels ~~724~~ 1724 deflects the second beam ~~742~~ 1742 to provide the second reflected beam ~~752~~ 1752. The holograms on the first and second groups of pixels are selected, (examples were described for FIGS. 13a, 13b and 15), so that the first and second reflected beams ~~751,752~~ 1751, 1752 are mutually parallel; the third beam ~~753~~ 1753 is routed in a different direction. The consequence of this is that the first and second beams ~~751,752~~ 1751, 1752, after passing again through the lens ~~721~~ 1721 become incident at a common point ~~726~~ 1726 on the grating ~~720~~ 1720, and emerge as main out beam ~~714~~ 1714. The third beam ~~753~~ 1753 is incident upon a different point on the grating ~~720~~ 1720 and emerges into as the drop beam ~~713~~ 1713.

Electronic Acknowledgement Receipt

EFS ID:	10689655
Application Number:	12710913
International Application Number:	
Confirmation Number:	9661
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Customer Number:	21005
Filer:	Timothy J. Meagher/Karen Kenney
Filer Authorized By:	Timothy J. Meagher
Attorney Docket Number:	3274.1003-004
Receipt Date:	08-AUG-2011
Filing Date:	23-FEB-2010
Time Stamp:	19:15:02
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$400
RAM confirmation Number	5792
Deposit Account	080380
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	32741003004transmittal.pdf	184504 fa0f9bbfbc30162e917c3c1e68f9ee7aeb07 4aed	no	3

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
2	Drawings-only black and white line drawings	32741003004drawings.pdf	85172 90204a3698f3677f8d1118dd301d53d5756 52090	no	2

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
3	Transmittal Letter	32741003004SIDS.pdf	231345 6a44c1f9651b0cb5f3d579a6fcbf97665bc1 65aa	no	3

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
4	Information Disclosure Statement (IDS) Form (SB08)	32741003004listingofrefs.pdf	89253 55c6d3156d7f4290f08434a4c1940ac34df8 24f4	no	1

Warnings:

Information:

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Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
5		32741003004amendment.pdf	884002 e1808010350579a7c1c38df43a74e829c99c fbdf	yes	13

Multipart Description/PDF files in .zip description

Document Description	Start	End
Amendment/Req. Reconsideration-After Non-Final Reject	1	1
Specification	2	3
Claims	4	9
Drawings-only black and white line drawings	10	10
Applicant Arguments/Remarks Made in an Amendment	11	13

Warnings:

Information:

6	Fee Worksheet (SB06)	fee-info.pdf	31909 7c7f1598fab153e71567cf73d6ff6d577d529778	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	1506185	

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

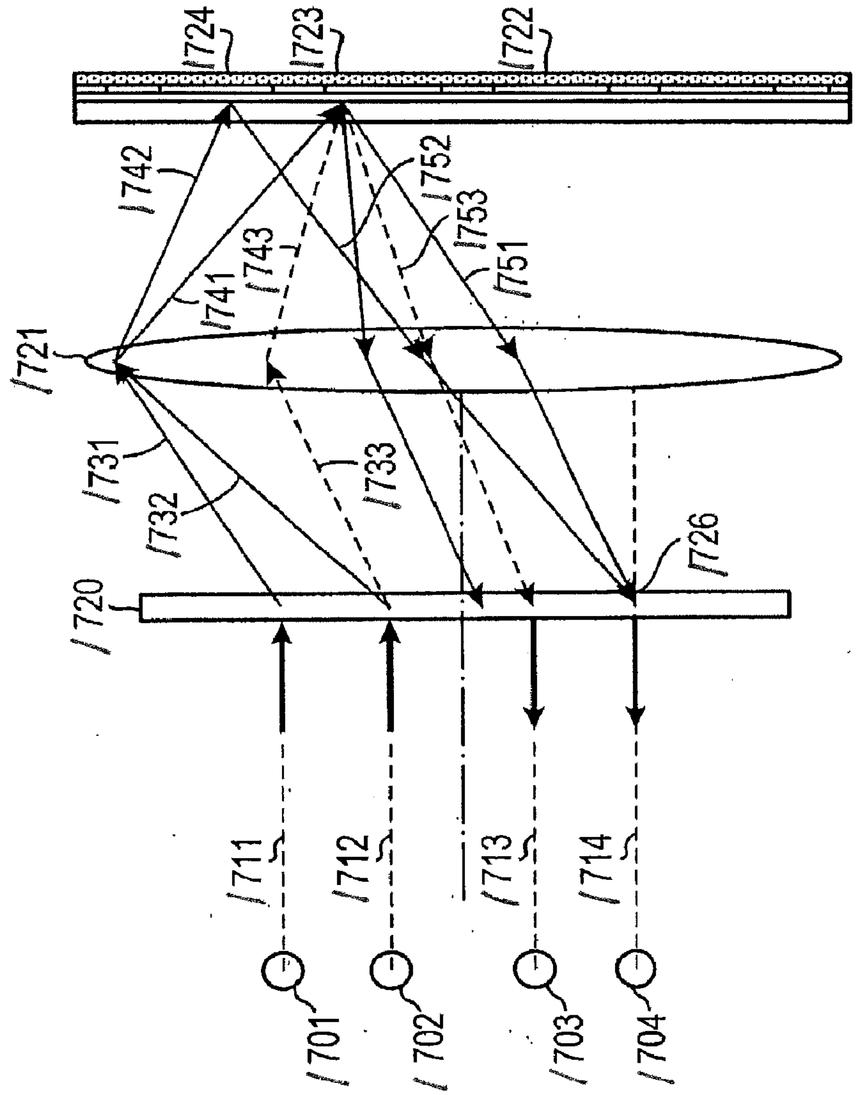
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FIG. 29

TJM/jtk (bmw)
August 8, 2011

PATENT APPLICATION
DOCKET NO.: 3274.1003-004

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2873
Filed:	February 23, 2010	Examiner:	Ben, Loha
Confirmation No.:	9661		
For:	Optical Processing		

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TRANSMITTAL LETTER FOR SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Information Disclosure Statement is submitted:

☐ under 37 CFR 1.97(b), or
(Within any one of the following time periods: three months of filing national application (other than a CPA) or date of entry of the national stage in an international application; or before the mailing date of a first office action on the merits; or before the mailing of a first office action after the filing of a Request for Continued Examination).

☒ under 37 CFR 1.97(c) together with either:
- ☐ a Statement under 37 CFR 1.97(e), as checked below, or
- ☒ a $180.00 fee under 37 CFR 1.17(p), or

(After the 37 CFR 1.97(b) time period, but before any of a final action, notice of allowance, or an action that closes prosecution, whichever occurs first)

☐ under 37 CFR 1.97(d) together with:
- ☐ a Statement under 37 CFR 1.97(e), as checked below, and
- ☐ a $180.00 fee under 37 CFR 1.17(p), or

(Filed after final action, notice of allowance, whichever occurs first, or if prosecution otherwise closes, but on or before payment of the issue fee)

☐ under 37 CFR 1.97(i):
Applicant requests that the IDS and cited reference(s) be placed in the application file.
(Filed after payment of issue fee)

Statement Under 37 CFR 1.97(e)

☐ Each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement; or

☐ No item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the undersigned, after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of this Information Disclosure Statement.

Statement Under 37 CFR 1.704(d) (Patent Term Adjustment)
Applies to original applications (other than design) filed on or after May 29, 2000

☐ Each item of information contained in the Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart application and this communication was not received by any individual designated in § 1.56(c) more than thirty days prior to the filing of the Information Disclosure Statement.

☒ Enclosed herewith is a Listing of References. Copies of the cited references are enclosed except as indicated below or in the attached Listing of References.

☐ Copies of the cited references submitted with an Information Disclosure Statement in prior application, U.S. Application No. [ ], to which priority under 35 U.S.C. 120 is claimed, are not required under 37 CFR 1.98(d)(1) and (2) and are thus not provided.

☐ The listed references were cited in the enclosed Search Report in counterpart foreign application [add application number], which is listed in the attached Listing of References.

☐ The "concise explanation" requirement (non-English references) for reference(s) [ ] under 37 CFR 1.98(a)(3) is satisfied by:

- ☐ the explanation provided on the attached sheet.
- ☐ the explanation provided in the Specification.
- ☐ submission of the enclosed International Search Report.
- ☐ submission of the enclosed English-language version of a foreign Search Report and/or foreign Office Action.
- ☐ the enclosed English language abstract.

Method of payment:

☐ Authorization is NOT granted to charge any fees which may be due in this matter to our Deposit Account.

☒ Please charge Deposit Account 08-0380 in the amount of $180.

☐ A check for the fee noted above is enclosed, or the fee has been included in the check with the accompanying Reply.

☒ Please charge any deficiency in fees and credit any overpayment to Deposit Account 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By [signature]

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Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133
Dated: 8/8/11

Electronic Patent Application Fee Transmittal

Application Number:	12710913
Filing Date:	23-Feb-2010
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Filer:	Timothy J. Meagher/Karen Kenney
Attorney Docket Number:	3274.1003-004

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Independent claims in excess of 3	1201	1	220	220
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Submission- Information Disclosure Stmt	1806	1	180	180
	Total in USD ($)			**400**

TS0002423

TJM/jtk (bmw)
August 8, 2011

PATENT APPLICATION
DOCKET NO. 3274.1003-004

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2873
Filed:	February 23, 2010	Examiner:	Ben, Loha
Confirmation No.:	9661		
For:	Optical Processing		

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or is being facsimile transmitted to the United States Patent and Trademark Office on:

Date ______ Signature ______

______

Typed or printed name of person signing certificate

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Transmitted herewith is an Amendment for filing in the above-identified application.

☐ Small entity status of this application under 37 CFR 1.9 and 1.27 has been established by a Small Entity Statement previously submitted.

☐ A Small Entity Statement to establish small entity status under 37 CFR 1.9 and 1.27 is enclosed.

1117961.1

The claims fee has been calculated as shown below:

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NO. PREVIOUSLY PAID FOR	PRESENT EXTRA	SMALL ENTITY RATE	SMALL ENTITY ADDIT. FEE	OR	OTHER THAN SMALL ENTITY RATE	OTHER THAN SMALL ENTITY ADDIT. FEE
TOTAL	30	MINUS	* 30	0	X $ 26	$		X $52	$ 0
INDEP	9	MINUS	** 8	1	X $110	$		X $220	$ 220
☐ FIRST PRESENTATION OF MULTIPLE DEP. CLAIM					+ $195	$		+ $390	$
					TOTAL =	$ 0		TOTAL =	$ 220

* not fewer than 20
** not fewer than 3

The Application Size Fee has been calculated as shown below:
(Effective for cases filed on or after December 8, 2004)

Actual Sheets (Including current amendment)	Highest No. of Sheets Paid For (At least 100)	No. of Additional Units Required (Increments of 50 sheets)	SMALL ENTITY Rate	SMALL ENTITY Total Amount Owed	OTHER THAN SMALL ENTITY Rate	OTHER THAN SMALL ENTITY Total Amount Owed	Payment Sufficient for up to
143	150	0	X $135	$[ ]	X $270	$[ ]	150 Sheets

Petition for Extension of Time

☐ Applicant hereby petitions to extend the time to respond to the [ ] dated [ ] for [ ] month(s) from [ ] to [ ]. The appropriate fee is set forth below.

☐ *[For action-specific language in an extension of time, select the appropriate option from the Firm Templates]*

Please charge Deposit Account No. 08-0380 for the following fees:

☐	Petition for [ ] month Extension of Time	$
☒	Claims Fee	$ 220
☐	Application Size Fee	$
☒	Other Fees:	
	Information Disclosure Statement	$ 180
		$
	TOTAL:	$ 400

A check is enclosed in payment of the following fees:

☐	Petition for [ ] month Extension of Time	$
☐	Claims Fee	$
☐	Application Size Fee	$
☐	Other Fees:	
		$
		$
	TOTAL:	$

☒ Please charge any deficiency or credit any overpayment in the fees that may be due in this matter to Deposit Account No. 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By [signature]

Timothy J. Meagher
Registration No.: 39,302
Telephone (978) 341-0036
Facsimile (978) 341-0136

Concord, Massachusetts 01742-9133

Dated: 8/8/11

1117961.1

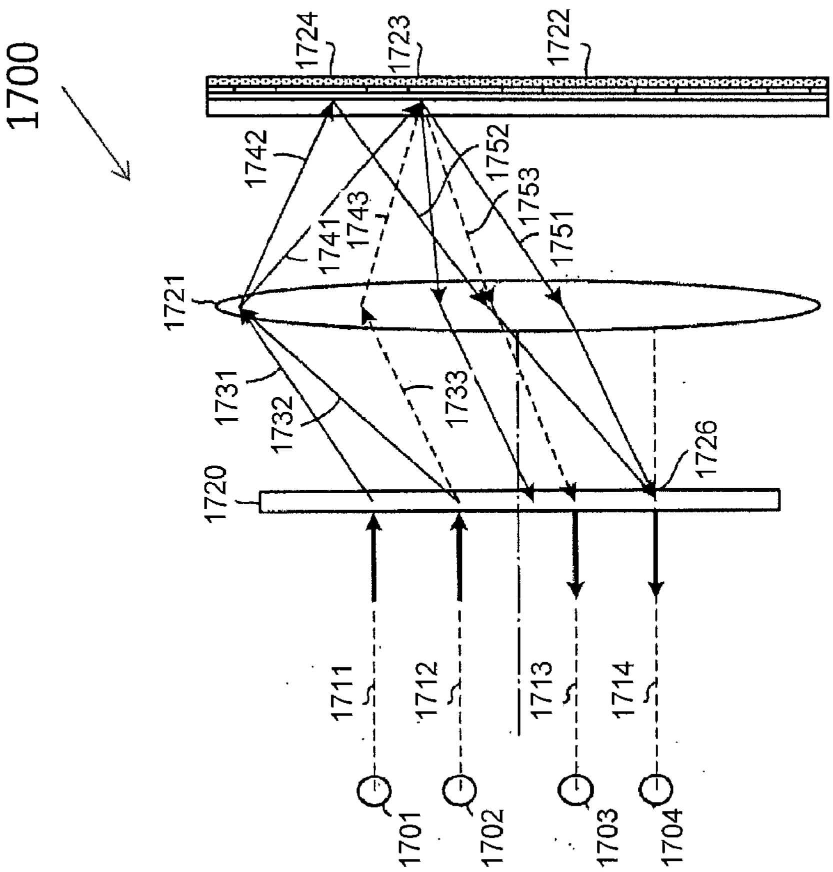
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FIG. 29

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2873
Filed:	February 23, 2010	Examiner:	Ben, Loha
Confirmation No:	9661		
For:	Optical Processing		

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or is being facsimile transmitted to the United States Patent and Trademark Office on:

Date   Signature

Typed or printed name of person signing certificate

AMENDMENT

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Amendment is being filed in response to the Office Action mailed from the U.S. Patent and Trademark Office on May 6, 2011 in the above-identified application. Reconsideration and further examination are requested.

Please amend the application as follows:

Substitute for form 1449B/PTO **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **AUGUST 8, 2011** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		APPLICATION NO. 12/710,913
	FIRST NAMED INVENTOR Melanie Holmes		FILING DATE February 23, 2010
	EXAMINER Ben, Loha	CONFIRMATION NO. 9661	GROUP 2873

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
	A66	7,436,588 B2	10-2008	Rothenberg *et al.*
	A67	5,661,577	08-1997	Jenkins *et al.*
	A68	5,416,616	05-1995	Jenkins *et al.*
	A69	5,285,308	02-1994	Jenkins *et al.*
	A70			
	A71			
	A72			
	A73			
	A74			
	A75			
	A76			
	A77			
	A78			
	A79			
	A80			
	A81			
	A82			

Copies of issued U.S. Patents and Published U.S. Applications are not required and are not being provided. We are not listing separately any prior U.S. Patent Office communications regarding the cited documents because the Examiner has access to any such actions through PAIR.

EXAMINER	DATE CONSIDERED

1117950.1

PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number: 12/710,913
Filing Date: 02/23/2010
☐ To be Mailed

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY ☐ RATE ($)	SMALL ENTITY FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
			TOTAL			TOTAL	

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

AMENDMENT

08/08/2011	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 30	Minus	** 30	= 0	X $ =		OR	X $52=	0
Independent (37 CFR 1.16(h))	* 9	Minus	***8	= 1	X $ =		OR	X $220=	220
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	**220**

AMENDMENT

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/YUVANNA CHAPHIV/

Approved

/L.B./

10/15/2011

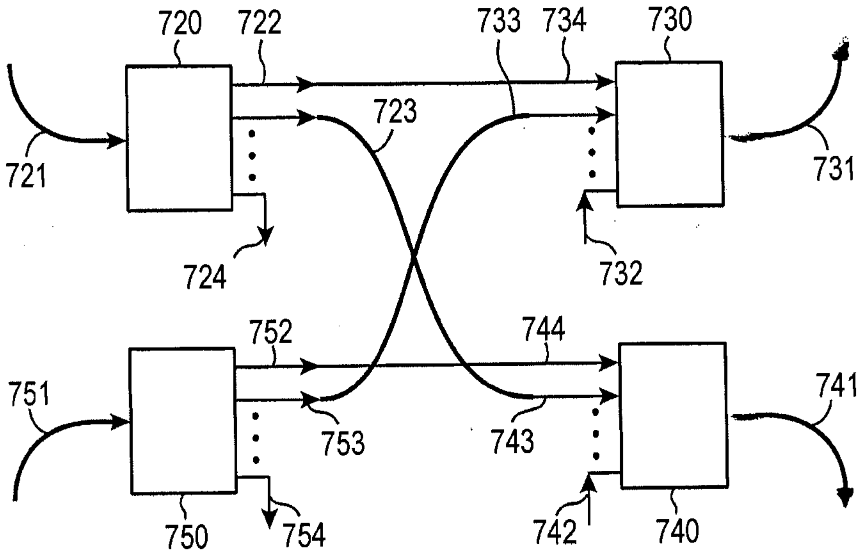

FIG. 23

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

BIB DATA SHEET

CONFIRMATION NO. 9661

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
12/710,913	02/23/2010 **RULE**	359	2873	3274.1003-004

APPLICANTS
Melanie Holmes, Suffolk, UNITED KINGDOM;

**** CONTINUING DATA ***************************
This application is a CON of 11/978,258 10/29/2007
which is a CON of 11/515,389 09/01/2006 PAT 7,612,930
which is a DIV of 10/487,810 09/10/2004 PAT 7,145,710
which is a 371 of PCT/GB02/04011 09/02/2002

**** FOREIGN APPLICATIONS ***************************
UNITED KINGDOM 0121308.1 09/03/2001

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****
03/04/2010

Foreign Priority claimed ☑ Yes ☐ No 35 USC 119(a-d) conditions met ☑ Yes ☐ No Verified and Acknowledged /LOHA BEN/ Examiner's Signature	☑ Met after Allowance /LB/ Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		UNITED KINGDOM	36	~~30~~ 21	~~8~~ 6

ADDRESS

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133
UNITED STATES

TITLE

OPTICAL PROCESSING

FILING FEE RECEIVED	FEES: Authority has been given in Paper	
3330	No.____________ to charge/credit DEPOSIT ACCOUNT No.____________ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other ________________ ☐ Credit

WEST Search History for Application 12710913

Creation Date: 2011101515:08

Prior Art Searches

Query	DB	Op.	Plur.	Thes.	Date
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME hologra$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME hologra$8 SAME display$3 SAME control$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME hologra$8 SAME display$3 SAME control$4.CLM.	PGPB	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME hologra$8 SAME (display$3 or delineat$3) SAME control$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME hologra$8 SAME (display$3 or delineat$3) SAME control$4.CLM.	PGPB	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
(((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4) and (display$3 or comput$3 or process$3 or delineat$3) SAME hologra$8 SAME control$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
(reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME disper$8 SAME (focus$4 or conver$5) SAME hologra$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
(reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME disper$8 SAME (focus$4 or conver$5) SAME (hologra$8 WITH	PGPB, USPT, USOC, EPAB, JPAB, DWPI,	OR	YES		10-15-2011

TS0002433

(locat$4 or position$3)) SAME control$$8 SAME direct$4	TDBD				
((reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME disper$8 SAME (focus$4 or conver$5) SAME hologra$8) and (hologra$8 WITH (locat$4 or position$3)) SAME control$$8 SAME direct$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
(reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME (disper$8 or grating$1) SAME (focus$4 or conver$5) SAME hologra$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
((reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME (disper$8 or grating$1) SAME (focus$4 or conver$5) SAME hologra$8) and (hologra$8 WITH (locat$4 or position$3)) SAME control$$8 SAME direct$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
(reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME disper$8 SAME (focus$4 or conver$5) SAME (hologra$8 WITH (locat$4 or position$3)) SAME control$$8 SAME direct$4.CLM.	PGPB	OR	YES		10-15-2011

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

21005 7590 10/18/2011
HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

EXAMINER	
BEN, LOHA	
ART UNIT	PAPER NUMBER
2873	

DATE MAILED: 10/18/2011

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

TITLE OF INVENTION: OPTICAL PROCESSING

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1740	$300	$0	$2040	01/18/2012

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

21005 7590 10/18/2011

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)

(Signature)

(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

TITLE OF INVENTION: OPTICAL PROCESSING

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1740	$300	$0	$2040	01/18/2012

EXAMINER	ART UNIT	CLASS-SUBCLASS
BEN, LOHA	2873	359-279000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 ____________________

2 ____________________

3 ____________________

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies ____________________

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number ____________ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

❑ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

❑ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature ____________________ Date ____________________

Typed or printed name ____________________ Registration No. ____________________

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

21005 7590 10/18/2011

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

EXAMINER	
BEN, LOHA	
ART UNIT	**PAPER NUMBER**
2873	

DATE MAILED: 10/18/2011

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 02/11)

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 12/710,913	Applicant(s) HOLMES, MELANIE	
	Examiner LOHA BEN	Art Unit 2873	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *Applicant's Amendment dated 08/08/2011*.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *1-13 and 23-30*.
4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☒ All b) ☐ Some* c) ☐ None of the:
   1. ☐ Certified copies of the priority documents have been received.
   2. ☒ Certified copies of the priority documents have been received in Application No. *10/487,810* .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
6. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
   1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
7. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 08/08/11
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☒ Examiner's Amendment/Comment
8. ☒ Examiner's Statement of Reasons for Allowance
9. ☒ Other *See Continuation Sheet*.

Continuation of Attachment(s) 9. Other: Copies of approved Figs. 23 and 29.

EXAMINER'S AMENDMENT

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

The application has been amended as follows:

In the Claims

Claims 14-22, which were withdrawn by Applicant in Amendment dated 08/08/2011, have now been cancelled to pave the way for claims 1-13 and 23-30 to be passed to issue.

In the Drawings

Fig. 23, which was submitted on 02/23/2011, and disapproved by the Examiner on 05/04/2011, has now been approved.

REASONS FOR ALLOWANCE

The following is an examiner's statement of reasons for allowance: References of record, taken singly or in combination, fail to teach or fairly suggest the optical processor of independent claim 1 that has a reflective SLM, a dispersion device and a focusing device, wherein the processor is designed such that controllable elements of the SLM display different holograms in the manner now presented in the claim. With respect to independent method claim 23 which is to operate an optical processor that has the exact same elements and function called for in claim 1, the various steps recited therein are not seen taught or suggested in the art of record. As regards the method of controlling input light of claim 26, the method of directing light of claim 27, and the method of measuring at least one spectral property of claim 29, the various steps called for in the respective claims involve the same elements and at least substantially same functions noted in claim 1. Finally, for the optical processor of independent claim 30, the scope of which is somewhat narrower than that of claim 1 by the fact that the processor recited is intended to be arranged to function specifically as one of the elements as listed in the claim.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled “Comments on Statement of Reasons for Allowance.”

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to LOHA BEN whose telephone number is (571)272-2323. The examiner can normally be reached on M-SAT, generally between 12:01 p.m. to 8:00 p.m.

If attempts to reach the examiner by telephone are unsuccessful, the examiner’s supervisor, Ricky Mack, can be reached on M-, at (571) 272-2333. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

October 15, 2011

/Loha Ben/
Primary Examiner, Art Unit 2873

Approved

/L.B./

10/15/2011

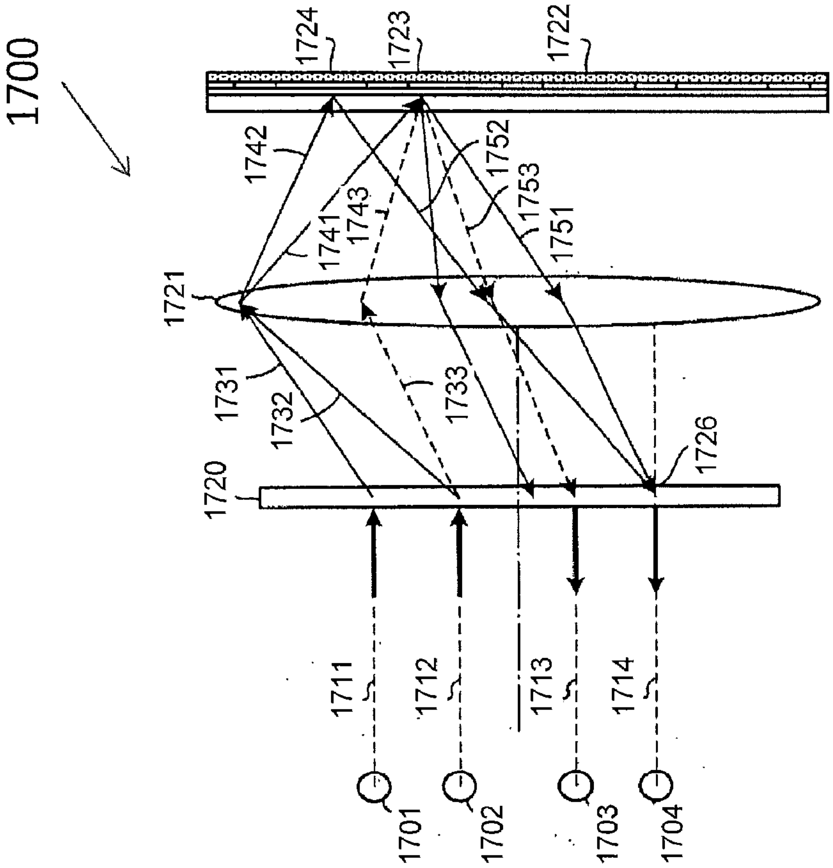

FIG. 29

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12710913	HOLMES, MELANIE
	Examiner	**Art Unit**
	LOHA BEN	2873

SEARCHED

Class	Subclass	Date	Examiner
359	3,9,11,237-239,279,556,558,559,566	05/04/2011	LB
385	15-18,22,31,43,129,133,146,147,901	05/04/2011	LB
356	326,328	05/04/2011	LB
362	26,602	05/04/2011	LB
369	103	05/04/2011	LB

SEARCH NOTES

Search Notes	Date	Examiner
WEST & EAST	05/04/2011	LB
WEST	10/15/2011	LB

INTERFERENCE SEARCH

Class	Subclass	Date	Examiner
See WEST	See WEST	05/04/2011	LB
See WEST	See WEST	10/15/2011	LB

Index of Claims	Application/Control No. 12710913	Applicant(s)/Patent Under Reexamination HOLMES, MELANIE
	Examiner LOHA BEN	Art Unit 2873

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	08/17/2010	05/04/2011	10/15/2011						
1	1	÷	=	=						
2	2	÷	=	=						
3	3	÷	=	=						
4	4	÷	=	=						
5	5	÷	=	=						
6	6	÷	=	=						
7	7	÷	=	=						
8	8	÷	=	=						
9	9	÷	=	=						
10	10	÷	=	=						
11	11	÷	=	=						
12	12	÷	=	=						
13	13	÷	=	=						
	14	÷	N	-						
	15	÷	N	-						
	16	÷	N	-						
	17	÷	N	-						
	18	÷	N	-						
	19	÷	N	-						
	20	÷	N	-						
	21	÷	N	-						
	22	÷	N	-						
14	23	÷	=	=						
15	24	÷	=	=						
16	25	÷	✓	=						
17	26	÷	=	=						
18	27	÷	=	=						
19	28	÷	=	=						
20	29	÷	✓	=						
21	30	÷	=	=						

Issue Classification

Application/Control No.	Applicant(s)/Patent Under Reexamination
12710913	HOLMES, MELANIE
Examiner	**Art Unit**
LOHA BEN	2873

ORIGINAL

CLASS	SUBCLASS
359	279

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				
359	9	11	238		

INTERNATIONAL CLASSIFICATION

CLAIMED					NON-CLAIMED
G	0	2	F	1 / 01 (2006.01.01)	
G	0	3	H	1 / 08 (2006.01.01)	

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1		17												
2	2		18												
3	3		19												
4	4		20												
5	5		21												
6	6		22												
7	7	14	23												
8	8	15	24												
9	9	16	25												
10	10	17	26												
11	11	18	27												
12	12	19	28												
13	13	20	29												
	14	21	30												
	15														
	16														

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 21
/LOHA BEN/ Primary Examiner.Art Unit 2873 (Primary Examiner)	20111015 (Date)	O.G. Print Claim(s): 1 / O.G. Print Figure: 29

Mail room date: 08/08/2011

Substitute for form 1449B/PTO **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **AUGUST 8, 2011** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004	APPLICATION NO. 12/710,913	
	FIRST NAMED INVENTOR Melanie Holmes	FILING DATE February 23, 2010	
	EXAMINER Ben, Loha	CONFIRMATION NO. 9661	GROUP 2873

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
/L.B./	A66	7,436,588 B2	10-2008	Rothenberg *et al.*
/L.B./	A67	5,661,577	08-1997	Jenkins *et al.*
/L.B./	A68	5,416,616	05-1995	Jenkins *et al.*
/L.B./	A69	5,285,308	02-1994	Jenkins *et al.*
	A70			
	A71			
	A72			
	A73			
	A74			
	A75			
	A76			
	A77			
	A78			
	A79			
	A80			
	A81			
	A82			

Copies of issued U.S. Patents and Published U.S. Applications are not required and are not being provided. We are not listing separately any prior U.S. Patent Office communications regarding the cited documents because the Examiner has access to any such actions through PAIR.

EXAMINER /Loha Ben/	DATE CONSIDERED 10/15/2011

1117950.1

CONSIDERED: /L.B./

TS0002448

Electronic Patent Application Fee Transmittal

Application Number:	12710913
Filing Date:	23-Feb-2010
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Filer:	Timothy J. Meagher/Nadine Kush
Attorney Docket Number:	3274.1003-004

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Request for continued examination	1801	1	930	930
	Total in USD ($)			**930**

Substitute for form 1449B/PTO **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **January 13, 2012** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		APPLICATION NO. 12/710,913
	FIRST NAMED INVENTOR Melanie Holmes		FILING DATE February 23, 2010
	EXAMINER Ben, Loha	CONFIRMATION NO. 9661	GROUP 2873

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
	A70	8,089,683 B2	01-03-2012	Holmes
	A71	7,079,723 B2	07-18-2006	Bortolini *et al.*
	A72	6,990,268 B2	01-24-2006	Weverka
	A73	6,813,408 B2	11-02-2004	Bortolini
	A74	6,542,268 B1	04-01-2003	Rotolo *et al.*
	A75	6,175,432 B1	01-16-2001	Wu *et al.*
	A76	5,953,143	09-14-1999	Sharony *et al.*
	A77	5,495,356	02-27-1996	Sharony *et al.*
	A78	6,507,685 B1	01-14-2003	Polynkin *et al.*
	A79	6,504,976 B1	01-07-2003	Polynkin *et al.*

Copies of issued U.S. Patents and Published U.S. Applications are not required and are not being provided. We are not listing separately any prior U.S. Patent Office communications regarding the cited documents because the Examiner has access to any such actions through PAIR.

EXAMINER	DATE CONSIDERED

Electronic Acknowledgement Receipt

EFS ID:	11828930
Application Number:	12710913
International Application Number:	
Confirmation Number:	9661
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Customer Number:	21005
Filer:	Timothy J. Meagher/Nadine Kush
Filer Authorized By:	Timothy J. Meagher
Attorney Docket Number:	3274.1003-004
Receipt Date:	13-JAN-2012
Filing Date:	23-FEB-2010
Time Stamp:	14:05:54
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$930
RAM confirmation Number	335
Deposit Account	080380
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Request for Continued Examination (RCE)	32741003004RCE.PDF	136969 92ec40f1d6b2c4d34931927cffae08b9e6eea4a6	no	1
Warnings:					
This is not a USPTO supplied RCE SB30 form.					
Information:					
2	Transmittal Letter	32741003004IDS.PDF	235720 e189cdf911e7faa129f3001a2f7b02b680b5a329	no	3
Warnings:					
Information:					
3	Information Disclosure Statement (IDS) Form (SB08)	32741003004List.pdf	71591 29adb76716c34f478b16a18bc48e0ea48809776e	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
4	Fee Worksheet (SB06)	fee-info.pdf	30159 29b38c7e2041bede57ab649cbc484779f9fdc6f9	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	474439	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

REQUEST FOR CONTINUED EXAMINATION (RCE) TRANSMITTAL	*Application Number*	12/710,913
	Filing Date	February 23, 2010
	Confirmation Number	9661
	First Named Inventor	Melanie Holmes
Subsection (b) of 35 U.S.C. § 132, effective on May 29, 2000, provides for continued examination of a utility or plant application filed on or after June 8, 1995. See The American Inventors Protection Act of 1999 (AIPA)	*Group Art Unit*	2873
	Examiner Name	Ben, Loha
	Attorney Docket Number	3274.1003-004

This is a Request for Continued Examination (RCE) under 37 CFR § 1.114 of the above-identified application.
Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. See instruction Sheet for RCEs (not to be submitted to the USPTO) on page 2.

1. **Submission required under 37 CFR § 1.114**

Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).

a. ☐ Previously submitted
   - i. ☐ Consider the amendment(s)/reply under 37 CFR § 1.116 previously filed on [ ].
     (Any unentered amendment(s) referred to above will be entered).
   - ii ☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on [ ].
   - iii. ☐ Other - - [ ]

b. ☐ Please do not enter the amendment(s)/reply under 37 CFR § 1.116 previously filed on [ ]

c. ☒ Enclosed
   - i. ☐ Amendment/Reply
   - ii. ☐ Affidavit(s)/Declaration(s)
   - iii. ☒ Information Disclosure Statement (IDS)
   - iv. ☐ Petition for Extension of Time - [ ] month(s) - [separate sheet] [included in amend. fee trans.]
   - v. ☐ Other - - [ ]

2. **Miscellaneous**

a. ☐ Suspension of action on the above-identified application is requested under 37 CFR § 1.103(c) for a period of [ ] months. (Period of suspension shall not exceed 3 months; Fee under 37 CFR § 1.17(i) **required**)

b. ☐ Other - - [ ]

3. **Fees** The RCE fee under 37 CFR § 1.17(e) is required by 37 CFR § 1.114 when the RCE is filed.

a. ☐ A check is enclosed for the fees indicated in b. in the total amount of $[ ]
   OR
   ☒ Authorization is granted to charge the fees indicated in b. in the total amount of $930 to Deposit Account No. 08-0380.

b. i. ☒ RCE fee required under 37 CFR § 1.17(e)
   - ii. ☐ Extension of time fee (37 CFR §§ 1.136 and 1.17)
   - iii. ☐ Amendment Fee
   - iv. ☐ Other - - [ ]

c. ☒ Authorization is hereby granted to charge any deficiency in fees or credit any overpayments to Deposit Account No. 08-0380.

SIGNATURE OF APPLICANT, ATTORNEY OR AGENT REQUIRED

Signature	[signature]	Registration No. (Attorney/Agent)	39,302
Name (Print/Type)	Timothy J. Meagher	Date	1/13/12

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the U.S. Postal Service with sufficient postage as first class mail in an envelope addressed: Mail Stop RCE, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or facsimile transmitted to the US Patent & Trademark Office on the date shown below:

Signature			
Name (Print/Type)		Date	

1169474.1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2873
Filed:	February 23, 2010	Examiner:	Ben, Loha
Confirmation No.:	9661		
For:	Optical Processing		

CERTIFICATE OF MAILING OR TRANSMISSION
I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or is being facsimile transmitted to the United States Patent and Trademark Office on:

Date　　　Signature

Typed or printed name of person signing certificate

TRANSMITTAL LETTER FOR SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Mail Stop RCE
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Supplemental Information Disclosure Statement is submitted:

☒ under 37 CFR 1.97(b), or
(Within any one of the following time periods: three months of filing national application (other than a CPA) or date of entry of the national stage in an international application; or before the mailing date of a first office action on the merits; or before the mailing of a first office action after the filing of a Request for Continued Examination).

☐ under 37 CFR 1.97(c) together with either:
- ☐ a Statement under 37 CFR 1.97(e), as checked below, or
- ☐ a $180.00 fee under 37 CFR 1.17(p), or

(After the 37 CFR 1.97(b) time period, but before any of a final action, notice of allowance, or an action that closes prosecution, whichever occurs first)

☐ under 37 CFR 1.97(d) together with:
- ☐ a Statement under 37 CFR 1.97(e), as checked below, and
- ☐ a $180.00 fee under 37 CFR 1.17(p), or

(Filed after final action, notice of allowance, whichever occurs first, or if prosecution otherwise closes, but on or before payment of the issue fee)

☐ under 37 CFR 1.97(i):
Applicant requests that the IDS and cited reference(s) be placed in the application file.
(Filed after payment of issue fee)

Statement Under 37 CFR 1.97(e)

☐ Each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement; or

☐ No item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the undersigned, after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of this Information Disclosure Statement.

Statement Under 37 CFR 1.704(d) (Patent Term Adjustment)

Applies to original applications (other than design) filed on or after May 29, 2000

☐ Each item of information contained in the Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart application and this communication was not received by any individual designated in § 1.56(c) more than thirty days prior to the filing of the Information Disclosure Statement.

☒ Enclosed herewith is a Listing of References. Copies of the cited references are enclosed except as indicated below or in the attached Listing of References.

☐ Copies of the cited references submitted with an Information Disclosure Statement in prior application, U.S. Application No. [ ], to which priority under 35 U.S.C. 120 is claimed, are not required under 37 CFR 1.98(d)(1) and (2) and are thus not provided.

☐ The listed references were cited in the enclosed Search Report in counterpart foreign application [add application number], which is listed in the attached Listing of References.

☐ The "concise explanation" requirement (non-English references) for reference(s) [ ] under 37 CFR 1.98(a)(3) is satisfied by:

- ☐ the explanation provided on the attached sheet.
- ☐ the explanation provided in the Specification.
- ☐ submission of the enclosed International Search Report.
- ☐ submission of the enclosed English-language version of a foreign Search Report and/or foreign Office Action.
- ☐ the enclosed English language abstract.

Method of payment:

☐ Authorization is NOT granted to charge any fees which may be due in this matter to our Deposit Account.

☐ Please charge Deposit Account 08-0380 in the amount of $[ ].

☐ A check for the fee noted above is enclosed, or the fee has been included in the check with the accompanying Reply.

☒ Please charge any deficiency in fees and credit any overpayment to Deposit Account 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By ______________________

Timothy J. Meagher
Registration No. 39,302
Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133
Dated: 1/13/12

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

BIB DATA SHEET

CONFIRMATION NO. 9661

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
12/710,913	02/23/2010 **RULE**	359	2873	3274.1003-004

APPLICANTS

Melanie Holmes, Suffolk, UNITED KINGDOM;

**** CONTINUING DATA *****************************

This application is a CON of 11/978,258 10/29/2007 PAT 8,089,683
which is a CON of 11/515,389 09/01/2006 PAT 7,612,930
which is a DIV of 10/487,810 09/10/2004 PAT 7,145,710
which is a 371 of PCT/GB02/04011 09/02/2002

**** FOREIGN APPLICATIONS ****************************

UNITED KINGDOM 0121308.1 09/03/2001

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****

03/04/2010

		STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
Foreign Priority claimed ☑ Yes ☐ No 35 USC 119(a-d) conditions met ☑ Yes ☐ No Verified and Acknowledged /LOHA BEN/ Examiner's Signature	☑ Met after Allowance /LB/ Initials	UNITED KINGDOM	36	~~30~~ 21	~~8~~ 6

ADDRESS

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133
UNITED STATES

TITLE

OPTICAL PROCESSING

FILING FEE RECEIVED		
3330	FEES: Authority has been given in Paper No.____________ to charge/credit DEPOSIT ACCOUNT No.____________ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other ________________ ☐ Credit

Index of Claims

	Application/Control No. 12710913	**Applicant(s)/Patent Under Reexamination** HOLMES, MELANIE
	Examiner LOHA BEN	**Art Unit** 2873

✓	**Rejected**	-	**Cancelled**	N	**Non-Elected**	A	**Appeal**
=	**Allowed**	÷	**Restricted**	I	**Interference**	O	**Objected**

☐ **Claims renumbered in the same order as presented by applicant** ☐ **CPA** ☐ **T.D.** ☐ **R.1.47**

CLAIM		**DATE**								
Final	Original	08/17/2010	05/04/2011	10/15/2011	01/23/2012					
1	1	÷	=	=	=					
2	2	÷	=	=	=					
3	3	÷	=	=	=					
4	4	÷	=	=	=					
5	5	÷	=	=	=					
6	6	÷	=	=	=					
7	7	÷	=	=	=					
8	8	÷	=	=	=					
9	9	÷	=	=	=					
10	10	÷	=	=	=					
11	11	÷	=	=	=					
12	12	÷	=	=	=					
13	13	÷	=	=	=					
	14	÷	N	-	-					
	15	÷	N	-	-					
	16	÷	N	-	-					
	17	÷	N	-	-					
	18	÷	N	-	-					
	19	÷	N	-	-					
	20	÷	N	-	-					
	21	÷	N	-	-					
	22	÷	N	-	-					
14	23	÷	=	=	=					
15	24	÷	=	=	=					
16	25	÷	✓	=	=					
17	26	÷	=	=	=					
18	27	÷	=	=	=					
19	28	÷	=	=	=					
20	29	÷	✓	=	=					
21	30	÷	=	=	=					

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12710913	HOLMES, MELANIE
	Examiner	**Art Unit**
	LOHA BEN	2873

ORIGINAL		INTERNATIONAL CLASSIFICATION					
CLASS	SUBCLASS	CLAIMED					NON-CLAIMED
359	279	G	0	2	F	1 / 01 (2006.01.01)	
		G	0	3	H	1 / 08 (2006.01.01)	

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				
359	9	11	238		
369	103				
356	326				

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1		17												
2	2		18												
3	3		19												
4	4		20												
5	5		21												
6	6		22												
7	7	14	23												
8	8	15	24												
9	9	16	25												
10	10	17	26												
11	11	18	27												
12	12	19	28												
13	13	20	29												
	14	21	30												
	15														
	16														

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 21	
/LOHA BEN/ Primary Examiner.Art Unit 2873 (Primary Examiner)	20120123 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 29

UNITED STATES PATENT AND TRADEMARK OFFICE

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NOTICE OF ALLOWANCE AND FEE(S) DUE

21005 7590 01/25/2012
HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

EXAMINER	
BEN, LOHA	
ART UNIT	PAPER NUMBER
2873	

DATE MAILED: 01/25/2012

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

TITLE OF INVENTION: OPTICAL PROCESSING

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1740	$300	$0	$2040	04/25/2012

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

21005 7590 01/25/2012

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)

(Signature)

(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

TITLE OF INVENTION: OPTICAL PROCESSING

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1740	$300	$0	$2040	04/25/2012

EXAMINER	ART UNIT	CLASS-SUBCLASS
BEN, LOHA	2873	359-279000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
   - ❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
   - ❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
   (1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
   (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

   1 ____________________
   2 ____________________
   3 ____________________

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:
- ❑ Issue Fee
- ❑ Publication Fee (No small entity discount permitted)
- ❑ Advance Order - # of Copies ____________________

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ❑ A check is enclosed.
- ❑ Payment by credit card. Form PTO-2038 is attached.
- ❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number ____________ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ❑ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.
- ❑ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature ______________________________ Date ______________________________

Typed or printed name ______________________________ Registration No. ______________________________

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

UNITED STATES PATENT AND TRADEMARK OFFICE

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United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

21005 7590 01/25/2012

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

EXAMINER	
BEN, LOHA	
ART UNIT	**PAPER NUMBER**
2873	

DATE MAILED: 01/25/2012

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 02/11)

TS0002463

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 12/710,913	Applicant(s) HOLMES, MELANIE	
	Examiner LOHA BEN	Art Unit 2873	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *Applicant's papers dated 01/13/2012*.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☒ The allowed claim(s) is/are *1-13 and 23-30*.

4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☒ All b) ☐ Some* c) ☐ None of the:
   1. ☒ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

6. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
   1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

7. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☒ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 01/13/12
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☒ Examiner's Amendment/Comment
8. ☒ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

TS0002465

EXAMINER'S AMENDMENT

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

The application has been amended as follows:

In the Claims

Reference should be made to the Amendment mailed on 10/18/2011.

In the Drawings

Reference should be made to the Amendment mailed on 10/18/2011.

REASONS FOR ALLOWANCE

The following is an examiner's statement of reasons for allowance: Reference should be made to the statement mailed on 10/18/2011, since there is no amendment made to any of the independent claims previously presented. As regards the IDS dated 01/13/2012, the references listed therein fail to teach or fairly suggest the invention as presented in all independent claims 1, 23, 26, 28, 29 and 30.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to LOHA BEN whose telephone number is (571)272-2323. The examiner can normally be reached on M-SAT, generally from 12:01 p.m. to 8:00 p.m.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Ricky Mack, can be reached on M-F, at (571) 272-2333. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

January 23, 2012

/Loha Ben/
Primary Examiner, Art Unit 2873

Search Notes	Application/Control No. 12710913	Applicant(s)/Patent Under Reexamination HOLMES, MELANIE
	Examiner LOHA BEN	Art Unit 2873

SEARCHED

Class	Subclass	Date	Examiner
359	3,9,11,237-239,279,556,558,559,566	05/04/2011	LB
385	15-18,22,31,43,129,133,146,147,901	05/04/2011	LB
356	326,328	05/04/2011	LB
362	26,602	05/04/2011	LB
369	103	05/04/2011	LB

SEARCH NOTES

Search Notes	Date	Examiner
WEST & EAST	05/04/2011	LB
WEST	10/15/2011	LB
WEST	01/22/2012	LB

INTERFERENCE SEARCH

Class	Subclass	Date	Examiner
See WEST	See WEST	05/04/2011	LB
See WEST	See WEST	10/15/2011	LB

WEST Search History for Application 12710913

Creation Date: 2012012215:14

Prior Art Searches

Query	DB	Op.	Plur.	Thes.	Date
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME holgra$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME holgra$8 SAME display$3 SAME control$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME holgra$8 SAME display$3 SAME control$4.CLM.	PGPB	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME holgra$8 SAME (display$3 or delineat$3) SAME control$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME holgra$8 SAME (display$3 or delineat$3) SAME control$4.CLM.	PGPB	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
		OR	YES		05-03-2011

TS0002469

(((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4) and (display$3 or comput$3 or process$3 or delineat$3) SAME hologra$8 SAME control$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD				
(reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME disper$8 SAME (focus$4 or conver$5) SAME hologra$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
(reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME disper$8 SAME (focus$4 or conver$5) SAME (hologra$8 WITH (locat$4 or position$3)) SAME control$$8 SAME direct$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
((reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME disper$8 SAME (focus$4 or conver$5) SAME hologra$8) and (hologra$8 WITH (locat$4 or position$3)) SAME control$$8 SAME direct$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
(reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME (disper$8 or grating$1) SAME (focus$4 or conver$5) SAME hologra$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
((reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME (disper$8 or grating$1) SAME (focus$4 or conver$5) SAME hologra$8) and (hologra$8 WITH (locat$4 or position$3)) SAME control$$8 SAME direct$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
(reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME disper$8 SAME (focus$4 or conver$5) SAME (hologra$8 WITH (locat$4 or position$3)) SAME control$$8 SAME direct$4.CLM.	PGPB	OR	YES		10-15-2011

(spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5 SAME (dispers$7 or grating$1) SAME (focus$4 or lens$2)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
(spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5 SAME (hologra$8 WITH location$1 WITH control$8)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
(spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5 SAME (hologra$8 WITH location$1) SAME control$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
(((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5))	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5))) and (holgra$8 WITH location$1) SAME control$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (holgra$8 WITH location$1) SAME control$8) and ((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5 SAME (dispers$7 or grating$1) SAME (focus$4 or lens$2))	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5))) and	PGPB, USPT, USOC,	OR	YES		01-22-2012

(hologra$8 WITH position$1) SAME control$8	EPAB, JPAB, DWPI, TDBD				
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (hologra$8 WITH position$1) SAME control$8) and ((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5 SAME (dispers$7 or grating$1) SAME (focus$4 or lens$2))	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5))) and (hologra$8 WITH (location$1 or position$1))	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (hologra$8 WITH (location$1 or position$1))) and process SAME (control$8 or regulat$3 or adjust$4) SAME ((common or single) WITH point$1)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (hologra$8 WITH (location$1 or position$1))) and process$3 SAME (control$8 or regulat$3 or adjust$4) SAME ((common or single) WITH point$1)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (hologra$8 WITH (location$1 or position$1))) and (control$8 or regulat$3 or adjust$4) SAME ((common or single) WITH point$1)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (hologra$8 WITH (location$1 or position$1)) and (control$8 or regulat$3 or adjust$4) SAME ((common or single) WITH point$1)) and processor$1	PGPB, USPT, USOC, EPAB, JPAB, DWPI,	OR	YES		01-22-2012

	TDBD				
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (hologra$8 WITH (location$1 or position$1)) and (control$8 or regulat$3 or adjust$4) SAME ((common or single) WITH point$1)) and (processor$1 WITH optical$2)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012

Notice of References Cited	Application/Control No. 12/710,913	Applicant(s)/Patent Under Reexamination HOLMES, MELANIE	
	Examiner LOHA BEN	Art Unit 2873	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,781,691 B2	08-2004	MacKinnon et al.	356/326
*	B	US-5,461,475	10-1995	Lerner et al.	356/300
*	C	US-5,548,418	08-1996	Gaynor et al.	359/20
*	D	US-6,195,184 B1	02-2001	Chao et al.	359/32
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Mail room date: 01/13/2012

Substitute for form 1449B/PTO **SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION** **LISTING OF REFERENCES** **January 13, 2012** (Use several sheets if necessary)	ATTORNEY DOCKET NO. 3274.1003-004		APPLICATION NO. 12/710,913
	FIRST NAMED INVENTOR Melanie Holmes		FILING DATE February 23, 2010
	EXAMINER Ben, Loha	CONFIRMATION NO. 9661	GROUP 2873

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
/L.B./	A70	8,089,683 B2	01-03-2012	Holmes
/L.B./	A71	7,079,723 B2	07-18-2006	Bortolini *et al.*
/L.B./	A72	6,990,268 B2	01-24-2006	Weverka
/L.B./	A73	6,813,408 B2	11-02-2004	Bortolini
/L.B./	A74	6,542,268 B1	04-01-2003	Rotolo *et al.*
/L.B./	A75	6,175,432 B1	01-16-2001	Wu *et al.*
/L.B./	A76	5,953,143	09-14-1999	Sharony *et al.*
/L.B./	A77	5,495,356	02-27-1996	Sharony *et al.*
/L.B./	A78	6,507,685 B1	01-14-2003	Polynkin *et al.*
/L.B./	A79	6,504,976 B1	01-07-2003	Polynkin *et al.*

Copies of issued U.S. Patents and Published U.S. Applications are not required and are not being provided. We are not listing separately any prior U.S. Patent Office communications regarding the cited documents because the Examiner has access to any such actions through PAIR.

EXAMINER /Loha Ben/	DATE CONSIDERED 01/23/2012

1169470

CONSIDERED: /L.B./

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

REQUEST FOR CONTINUED EXAMINATION (RCE) TRANSMITTAL

Subsection (b) of 35 U.S.C. § 132, effective on May 29, 2000, provides for continued examination of a utility or plant application filed on or after June 8, 1995. See The American Inventors Protection Act of 1999 (AIPA)

Application Number	12/710,913
Filing Date	February 23, 2010
Confirmation Number	9661
First Named Inventor	Melanie Holmes
Group Art Unit	2873
Examiner Name	Ben, Loha
Attorney Docket Number	3274.1003-004

This is a Request for Continued Examination (RCE) under 37 CFR § 1.114 of the above-identified application.
Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. See instruction Sheet for RCEs (not to be submitted to the USPTO) on page 2.

1. Submission required under 37 CFR § 1.114

Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).

a. ☐ Previously submitted
   i. ☐ Consider the amendment(s)/reply under 37 CFR § 1.116 previously filed on [ ].
   (Any unentered amendment(s) referred to above will be entered).
   ii ☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on [ ].
   iii. ☐ Other - - [ ]
b. ☐ Please do not enter the amendment(s)/reply under 37 CFR § 1.116 previously filed on [ ]
c. ☒ Enclosed
   i. ☒ Amendment/Reply
   ii. ☐ Affidavit(s)/Declaration(s)
   iii. ☐ Information Disclosure Statement (IDS)
   iv. ☐ Petition for Extension of Time - [ ] month(s) - [separate sheet] [included in amend. fee trans.]
   v. ☐ Other - - [ ]

2. Miscellaneous

a. ☐ Suspension of action on the above-identified application is requested under 37 CFR § 1.103(c) for a period of [ ] months. (Period of suspension shall not exceed 3 months; Fee under 37 CFR § 1.17(i) **required**)
b. ☐ Other - - [ ]

3. Fees The RCE fee under 37 CFR § 1.17(e) is required by 37 CFR § 1.114 when the RCE is filed.

a. ☐ A check is enclosed for the fees indicated in b. in the total amount of $[ ]
   OR
   ☒ Authorization is granted to charge the fees indicated in b. in the total amount of $4590 to Deposit Account No. 08-0380.
b. i. ☒ RCE fee required under 37 CFR § 1.17(e)
   ii. ☐ Extension of time fee (37 CFR §§ 1.136 and 1.17)
   iii. ☒ Amendment Fee
   iv. ☐ Other - - [ ]
c. ☒ Authorization is hereby granted to charge any deficiency in fees or credit any overpayments to Deposit Account No. 08-0380.

SIGNATURE OF APPLICANT, ATTORNEY OR AGENT REQUIRED

Signature	[signature]	Registration No. (Attorney/Agent)	39,302
Name (Print/Type)	Timothy J. Meagher	Date	4/25/12

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the U.S. Postal Service with sufficient postage as first class mail in an envelope addressed: Mail Stop RCE, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or facsimile transmitted to the US Patent & Trademark Office on the date shown below:

Signature			
Name (Print/Type)		Date	

TJM/jk
April 25, 2012

PATENT APPLICATION
DOCKET NO. 3274.1003-004

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2873
Filed:	February 23, 2010	Examiner:	Ben, Loha
Confirmation No.:	9661		
For:	Optical Processing		

CERTIFICATE OF MAILING OR TRANSMISSION

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_______________ _______________________________
Date Signature

____
Typed or printed name of person signing certificate

Mail Stop RCE
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Transmitted herewith is an Amendment for filing in the above-identified application.

☐ Small entity status of this application under 37 CFR 1.9 and 1.27 has been established by a Small Entity Statement previously submitted.

☐ A Small Entity Statement to establish small entity status under 37 CFR 1.9 and 1.27 is enclosed.

1203605.1

The claims fee has been calculated as shown below:

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NO. PREVIOUSLY PAID FOR	PRESENT EXTRA	SMALL ENTITY RATE	SMALL ENTITY ADDIT. FEE	OR	OTHER THAN SMALL ENTITY RATE	OTHER THAN SMALL ENTITY ADDIT. FEE
TOTAL	91	MINUS	* 30	61	X $ 30	$		X $60	$ 3660
INDEP	9	MINUS	** 9	0	X $125	$		X $250	$
☐ FIRST PRESENTATION OF MULTIPLE DEP. CLAIM					+ $225	$		+ $450	$

* not fewer than 20
** not fewer than 3

TOTAL = $ 0 TOTAL = $ 3660

The Application Size Fee has been calculated as shown below:
(Effective for cases filed on or after December 8, 2004)

Actual Sheets (Including current amendment)	Highest No. of Sheets Paid For (At least 100)	No. of Additional Units Required (Increments of 50 sheets)	SMALL ENTITY Rate	SMALL ENTITY Total Amount Owed	OTHER THAN SMALL ENTITY Rate	OTHER THAN SMALL ENTITY Total Amount Owed	Payment Sufficient for up to
150	150	0	X $155	$	X $310	$	150 Sheets

Petition for Extension of Time

☐ Applicant hereby petitions to extend the time to respond to the dated for month(s) from to . The appropriate fee is set forth below.

☐

Please charge Deposit Account No. 08-0380 for the following fees:

☐	Petition for ___ month Extension of Time	$
☒	Claims Fee	$ 3660
☐	Application Size Fee	$
☒	Other Fees:	
	Request for Continued Examination (RCE)	$ 930
		$
	TOTAL:	$ 4590

A check is enclosed in payment of the following fees:

☐	Petition for ___ month Extension of Time	$
☐	Claims Fee	$
☐	Application Size Fee	$
☐	Other Fees:	
		$
		$
	TOTAL:	$

☒ Please charge any deficiency or credit any overpayment in the fees that may be due in this matter to Deposit Account No. 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By [signature]

Timothy J. Meagher
Registration No.: 39,302
Telephone (978) 341-0036
Facsimile (978) 341-0136

Concord, Massachusetts 01742-9133

Dated: 4/25/12

1203605.1

Electronic Patent Application Fee Transmittal

Application Number:	12710913
Filing Date:	23-Feb-2010
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Filer:	Timothy J. Meagher/Julie Kertyzak
Attorney Docket Number:	3274.1003-004

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Claims in excess of 20	1202	61	60	3660
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Request for continued examination	1801	1	930	930
	Total in USD ($)			**4590**

Electronic Acknowledgement Receipt

EFS ID:	12625979
Application Number:	12710913
International Application Number:	
Confirmation Number:	9661
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Customer Number:	21005
Filer:	Timothy J. Meagher/Julie Kertyzak
Filer Authorized By:	Timothy J. Meagher
Attorney Docket Number:	3274.1003-004
Receipt Date:	25-APR-2012
Filing Date:	23-FEB-2010
Time Stamp:	16:12:53
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$4590
RAM confirmation Number	3255
Deposit Account	080380
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		32741003004Amend.PDF	1252780 f3908a1a7821e940da971ccb0af379cc5d5a6af2	yes	16

Multipart Description/PDF files in .zip description

Document Description	Start	End
Amendment Submitted/Entered with Filing of CPA/RCE	1	1
Claims	2	15
Applicant Arguments/Remarks Made in an Amendment	16	16

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
2	Request for Continued Examination (RCE)	32741003004RCE.PDF	131997 bacc18f460c7076f50746c19fe3f727270203c39	no	1

Warnings:

This is not a USPTO supplied RCE SB30 form.

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
3	Transmittal Letter	32741003004feetrans.PDF	173388 038f0da59ab3a35bfbd4cd11e2813f3e9093e5f9	no	3

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
4	Fee Worksheet (SB06)	fee-info.pdf	32045 cd28ca6980a2c02402bb1a9d89cce1e706ec6bae	no	2

Warnings:

Information:

Total Files Size (in bytes): 1590210

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

TJM/jk
04/25/12

PATENT APPLICATION
Attorney's Docket No.: 3274.1003-004

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2873
Filed:	February 23, 2010	Examiner:	Ben, Loha
Confirmation No:	9661		
For:	Optical Processing		

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____ ____ Date ________ Signature

Typed or printed name of person signing certificate

AMENDMENT

Mail Stop RCE
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450
Commissioner:

This Amendment is being filed with a Request for Continued Examination in lieu of payment of the Issue Fee. Reconsideration and further examination are requested.

Please amend the application as follows:

Amendments to the Claims

Please add new Claims 31-100. The Claim Listing below will replace all prior versions of the claims in the application:

Claim Listing

1. (Previously Presented) An optical processor having a reflective SLM, a dispersion device and a focussing device, wherein the SLM has an array of controllable elements, wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over at least part of the SLM, and wherein the processor is configured such that the controllable elements display different holograms at chosen locations of the SLM where said light is incident, for controlling directions at which light from respective said locations emerges.

2. (Original) The optical processor of claim 1, having control circuitry adapted to provide plural different holograms to the SLM.

3. (Original) The optical processor of claim 2, wherein said plural different holograms include respective holograms each for performing a different function, whereby controllable elements at respective chosen locations of the SLM may operate as selected ones of the group comprising: an optical add/drop multiplexer, an optical monitoring device, a channel equaliser, a channel controller, a programmable optical source, a programmable optical filter, an optical spectrum analyser, an evaluation device, a reconfigurable wavelength demultiplexer, and a reconfigurable wavelength multiplexer.

4. (Original) The optical processor of claim 1, having a single SLM.

5. (Original) The optical processor of claim 1, having more than one SLM, each having a respective array of controllable elements wherein the processor is configured such that light

from a common point on the dispersion device is spatially distributed over at least part of each SLM.

6. (Original) The optical processor of claim 1, configured so that said light from a common point on the dispersion device is substantially collimated when incident upon the SLM.

7. (Original) The optical processor of claim 1, further comprising at least one light sensor arranged to provide signals indicative of emergent light.

8. (Original) The optical processor of claim 7, having at least one light sensor arranged to provide signals indicative of light specularly reflected at the SLM.

9. (Original) The optical processor of claim 1, wherein the SLM is a Liquid Crystal on Silicon SLM.

10. (Original) The optical device of claim 1, wherein the SLM incorporates a quarter wave-plate.

11. (Original) The optical processor of claim 1, wherein each hologram occupies an array of controllable elements that has between 10 and 50 controllable elements in at least one dimension.

12. (Original) The optical processor of claim 1, wherein each hologram occupies an array of controllable elements that has a size in at least one dimension that is at least 2 times the 1/e spot half-width of the amplitude distribution of an incident beam in the corresponding direction.

13. (Previously Presented) The optical processor of claim 1, wherein the controllable elements are phase-modulating elements.

14. – 22. (Cancelled)

23. (Previously Presented) A method of operating an optical processor having a reflective SLM having an array of controllable elements, a dispersion device and a focussing device, wherein light beams from a common point on the dispersion device are spatially separate when incident upon the SLM, and wherein the SLM is configured to display holograms at respective locations of incidence of light to provide emergent beams having controllable directions, the method comprising delineating groups of individual controllable elements; selecting, from stored control data, control data for each group of controllable elements of the SLM; generating from the respective selected control data a respective hologram at each group of controllable elements; and varying the delineation of the groups and/or the selection of control data whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

24. (Previously Presented) A method of operating an optical processor according to claim 23, comprising selecting control of said light beams from the group comprising: control of direction, control of power, focussing, aberration compensation, sampling and beam shaping.

25. (Previously Presented) A method according to claim 23, comprising determining, by means of a control device, selection of the groups, selection of control data and delineation of the group boundaries in response to signals from sensors arranged to provide signals indicative of said emergent beams.

26.(Previously Presented) A method of controlling input light comprising: causing said light to become angularly dispersed by a dispersion device; focussing, by a focussing device, angularly dispersed light from the dispersion device to provide focussed light; making said focussed light incident upon a reflective SLM, whereby the light is spatially distributed across at least a part of the SLM, wherein the SLM has an array of controllable elements; and displaying respective holograms at respective locations of incidence of light to provide emergent light whose direction is controlled by the respective holograms.

27. (Previously Presented) A method of directing light using a reflective SLM, a dispersion device and a focussing device, wherein the reflective SLM has an array of controllable elements and wherein the arrangement is such that light from a common point on the dispersion device is spatially distributed over the reflective SLM, the method comprising: causing the controllable elements to display different holograms at chosen locations whereon light is incident, whereby light from said locations emerges in controllable directions.

28. (Previously Presented) The method of claim 27, wherein the controllable elements are phase-modulating elements.

29. (Previously Presented) A method, using a reflective SLM, a dispersion device and a focussing device, wherein the reflective SLM has an array of controllable elements and wherein the arrangement is such that light from a common point on the dispersion device is spatially distributed over the reflective SLM, of measuring at least one spectral property selected from: channel power, channel centre wavelength, channel bandwidth occupied and noise power between channels, the method comprising causing the controllable elements to display different holograms at chosen locations whereon light is incident, whereby light from said locations emerges in controllable directions to at least one sensor.

30. (Previously Presented) An optical processor arranged to function as at least one of the following: an optical add/drop multiplexer, an optical monitoring device, a channel equaliser, a channel controller, a programmable optical source, a programmable optical filter, an optical spectrum analyser, an evaluation device, a reconfigurable wavelength demultiplexer, and a reconfigurable wavelength multiplexer, the processor having a reflective SLM, a dispersion device and a focussing device, wherein the SLM has an array of controllable elements, wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over the SLM, and wherein the processor is configured such that the controllable elements display different holograms at chosen locations, whereby light from said locations emerges in respective directions, the directions deviating from a direction of specular reflection.

31. (New) The optical processor of claim 1 wherein the reflective SLM has a two-dimensional array of controllable elements, wherein the reflective SLM is configured such that each controllable element is selectable whereby two-dimensional groups of controllable elements are formed at chosen locations of the reflective SLM; wherein the processor is configured such that, using the focusing device, light from a common point on the dispersion device is spatially distributed by wavelength across at least one of the two-dimensional groups, and wherein the processor is configured such that each of the two-dimensional groups of controllable elements displays a different hologram at a chosen location of the reflective SLM.

32. (New) A method of operating an optical processor having a reflective SLM having a two-dimensional array of controllable elements, a dispersion device and a focusing device wherein light beams from a common point on the dispersion device are spatially separate when incident upon the SLM, and wherein the SLM is configured to display holograms at respective locations of incidence of light to provide emergent beams having controllable directions, the method comprising delineating two-dimensional groups of individual controllable elements; selecting, from stored control data, control data for each group of controllable elements of the SLM; generating from the respective selected control data a respective hologram at each group of controllable elements; and varying one of the delineation of the groups and the selection of control data whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

33. (New) The method of claim 32, further comprising:
selecting control of said light beams from the group comprising: control of direction, control of power, focusing, aberration compensation, sampling and beam shaping.

34. (New) The method according to claim 32, further comprising:
determining, by means of a control device, selection of the groups, selection of control data and delineation of the group boundaries in response to signals from sensors arranged to provide signals indicative of said emergent beams.

35. (New) The method of controlling light of claim 26, wherein the light is spatially distributed by frequency across at least a part of the SLM, wherein the SLM has a two-dimensional array of controllable elements; and wherein the step of displaying respective holograms comprises displaying the respective holograms using two-dimensional groups of controllable elements selected from said two dimensional array at respective locations of incidence of light to provide emergent light whose direction is controlled by respective holograms.

36. (New) The method of directing light of claim 27, wherein the reflective SLM has a two-dimensional array of controllable elements and wherein the arrangement is such that light from a common point on the dispersion device is spatially distributed over the reflective SLM using the focusing device, wherein the step of causing the controllable elements to display different holograms comprises using two-dimensional groups of controllable elements selected from said two dimensional array at chosen locations whereon light is incident, whereby light from said locations emerges in controllable directions.

37. (New) The method of claim 36, wherein the controllable elements are phase-modulating elements.

38. (New) An optical processor having a reflective SLM, a dispersion device and a focusing device, wherein the SLM has a two-dimensional array of controllable elements; wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over the SLM using the focusing device, and wherein the processor is configured such that the controllable elements display different holograms using two-dimensional groups of controllable elements selected from said two dimensional array at chosen locations, whereby light from said locations emerges in respective directions, the directions deviating from a direction of specular reflection.

39. (New) The optical processor of claim 31 having control circuitry operable to select controllable elements to delineate said two-dimensional groups of controllable elements, and to

vary one of the delineation of the groups and the selection of control data giving rise to the different holograms whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

40. (New) The optical processor of claim 31 having control circuitry operable to select controllable elements to delineate said two-dimensional groups of controllable elements, and to vary both of the delineation of the groups and the selection of control data giving rise to the different holograms whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

41. (New) A method of operating an optical processor having a reflective SLM having a two-dimensional array of controllable elements, a dispersion device and a focusing device wherein light beams from a common point on the dispersion device are spatially separate when incident upon the SLM, and wherein the SLM is configured to display holograms at respective locations of incidence of light to provide emergent beams having controllable directions, the method comprising:

delineating two-dimensional groups of individual controllable elements;

selecting, from stored control data, control data for each group of controllable elements of the SLM;

generating from the respective selected control data a respective hologram at each group of controllable elements; and

varying both the delineation of the groups and the selection of control data whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

42. (New) The method of claim 35, further comprising delineating a respective group of controllable elements for each chosen location whereby the emergent light is determined by the size, shape or position of said groups.

43. (New) The method of claim 36, further comprising delineating a respective group of controllable elements for each chosen location whereby the light emerging from said locations is determined by the size, shape or position of said groups.

44. (New) The optical processor of claim 38 further comprising means for delineating a respective group of controllable elements for each chosen location whereby the light from said locations is determined by the size, shape or position of said groups.

45.(New) The optical processor of claim 31 wherein the processor is configured such that, using the focusing device, light from a common point on the dispersion device is spatially distributed by wavelength across each of the two-dimensional groups wherein the spatial distribution extends across at least two of the two-dimensional groups.

46. (New) The optical processor of claim 31, further comprising at least one input and at least one output, and control circuitry operable to control how wavelengths of light received from said at least one input appear at said at least one output.

47. (New) The optical processor of claim 46 further comprising a broadband optical source operable to render light incident at the at least one input, the processor being operable to transfer incident light from the at least one input to said at least one output, and further comprising control circuitry operable to select wavelengths of light transferred.

48. (New) The optical processor of claim 46, wherein the optical processor is operable to perform at least one of: producing a desired output spectrum and synthesizing a comb spectrum.

49. (New). The optical processor of claim 48, wherein the optical processor is operable to vary the spectrum of light emerging from the at least one output.

50. (New) The optical processor of claim 31, further comprising plural inputs and at least one output, and control circuitry operable to select wavelengths appearing at said at least one output from said plural inputs.

51. (New) The optical processor of claim 48, having plural broadband optical sources arranged to render light incident at the plural inputs, the optical processor being arranged to transfer light from its inputs to said at least one output, and further comprising control circuitry operable to select wavelengths of light transferred.

52. (New) The optical processor of claim 46, further comprising control circuitry operable to create one or more wavelength channels at each output.

53. (New) The optical processor of claim 52, wherein the control circuitry is further operable to select center wavelengths of each said one or more wavelength channels at each output.

54. (New) The optical processor of claim 53, wherein the control circuitry is further operable to select said center wavelength to align with a desired center wavelength for the wavelength channel.

55. (New) The optical processor of claim 54, wherein each controllable element has an element width, and wherein the control circuitry is further operable to delineate a group of controllable elements for the channel, the processor constructed and arranged such that an input light beam exactly at the desired center wavelength for the channel arrives at the SLM such that the center of the incident light beam is within a half of said width from the center of the delineated group of controllable elements.

56. (New) The optical processor of claim 55, wherein the control circuitry is further operable to dynamically reassign controllable elements to the group for the particular channel.

57. (New) The optical processor of claim 31, wherein the two-dimensional array of controllable elements is continuous.

58 (New) The optical processor of claim 53, wherein the control circuitry is further operable to tune a center wavelength of said at least one wavelength channel at each output.

59. (New) The optical processor of claim 58, wherein the control circuitry is further operable to adapt said center wavelength towards a desired center wavelength for said channel.

60. (New). The optical processor of claim 52, wherein the control circuitry is further operable to select the passband of said at least one wavelength channel at each output.

61. (New) The optical processor of claim 52, wherein the control circuitry is further operable to vary the passband of said at least one wavelength channel at each output.

62. (New) The optical processor of claim 52, wherein the control circuitry is further operable to create a first channel to transfer light between an input and an output, and a second channel to transfer light between said input and said output, wherein the first and second channels have adjacent center wavelengths, thereby forming adjacent channels at said output; and to select control data to control the transfer between said input and said output, of light at wavelengths between the center wavelengths of the adjacent channels.

63. (New) The optical processor of claim 62, further comprising control circuitry operable to apply attenuation to light at wavelengths inside the created channels.

64. (New) The optical processor of claim 63 further comprising control circuitry operable to apply independent attenuation levels for each created channel.

65. (New) The optical processor of claim 62, wherein said control data for adjacent channels is selected to reduce the wavelength variation in the position of the emerging light at said output.

66. (New) The optical processor of claim 62 wherein said control data for adjacent channels is selected to control crosstalk in the emerging light at said output.

67. (New) The optical processor of claim 46, wherein the control circuitry is further operable to create a first channel to transfer light between an input and an output, and a second channel to transfer light between said input and said output, wherein the first and second channels have adjacent center wavelengths, thereby forming adjacent channels at said output; the processor being further constructed and arranged to couple light emerging at said output into a respective optical fiber, and to select control data to control the coupling efficiency into the fundamental mode of the optical fiber of emergent light at wavelengths between the center wavelengths of the adjacent channels.

68. (New) The optical processor of claim 67, wherein the holograms displayed are configured to create a set of diffraction orders in emergent light, and the emergent light includes crosstalk from unwanted diffraction orders.

69. (New) The optical processor of claim 31, further comprising control circuitry operable to predict the spatial distribution by wavelength of incident light across the SLM.

70. (New) The optical processor of claim 31 wherein each hologram is arranged to provide a phase ramp to incident light, and each phase ramp has a length that is spatially varied across the SLM to reduce wavelength variation in the deflection angle.

71. (New) The optical processor of claim 67 wherein said control data for adjacent channels is selected to control a stitching error between the adjacent holograms created by said control data.

72. (New) The optical processor of claim 67 wherein said control data for adjacent channels is selected to control the extinction of light at wavelengths between the center wavelengths of the adjacent channels.

73. (New) The optical processor of claim 2, wherein said plural different holograms are each displayed at the same time on a respective two-dimensional group of controllable elements at respective chosen locations of the SLM, wherein each hologram performs a different operation on a respective beam of light incident on the group of controllable elements where the hologram is displayed.

74. (New) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of a routing device.

75. (New) The optical processor of claim 74, wherein the said function of a routing device comprises 1:N routing.

76 (New) The optical processor of claim 73, wherein the said function of a routing device comprises N:1 routing.

77. (New) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of adding a wavelength channel.

78. (New) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of dropping a wavelength channel.

79. (New) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of an optical monitoring device.

80. (New) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of a channel equalizer.

81. (New) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of a channel controller.

82. (New) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of a programmable optical source.

83. (New) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of a programmable optical filter.

84. (New) The optical processor of claim 73 wherein at least one hologram causes the optical processor to perform the function of an optical spectrum analyzer.

85. (New) The optical processor of claim 73 wherein at least one hologram causes the optical processor to perform the function of an evaluation device.

86. (New) The optical processor of claim 73 wherein at least one hologram causes the optical processor to perform the function of a reconfigurable wavelength demultiplexer.

87. (New) The optical processor of claim 73 wherein at least one hologram causes the optical processor to perform the function of a reconfigurable wavelength multiplexer.

88. (New) The optical processor of claim 38, wherein the optical processor is an optical routing device.

89. (New) The optical processor of claim 38, wherein the optical processor is an optical add/drop multiplexer.

90. (New) The optical processor of claim 38, wherein the optical processor is configured to drop at least one signal from a WDM ensemble.

91. (New) The optical processor of claim 38, wherein the optical processor is configured to add at least one signal to a WDM ensemble.

92. (New) The optical processor of claim 38, wherein the optical processor is an optical monitoring device.

93. (New) The optical processor of claim 38, wherein the optical processor is a channel equalizer.

94. (New) The optical processor of claim 38, wherein the optical processor is a channel controller.

95.(New) The optical processor of claim 38, wherein the optical processor is a programmable optical source.

96. (New) The optical processor of claim 38, wherein the optical processor is a programmable optical filter.

97. (New) The optical processor of claim 38, wherein the optical processor is an optical spectrum analyzer.

98. (New) The optical processor of claim 38, wherein the optical processor is an evaluation device.

99. (New) The optical processor of claim 38, wherein the optical processor is a reconfigurable wavelength demultiplexer.

100. (New) The optical processor of claim 38, wherein the optical processor is a reconfigurable wavelength multiplexer.

REMARKS

Claims 1-13, 23-30 are pending. Claims 31-100 are new. No new matter is added. Entry of the new claims is respectfully requested.

CONCLUSION

In view of the above amendments and remarks, it is believed that all claims are in condition for allowance, and it is respectfully requested that the application be passed to issue. If the Examiner feels that a telephone conference would expedite prosecution of this case, the Examiner is invited to call the undersigned.

Respectfully submitted,

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Date: 4/25/12

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PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number: 12/710,913
Filing Date: 02/23/2010
☐ To be Mailed

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY ☐ RATE ($)	SMALL ENTITY FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
			TOTAL			TOTAL	

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

AMENDMENT	04/25/2012	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 91	Minus	** 30	= 61	X $ =		OR	X $60=	3660
	Independent (37 CFR 1.16(h))	* 9	Minus	***9	= 0	X $ =		OR	X $250=	0
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	**3660**

AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/DOROTHY BELL/

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12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

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EXAMINER	
BEN, LOHA	

ART UNIT	PAPER NUMBER
2872	

MAIL DATE	DELIVERY MODE
05/30/2012	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

PTOL-90A (Rev. 04/07)

Office Action Summary	Application No.	Applicant(s)	
	12/710,913	HOLMES, MELANIE	
	Examiner	Art Unit	
	LOHA BEN	2872	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 2 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on 25 April 2012.

2a)☐ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☒ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

5)☒ Claim(s) 1-13 and 23-100 is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☒ Claim(s) 1-13 and 23-100 is/are allowed.

7)☐ Claim(s) _____ is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

12)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

13)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☒ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.

4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

5) ☐ Notice of Informal Patent Application

6) ☐ Other: _____.

DETAILED ACTION

This application is in condition for allowance except for the following formal matters:

In the Claims

In claim 6: on line 2, after “collimated”, -- by the focusing device – should be inserted to be precise.

In claim 8: on line 1, “having” should be replaced with – wherein the --, and after “sensor”, -- is – should be inserted.

In claim 12: on line 3, after "in", "the" should be -- a --.

In claims **23, 32 and 41**: on line 2, after “wherein”, -- the processor is designed such that – should be inserted to provide an inherent function of the focusing device, otherwise the claim is indefinite for failing to particularly point out what the focusing device is for; on line 3, “separate” should be – separated --; and on line 5, “light” should be replaced with – said light beams --.

In claims **24 and 33**: on line 2, “the” should be replaced with – a --, otherwise “the group” recited has no antecedent basis.

In claim 26: on line 6, before “light” (first occurrence), -- said – should be inserted.

In claims **27 and 29**: on line 3, before “such”, -- configured – should be inserted.

In claim 35: on line 5, before “light”, -- said – should be inserted; and on line 6, after “by”, -- said – should be inserted.

In claim 36: on line 2, after “is”, -- configured – should be inserted; and on line 6, after “at” and “whereon”, -- said – should be inserted.

In claim 53: on line 2, “wavelengths” should be – wavelength – to provide antecedent basis for the phrase “said center wavelength” recited on line 2 of claim 54, and after “each”, -- of – should be inserted.

In claim 56: on line 2, after “for”, “the” should be replaced with – a --.

In claims **58, 60 and 61**: on line 2, the phrase “said at least one wavelength channel” should be replaced with – each of one or more wavelength channels --, otherwise the phrase mentioned has no antecedent basis.

In claim 58: on line 2, “a” should be replaced with – the --.

In claim 62: on line 5, after “transfer”, -- of light – should be inserted.

In claims **65, 66, 71 and 72**: on line 1, before “adjacent”, -- said – should be inserted.

In claim 71: on line 2, “the” should be deleted, otherwise “the adjacent holograms” recited has no antecedent basis.

In claim 76: on line 1, “73” should be – 74 --, otherwise “the said function” recited has no antecedent basis.

Prosecution on the merits is closed in accordance with the practice under *Ex parte Quayle*, 25 USPQ 74, 453 O.G. 213, (Comm’r Pat. 1935).

A shortened statutory period for reply to this action is set to expire **TWO MONTHS** from the mailing date of this letter.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to LOHA BEN whose telephone number is (571)272-2323. The examiner can normally be reached on M-SAT, generally from 12:01 p.m. to 8:00 p.m.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Ricky Mack, can be reached on M-F, at (571) 272-2333. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

May 26, 2012

/Loha Ben/
Primary Examiner, Art Unit 2872

WEST Search History for Application 12710913

Creation Date: 2012052514:06

Prior Art Searches

Query	DB	Op.	Plur.	Thes.	Date
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME holo gra$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME holo gra$8 SAME display$3 SAME control$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME holo gra$8 SAME display$3 SAME control$4.CLM.	PGPB	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME holo gra$8 SAME (display$3 or delineat$3) SAME control$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4 SAME holo gra$8 SAME (display$3 or delineat$3) SAME control$4.CLM.	PGPB	OR	YES		05-03-2011
((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-03-2011
		OR	YES		05-03-2011

(((spatial$2 or SLM$1) WITH (reflect$5 or mirror42)) SAME (dispers$3 or grating$1 or diffract$5) SAME focus$4) and (display$3 or comput$3 or process$3 or delineat$3) SAME hologra$8 SAME control$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD				
(reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME disper$8 SAME (focus$4 or conver$5) SAME hologra$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
(reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME disper$8 SAME (focus$4 or conver$5) SAME (hologra$8 WITH (locat$4 or position$3)) SAME control$$8 SAME direct$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
((reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME disper$8 SAME (focus$4 or conver$5) SAME hologra$8) and (hologra$8 WITH (locat$4 or position$3)) SAME control$$8 SAME direct$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
(reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME (disper$8 or grating$1) SAME (focus$4 or conver$5) SAME hologra$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
((reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME (disper$8 or grating$1) SAME (focus$4 or conver$5) SAME hologra$8) and (hologra$8 WITH (locat$4 or position$3)) SAME control$$8 SAME direct$4	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		10-15-2011
(reflect$5 or mirror$2 or micro-mirror$2) SAME (SLM$1 or spatial$2) SAME disper$8 SAME (focus$4 or conver$5) SAME (hologra$8 WITH (locat$4 or position$3)) SAME control$$8 SAME direct$4.CLM.	PGPB	OR	YES		10-15-2011

(spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5 SAME (dispers$7 or grating$1) SAME (focus$4 or lens$2)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
(spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5 SAME (holgra$8 WITH location$1 WITH control$8)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
(spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5 SAME (holgra$8 WITH location$1) SAME control$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
(((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5))	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5))) and (holgra$8 WITH location$1) SAME control$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (holgra$8 WITH location$1) SAME control$8) and ((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5 SAME (dispers$7 or grating$1) SAME (focus$4 or lens$2))	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5))) and	PGPB, USPT, USOC,	OR	YES		01-22-2012

(hologra$8 WITH position$1) SAME control$8	EPAB, JPAB, DWPI, TDBD				
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (hologra$8 WITH position$1) SAME control$8) and ((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5 SAME (dispers$7 or grating$1) SAME (focus$4 or lens$2))	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5))) and (hologra$8 WITH (location$1 or position$1))	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (hologra$8 WITH (location$1 or position$1))) and process SAME (control$8 or regulat$3 or adjust$4) SAME ((common or single) WITH point$1)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (hologra$8 WITH (location$1 or position$1))) and process$3 SAME (control$8 or regulat$3 or adjust$4) SAME ((common or single) WITH point$1)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (hologra$8 WITH (location$1 or position$1))) and (control$8 or regulat$3 or adjust$4) SAME ((common or single) WITH point$1)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (hologra$8 WITH (location$1 or position$1)) and (control$8 or regulat$3 or adjust$4) SAME ((common or single) WITH point$1)) and processor$1	PGPB, USPT, USOC, EPAB, JPAB, DWPI,	OR	YES		01-22-2012

TS0002511

	TDBD				
((((spatial$2 or mirror$2 or micro-mirror$2 or valve$1 or micro-electromechanical$2) SAME modulat$3 SAME reflect$5) or (SLM$1 WITH reflect$5)) and (hologra$8 WITH (location$1 or position$1)) and (control$8 or regulat$3 or adjust$4) SAME ((common or single) WITH point$1)) and (processor$1 WITH optical$2)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		01-22-2012
((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3)) SAME (dispers$7 or diffract$7 or grating$1) SAME (lens$2 or focus$4 or collimat$3)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-24-2012
((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3) WITH hologra$8)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-24-2012
((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3) WITH hologra$8) SAME control$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-24-2012
((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3)) SAME (dispers$7 or diffract$7 or grating$1) SAME (lens$2 or focus$4 or collimat$3) SAME control$8	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-24-2012
(((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3)) SAME (dispers$7 or diffract$7 or grating$1) SAME (lens$2 or focus$4 or collimat$3) SAME control$8) and (((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3) WITH hologra$8) SAME control$8)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-24-2012
((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3) WITH hologra$8) SAME (control$8 WITH (display$3 or direction$1 or independen$3))	PGPB, USPT, USOC,	OR	YES		05-24-2012

TS0002512

	EPAB, JPAB, DWPI, TDBD				
((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3)) SAME (dispers$7 or diffract$7 or grating$1) SAME (lens$2 or focus$4 or collimat$3) SAME (control$8 WITH (display$3 or direction$1 or independen$3))	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-24-2012
(((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3)) SAME (dispers$7 or diffract$7 or grating$1) SAME (lens$2 or focus$4 or collimat$3) SAME (control$8 WITH (display$3 or direction$1 or independen$3))) and (((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3) WITH hologra$8) SAME (control$8 WITH (display$3 or direction$1 or independen$3)))	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-24-2012
((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3)) SAME (dispers$7 or diffract$7 or grating$1) SAME (lens$2 or focus$4 or collimat$3) SAME (control$8 WITH (display$3 or direction$1 or independen$3)) SAME ((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3) WITH hologra$8)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-24-2012
((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3)) SAME (dispers$7 or diffract$7 or grating$1) SAME (lens$2 or focus$4 or collimat$3) SAME (control$8 WITH (display$3 or direction$1 or independen$3)) SAME ((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3) WITH hologra$8).CLM.	PGPB	OR	YES		05-24-2012
(dispers$7 or diffract$7 or grating$1) SAME ((SLM$1 or spatial$2) WITH (on or thereon or whereon) WITH hologra$8)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-25-2012
((dispers$7 or diffract$7 or grating$1) SAME ((SLM$1 or spatial$2) WITH (on or thereon or whereon) WITH hologra$8)) and (focus$4 or collimat$3) SAME (dispers$7 or diffract$7 or grating$1)	PGPB, USPT, USOC, EPAB, JPAB, DWPI,	OR	YES		05-25-2012

	TDBD				
(dispers$7 or diffract$7 or grating$1) SAME ((SLM$1 or mirror$2 or reflect$7) WITH (on or thereon or whereon) WITH hologra$8)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-25-2012
((dispers$7 or diffract$7 or grating$1) SAME ((SLM$1 or mirror$2 or reflect$7) WITH (on or thereon or whereon) WITH hologra$8)) and (focus$4 or collimat$3) SAME (dispers$7 or diffract$7 or grating$1)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-25-2012
(dispers$7 or diffract$7 or grating$1) SAME (SLM$1 WITH reflect$7 WITH (on or thereon or whereon) WITH hologra$8)	PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD	OR	YES		05-25-2012

Index of Claims

	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12710913	HOLMES, MELANIE
	Examiner	**Art Unit**
	LOHA BEN	2873

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	08/17/2010	05/04/2011	10/15/2011	01/23/2012	05/26/2012				
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2	2	÷	=	=	=	=				
3	3	÷	=	=	=	=				
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6	6	÷	=	=	=	=				
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8	8	÷	=	=	=	=				
9	9	÷	=	=	=	=				
10	10	÷	=	=	=	=				
11	11	÷	=	=	=	=				
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Index of Claims	Application/Control No. 12710913	Applicant(s)/Patent Under Reexamination HOLMES, MELANIE
	Examiner LOHA BEN	Art Unit 2873

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	08/17/2010	05/04/2011	10/15/2011	01/23/2012	05/26/2012				
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Index of Claims	Application/Control No. 12710913	Applicant(s)/Patent Under Reexamination HOLMES, MELANIE
	Examiner LOHA BEN	Art Unit 2873

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	08/17/2010	05/04/2011	10/15/2011	01/23/2012	05/26/2012				
	73					=				
	74					=				
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	100					=				

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12710913	HOLMES, MELANIE
	Examiner	**Art Unit**
	LOHA BEN	2873

SEARCHED

Class	Subclass	Date	Examiner
359	3,9,11,237-239,279,556,558,559,566	05/04/2011	LB
385	15-18,22,31,43,129,133,146,147,901	05/04/2011	LB
356	326,328	05/04/2011	LB
362	26,602	05/04/2011	LB
369	103	05/04/2011	LB
359	All updated plus 24,29	05/24/2012	LB
385	All updated	05/24/2012	LB
356	All updated	05/24/2012	LB
362	All updated	05/24/2012	LB
369	All updated plus 44.29,100	05/24/2012	LB
398	49,79	05/24/2012	LB

SEARCH NOTES

Search Notes	Date	Examiner
WEST & EAST	05/04/2011	LB
WEST	10/15/2011	LB
WEST	01/22/2012	LB
WEST & EAST	05/24/2012	LB
WEST	05/25/2012	LB

INTERFERENCE SEARCH

Class	Subclass	Date	Examiner
See WEST	See WEST	05/04/2011	LB
See WEST	See WEST	10/15/2011	LB
See WEST	See WEST	05/24/2012	LB

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	1508	((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3)) SAME (hologra$8 WITH (SLM$1 or spatial$2 or modulat$3))	USPAT	OR	OFF	2012/05/24 19:28
L2	36750	((mirror$2 or reflect$5 or SLM$1 or spatial$2 or modulat$3) WITH control$8 WITH (display$3 or direction$1 or independen$3))	USPAT	OR	OFF	2012/05/24 19:31
L3	2808	((mirror$2 or reflect$5) WITH (SLM$1 or spatial$2 or modulat$3)) SAME (dispers$7 or diffract$7 or grating$1) SAME (focus$4 or lens$2 or collimat$3)	USPAT	OR	OFF	2012/05/24 19:34
L4	90	L1 and L2 and L3	USPAT	OR	OFF	2012/05/24 19:34
L5	30	359/279,237-239,3,9,11,24,29,556,558,559,566.CCLS. and L4	USPAT	OR	OFF	2012/05/24 19:36
L6	6	385/15-18,22,31,43,129,133,146,147.CCLS. and L4	USPAT	OR	OFF	2012/05/24 19:37
L7	17	369/100,103,44.29.CCLS. and L4	USPAT	OR	OFF	2012/05/24 19:37
L8	2	398/49,79.CCLS. and L4	USPAT	OR	OFF	2012/05/24 19:38
L9	5	356/326,328.CCLS. and L4	USPAT	OR	OFF	2012/05/24 19:38
L10	0	362/26,602.CCLS. and L4	USPAT	OR	OFF	2012/05/24 19:38

5/24/2012 7:57:31 PM
C:\Users\lben\Documents\EAST\Workspaces\855.wsp

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BIB DATA SHEET

CONFIRMATION NO. 9661

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
12/710,913	02/23/2010 **RULE**	359	2872	3274.1003-004

APPLICANTS
Melanie Holmes, Suffolk, UNITED KINGDOM;

** **CONTINUING DATA** **************************
This application is a CON of 11/978,258 10/29/2007 PAT 8,089,683
which is a CON of 11/515,389 09/01/2006 PAT 7,612,930
which is a DIV of 10/487,810 09/10/2004 PAT 7,145,710
which is a 371 of PCT/GB02/04011 09/02/2002

** **FOREIGN APPLICATIONS** **************************
UNITED KINGDOM 0121308.1 09/03/2001

** **IF REQUIRED, FOREIGN FILING LICENSE GRANTED** **
03/04/2010

Foreign Priority claimed ☑ Yes ☐ No 35 USC 119(a-d) conditions met ☑ Yes ☐ No Verified and Acknowledged /LOHA BEN/ Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		UNITED KINGDOM	36	~~30~~ 91	~~8~~ 9

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CONCORD, MA 01742-9133
UNITED STATES

TITLE
OPTICAL PROCESSING

FILING FEE RECEIVED		
6990	FEES: Authority has been given in Paper No.____________ to charge/credit DEPOSIT ACCOUNT No.____________ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other ________________ ☐ Credit

Notice of References Cited	Application/Control No. 12/710,913	Applicant(s)/Patent Under Reexamination HOLMES, MELANIE	
	Examiner LOHA BEN	Art Unit 2872	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-5,515,354	05-1996	Miyake et al.	369/112.07
*	B	US-5,293,038	03-1994	Kadowaki et al.	250/216
*	C	US-5,856,048	01-1999	Tahara et al.	430/1
*	D	US-5,329,384	07-1994	Setani et al.	358/514
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	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Electronic Acknowledgement Receipt

EFS ID:	13357221
Application Number:	12710913
International Application Number:	
Confirmation Number:	9661
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Customer Number:	21005
Filer:	Timothy J. Meagher/Julie Kertyzak
Filer Authorized By:	Timothy J. Meagher
Attorney Docket Number:	3274.1003-004
Receipt Date:	27-JUL-2012
Filing Date:	23-FEB-2010
Time Stamp:	14:16:39
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	32741003004feetrans.PDF	188753 30e5ad92ee56ad0b98dbab1bf2ba9af5bf36600c	no	3

Warnings:

Information:

2		32741003004Amend.PDF	1454080 7f71938134aa917514b8b6447ad78ec61b0a6ed9	yes	17

Multipart Description/PDF files in .zip description

Document Description	Start	End
Amendment/Req. Reconsideration-After Non-Final Reject	1	1
Claims	2	16
Applicant Arguments/Remarks Made in an Amendment	17	17

Warnings:

Information:

Total Files Size (in bytes):	1642833

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

TJM/jk
July 27, 2012

PATENT APPLICATION
DOCKET NO. 3274.1003-004

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2872
Filed:	February 23, 2010	Examiner:	Ben, Loha
Confirmation No.:	9661		
For:	Optical Processing		

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, or is being facsimile transmitted to the United States Patent and Trademark Office on:

Date Signature

Typed or printed name of person signing certificate

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Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Transmitted herewith is an Amendment for filing in the above-identified application.

☐ Small entity status of this application under 37 CFR 1.9 and 1.27 has been established by a Small Entity Statement previously submitted.

☐ A Small Entity Statement to establish small entity status under 37 CFR 1.9 and 1.27 is enclosed.

The claims fee has been calculated as shown below:

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NO. PREVIOUSLY PAID FOR	PRESENT EXTRA	SMALL ENTITY RATE	SMALL ENTITY ADDIT. FEE		OTHER THAN SMALL ENTITY RATE	OTHER THAN SMALL ENTITY ADDIT. FEE
TOTAL	91	MINUS	* 91	0	X $ 30	$	OR	X $60	$
INDEP	9	MINUS	** 9	0	X $125	$		X $250	$
☐ FIRST PRESENTATION OF MULTIPLE DEP. CLAIM					+ $225	$		+ $450	$

* not fewer than 20
** not fewer than 3

TOTAL = $ ______ TOTAL = $ ______

The Application Size Fee has been calculated as shown below:
(Effective for cases filed on or after December 8, 2004)

Actual Sheets (Including current amendment)	Highest No. of Sheets Paid For (At least 100)	No. of Additional Units Required (Increments of 50 sheets)	SMALL ENTITY Rate	SMALL ENTITY Total Amount Owed	OTHER THAN SMALL ENTITY Rate	OTHER THAN SMALL ENTITY Total Amount Owed	Payment Sufficient for up to
150	150	0	X $155	$	X $310	$	150 Sheets

Petition for Extension of Time

☐ Applicant hereby petitions to extend the time to respond to the dated for month(s) from to . The appropriate fee is set forth below.

☐

Please charge Deposit Account No. 08-0380 for the following fees:

- ☐ Petition for ______ month Extension of Time $ ______
- ☐ Claims Fee $ ______
- ☐ Application Size Fee $ ______
- ☐ Other Fees:

______ $ ______

______ $ ______

TOTAL: $ ______

A check is enclosed in payment of the following fees:

- ☐ Petition for ______ month Extension of Time $ ______
- ☐ Claims Fee $ ______
- ☐ Application Size Fee $ ______
- ☐ Other Fees:

______ $ ______

______ $ ______

TOTAL: $ ______

☒ Please charge any deficiency or credit any overpayment in the fees that may be due in this matter to Deposit Account No. 08-0380.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By ______

Timothy J. Meagher
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Telephone (978) 341-0036
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Concord, Massachusetts 01742-9133

Dated: 7/27/12

1243965.1

REMARKS

The claims have been amended in accordance with suggestions made by the Examiner in the Office Action dated May 30, 2012.

CONCLUSION

In view of the above amendments and remarks, it is believed that all claims are in condition for allowance, and it is respectfully requested that the application be passed to issue. If the Examiner feels that a telephone conference would expedite prosecution of this case, the Examiner is invited to call the undersigned.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By [signature]
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Date: 7/27/12

1234524.1

Amendments to the Claims

Please amend Claims 6, 8, 12, 23, 24, 26, 27, 29, 32, 33, 35, 36, 41, 53, 56, 58, 60, 61, 62, 65, 66, 71, 72 and 76. The Claim Listing below will replace all prior versions of the claims in the application:

Claim Listing

1. (Previously presented) An optical processor having a reflective SLM, a dispersion device and a focussing device, wherein the SLM has an array of controllable elements, wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over at least part of the SLM, and wherein the processor is configured such that the controllable elements display different holograms at chosen locations of the SLM where said light is incident, for controlling directions at which light from respective said locations emerges.

2. (Original) The optical processor of claim 1, having control circuitry adapted to provide plural different holograms to the SLM.

3. (Original) The optical processor of claim 2, wherein said plural different holograms include respective holograms each for performing a different function, whereby controllable elements at respective chosen locations of the SLM may operate as selected ones of the group comprising: an optical add/drop multiplexer, an optical monitoring device, a channel equaliser, a channel controller, a programmable optical source, a programmable optical filter, an optical spectrum analyser, an evaluation device, a reconfigurable wavelength demultiplexer, and a reconfigurable wavelength multiplexer.

4. (Original) The optical processor of claim 1, having a single SLM.

5. (Original) The optical processor of claim 1, having more than one SLM, each having a respective array of controllable elements wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over at least part of each SLM.

6. (Currently amended) The optical processor of claim 1, configured so that said light from a common point on the dispersion device is substantially collimated by the focusing device when incident upon the SLM.

7. (Original) The optical processor of claim 1, further comprising at least one light sensor arranged to provide signals indicative of emergent light.

8. (Currently amended) The optical processor of claim 7, ~~having~~ wherein the at least one light sensor is arranged to provide signals indicative of light specularly reflected at the SLM.

9. (Original) The optical processor of claim 1, wherein the SLM is a Liquid Crystal on Silicon SLM.

10. (Original) The optical device of claim 1, wherein the SLM incorporates a quarter wave-plate.

11. (Original) The optical processor of claim 1, wherein each hologram occupies an array of controllable elements that has between 10 and 50 controllable elements in at least one dimension.

12. (Currently amended) The optical processor of claim 1, wherein each hologram occupies an array of controllable elements that has a size in at least one dimension that is at least 2 times the 1/e spot half-width of the amplitude distribution of an incident beam in ~~the~~ a corresponding direction.

13. (Previously presented) The optical processor of claim 1, wherein the controllable elements are phase-modulating elements.

14. – 22. (Cancelled)

23. (Currently amended) A method of operating an optical processor having a reflective SLM having an array of controllable elements, a dispersion device and a focussing device, wherein the processor is designed such that light beams from a common point on the dispersion device are spatially ~~separate~~ separated when incident upon the SLM, and wherein the SLM is configured to display holograms at respective locations of incidence of ~~light~~ said light beams to provide emergent beams having controllable directions, the method comprising delineating groups of individual controllable elements; selecting, from stored control data, control data for each group of controllable elements of the SLM; generating from the respective selected control data a respective hologram at each group of controllable elements; and varying the delineation of the groups and/or the selection of control data whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

24. (Currently amended) A method of operating an optical processor according to claim 23, comprising selecting control of said light beams from ~~the~~ a group comprising: control of direction, control of power, focussing, aberration compensation, sampling and beam shaping.

25. (Previously presented) A method according to claim 23, comprising determining, by means of a control device, selection of the groups, selection of control data and delineation of the group boundaries in response to signals from sensors arranged to provide signals indicative of said emergent beams.

26.(Currently amended) A method of controlling input light comprising: causing said light to become angularly dispersed by a dispersion device; focussing, by a focussing device, angularly dispersed light from the dispersion device to provide focussed light; making said focussed light incident upon a reflective SLM, whereby the light is spatially distributed across at least a part of the SLM, wherein the SLM has an array of controllable elements; and displaying respective holograms at respective locations of incidence of said light to provide emergent light whose direction is controlled by the respective holograms.

27. (Currently amended) A method of directing light using a reflective SLM, a dispersion device and a focussing device, wherein the reflective SLM has an array of controllable elements and wherein the arrangement is configured such that light from a common point on the dispersion device is spatially distributed over the reflective SLM, the method comprising: causing the controllable elements to display different holograms at chosen locations whereon light is incident, whereby light from said locations emerges in controllable directions.

28. (Previously presented) The method of claim 27, wherein the controllable elements are phase-modulating elements.

29. (Currently amended) A method, using a reflective SLM, a dispersion device and a focussing device, wherein the reflective SLM has an array of controllable elements and wherein the arrangement is configured such that light from a common point on the dispersion device is spatially distributed over the reflective SLM, of measuring at least one spectral property selected from: channel power, channel centre wavelength, channel bandwidth occupied and noise power between channels, the method comprising causing the controllable elements to display different holograms at chosen locations whereon light is incident, whereby light from said locations emerges in controllable directions to at least one sensor.

30. (Previously presented) An optical processor arranged to function as at least one of the following: an optical add/drop multiplexer, an optical monitoring device, a channel equaliser, a channel controller, a programmable optical source, a programmable optical filter, an optical spectrum analyser, an evaluation device, a reconfigurable wavelength demultiplexer, and a reconfigurable wavelength multiplexer, the processor having a reflective SLM, a dispersion device and a focussing device, wherein the SLM has an array of controllable elements, wherein

the processor is configured such that light from a common point on the dispersion device is spatially distributed over the SLM, and wherein the processor is configured such that the controllable elements display different holograms at chosen locations, whereby light from said locations emerges in respective directions, the directions deviating from a direction of specular reflection.

31. (Previously presented) The optical processor of claim 1 wherein the reflective SLM has a two-dimensional array of controllable elements, wherein the reflective SLM is configured such that each controllable element is selectable whereby two-dimensional groups of controllable elements are formed at chosen locations of the reflective SLM; wherein the processor is configured such that, using the focusing device, light from a common point on the dispersion device is spatially distributed by wavelength across at least one of the two-dimensional groups, and wherein the processor is configured such that each of the two-dimensional groups of controllable elements displays a different hologram at a chosen location of the reflective SLM.

32. (Currently amended) A method of operating an optical processor having a reflective SLM having a two-dimensional array of controllable elements, a dispersion device and a focusing device wherein the processor is designed such that light beams from a common point on the dispersion device are spatially ~~separate~~ separated when incident upon the SLM, and wherein the SLM is configured to display holograms at respective locations of incidence of ~~light~~ said light beams to provide emergent beams having controllable directions, the method comprising delineating two-dimensional groups of individual controllable elements; selecting, from stored control data, control data for each group of controllable elements of the SLM; generating from the respective selected control data a respective hologram at each group of controllable elements; and varying one of the delineation of the groups and the selection of control data whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

33. (Currently amended) The method of claim 32, further comprising:
selecting control of said light beams from ~~the~~ a group comprising: control of direction, control of power, focusing, aberration compensation, sampling and beam shaping.

34. (Previously presented) The method according to claim 32, further comprising:
determining, by means of a control device, selection of the groups, selection of control data and delineation of the group boundaries in response to signals from sensors arranged to provide signals indicative of said emergent beams.

35. (Currently amended) The method of controlling light of claim 26, wherein the light is spatially distributed by frequency across at least a part of the SLM, wherein the SLM has a two-dimensional array of controllable elements; and wherein the step of displaying respective holograms comprises displaying the respective holograms using two-dimensional groups of controllable elements selected from said two dimensional array at respective locations of incidence of said light to provide emergent light whose direction is controlled by said respective holograms.

36. (Currently amended) The method of directing light of claim 27, wherein the reflective SLM has a two-dimensional array of controllable elements and wherein the arrangement is configured such that light from a common point on the dispersion device is spatially distributed over the reflective SLM using the focusing device, wherein the step of causing the controllable elements to display different holograms comprises using two-dimensional groups of controllable elements selected from said two dimensional array at said chosen locations whereon said light is incident, whereby light from said locations emerges in controllable directions.

37. (Previously presented) The method of claim 36, wherein the controllable elements are phase-modulating elements.

38. (Previously presented) An optical processor having a reflective SLM, a dispersion device and a focusing device, wherein the SLM has a two-dimensional array of controllable elements;

wherein the processor is configured such that light from a common point on the dispersion device is spatially distributed over the SLM using the focusing device, and wherein the processor is configured such that the controllable elements display different holograms using two-dimensional groups of controllable elements selected from said two dimensional array at chosen locations, whereby light from said locations emerges in respective directions, the directions deviating from a direction of specular reflection.

39. (Previously presented) The optical processor of claim 31 having control circuitry operable to select controllable elements to delineate said two-dimensional groups of controllable elements, and to vary one of the delineation of the groups and the selection of control data giving rise to the different holograms whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

40. (Previously presented) The optical processor of claim 31 having control circuitry operable to select controllable elements to delineate said two-dimensional groups of controllable elements, and to vary both of the delineation of the groups and the selection of control data giving rise to the different holograms whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

41. (Currently amended) A method of operating an optical processor having a reflective SLM having a two-dimensional array of controllable elements, a dispersion device and a focusing device wherein the processor is designed such that light beams from a common point on the dispersion device are spatially ~~separate~~ separated when incident upon the SLM, and wherein the SLM is configured to display holograms at respective locations of incidence of ~~light~~ said light beams to provide emergent beams having controllable directions, the method comprising:

delineating two-dimensional groups of individual controllable elements;

selecting, from stored control data, control data for each group of controllable elements of the SLM;

generating from the respective selected control data a respective hologram at each group of controllable elements; and varying both the delineation of the groups and the selection of control data whereby upon illumination of said groups by respective light beams, respective emergent light beams from the groups are controllable independently of each other.

42. (Previously presented) The method of claim 35, further comprising delineating a respective group of controllable elements for each chosen location whereby the emergent light is determined by the size, shape or position of said groups.

43. (Previously presented) The method of claim 36, further comprising delineating a respective group of controllable elements for each chosen location whereby the light emerging from said locations is determined by the size, shape or position of said groups.

44. (Previously presented) The optical processor of claim 38 further comprising means for delineating a respective group of controllable elements for each chosen location whereby the light from said locations is determined by the size, shape or position of said groups.

45. (Previously presented) The optical processor of claim 31 wherein the processor is configured such that, using the focusing device, light from a common point on the dispersion device is spatially distributed by wavelength across each of the two-dimensional groups wherein the spatial distribution extends across at least two of the two-dimensional groups.

46. (Previously presented) The optical processor of claim 31, further comprising at least one input and at least one output, and control circuitry operable to control how wavelengths of light received from said at least one input appear at said at least one output.

47. (Previously presented) The optical processor of claim 46 further comprising a broadband optical source operable to render light incident at the at least one input, the processor being operable to transfer incident light from the at least one input to said at least one output, and further comprising control circuitry operable to select wavelengths of light transferred.

48. (Previously presented) The optical processor of claim 46, wherein the optical processor is operable to perform at least one of: producing a desired output spectrum and synthesizing a comb spectrum.

49. (Previously presented) The optical processor of claim 48, wherein the optical processor is operable to vary the spectrum of light emerging from the at least one output.

50. (Previously presented) The optical processor of claim 31, further comprising plural inputs and at least one output, and control circuitry operable to select wavelengths appearing at said at least one output from said plural inputs.

51. (Previously presented) The optical processor of claim 48, having plural broadband optical sources arranged to render light incident at the plural inputs, the optical processor being arranged to transfer light from its inputs to said at least one output, and further comprising control circuitry operable to select wavelengths of light transferred.

52. (Previously presented) The optical processor of claim 46, further comprising control circuitry operable to create one or more wavelength channels at each output.

53. (Currently amended) The optical processor of claim 52, wherein the control circuitry is further operable to select center ~~wavelengths~~ wavelength of each of said one or more wavelength channels at each output.

54. (Previously presented) The optical processor of claim 53, wherein the control circuitry is further operable to select said center wavelength to align with a desired center wavelength for the wavelength channel.

55. (Previously presented) The optical processor of claim 54, wherein each controllable element has an element width, and wherein the control circuitry is further operable to delineate a group of controllable elements for the channel, the processor constructed and arranged such that an input

light beam exactly at the desired center wavelength for the channel arrives at the SLM such that the center of the incident light beam is within a half of said width from the center of the delineated group of controllable elements.

56. (Currently amended) The optical processor of claim 55, wherein the control circuitry is further operable to dynamically reassign controllable elements to the group for ~~the~~ a particular channel.

57. (Previously presented) The optical processor of claim 31, wherein the two-dimensional array of controllable elements is continuous.

58. (Currently amended) The optical processor of claim 53, wherein the control circuitry is further operable to tune [[a]] the center wavelength of ~~said at least one wavelength channel~~ each of one or more wavelength channels at each output.

59. (Previously presented) The optical processor of claim 58, wherein the control circuitry is further operable to adapt said center wavelength towards a desired center wavelength for said channel.

60. (Currently amended). The optical processor of claim 52, wherein the control circuitry is further operable to select the passband of ~~said at least one wavelength channel~~ each of one or more wavelength channels at each output.

61. (Currently amended) The optical processor of claim 52, wherein the control circuitry is further operable to vary the passband of ~~said at least one wavelength channel~~ each of one or more wavelength channels at each output.

62. (Currently amended) The optical processor of claim 52, wherein the control circuitry is further operable to create a first channel to transfer light between an input and an output, and a second channel to transfer light between said input and said output, wherein the first and second

channels have adjacent center wavelengths, thereby forming adjacent channels at said output; and to select control data to control the transfer of light between said input and said output, of light at wavelengths between the center wavelengths of the adjacent channels.

63. (Previously presented) The optical processor of claim 62, further comprising control circuitry operable to apply attenuation to light at wavelengths inside the created channels.

64. (Previously presented) The optical processor of claim 63 further comprising control circuitry operable to apply independent attenuation levels for each created channel.

65. (Currently amended) The optical processor of claim 62, wherein said control data for said adjacent channels is selected to reduce the wavelength variation in the position of the emerging light at said output.

66. (Currently amended) The optical processor of claim 62 wherein said control data for said adjacent channels is selected to control crosstalk in the emerging light at said output.

67. (Previously presented) The optical processor of claim 46, wherein the control circuitry is further operable to create a first channel to transfer light between an input and an output, and a second channel to transfer light between said input and said output, wherein the first and second channels have adjacent center wavelengths, thereby forming adjacent channels at said output; the processor being further constructed and arranged to couple light emerging at said output into a respective optical fiber, and to select control data to control the coupling efficiency into the fundamental mode of the optical fiber of emergent light at wavelengths between the center wavelengths of the adjacent channels.

68. (Previously presented) The optical processor of claim 67, wherein the holograms displayed are configured to create a set of diffraction orders in emergent light, and the emergent light includes crosstalk from unwanted diffraction orders.

69. (Previously presented) The optical processor of claim 31, further comprising control circuitry operable to predict the spatial distribution by wavelength of incident light across the SLM.

70. (Previously presented) The optical processor of claim 31 wherein each hologram is arranged to provide a phase ramp to incident light, and each phase ramp has a length that is spatially varied across the SLM to reduce wavelength variation in the deflection angle.

71. (Currently amended) The optical processor of claim 67 wherein said control data for said adjacent channels is selected to control a stitching error between ~~the~~ adjacent holograms created by said control data.

72. (Currently amended) The optical processor of claim 67 wherein said control data for said adjacent channels is selected to control the extinction of light at wavelengths between the center wavelengths of the adjacent channels.

73. (Previously presented) The optical processor of claim 2, wherein said plural different holograms are each displayed at the same time on a respective two-dimensional group of controllable elements at respective chosen locations of the SLM, wherein each hologram performs a different operation on a respective beam of light incident on the group of controllable elements where the hologram is displayed.

74. (Previously presented) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of a routing device.

75. (Previously presented) The optical processor of claim 74, wherein the said function of a routing device comprises 1:N routing.

76. (Currently amended) The optical processor of claim ~~73~~ 74, wherein the said function of a routing device comprises N:1 routing.

77. (Previously presented) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of adding a wavelength channel.

78. (Previously presented) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of dropping a wavelength channel.

79. (Previously presented) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of an optical monitoring device.

80. (Previously presented) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of a channel equalizer.

81. (Previously presented) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of a channel controller.

82. (Previously presented) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of a programmable optical source.

83. (Previously presented) The optical processor of claim 73, wherein at least one hologram causes the optical processor to perform the function of a programmable optical filter.

84. (Previously presented) The optical processor of claim 73 wherein at least one hologram causes the optical processor to perform the function of an optical spectrum analyzer.

85. (Previously presented) The optical processor of claim 73 wherein at least one hologram causes the optical processor to perform the function of an evaluation device.

86. (Previously presented) The optical processor of claim 73 wherein at least one hologram causes the optical processor to perform the function of a reconfigurable wavelength demultiplexer.

87. (Previously presented) The optical processor of claim 73 wherein at least one hologram causes the optical processor to perform the function of a reconfigurable wavelength multiplexer.

88. (Previously presented) The optical processor of claim 38, wherein the optical processor is an optical routing device.

89. (Previously presented) The optical processor of claim 38, wherein the optical processor is an optical add/drop multiplexer.

90. (Previously presented) The optical processor of claim 38, wherein the optical processor is configured to drop at least one signal from a WDM ensemble.

91. (Previously presented) The optical processor of claim 38, wherein the optical processor is configured to add at least one signal to a WDM ensemble.

92. (Previously presented) The optical processor of claim 38, wherein the optical processor is an optical monitoring device.

93. (Previously presented) The optical processor of claim 38, wherein the optical processor is a channel equalizer.

94. (Previously presented) The optical processor of claim 38, wherein the optical processor is a channel controller.

95. (Previously presented) The optical processor of claim 38, wherein the optical processor is a programmable optical source.

96. (Previously presented) The optical processor of claim 38, wherein the optical processor is a programmable optical filter.

97. (Previously presented) The optical processor of claim 38, wherein the optical processor is an optical spectrum analyzer.

98. (Previously presented) The optical processor of claim 38, wherein the optical processor is an evaluation device.

99. (Previously presented) The optical processor of claim 38, wherein the optical processor is a reconfigurable wavelength demultiplexer.

100. (Previously presented) The optical processor of claim 38, wherein the optical processor is a reconfigurable wavelength multiplexer.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Melanie Holmes		
Application No.:	12/710,913	Group:	2872
Filed:	February 23, 2010	Examiner:	Ben, Loha
Confirmation No:	9661		
For:	Optical Processing		

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Typed or printed name of person signing certificate

AMENDMENT IN RESPONSE TO EX PARTE QUAYLE ACTION

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

This Amendment is being filed in response to the Ex Parte Quayle Action mailed from the U.S. Patent and Trademark Office on May 30, 2012 in the above-identified application.

Please amend the application as follows:

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number	Filing Date	
12/710,913	02/23/2010	☐ To be Mailed

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)	SMALL ENTITY ☐		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	07/30/2012	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 91	Minus	** 91	= 0	X $ =		OR	X $60=	0
	Independent (37 CFR 1.16(h))	* 9	Minus	***9	= 0	X $ =		OR	X $250=	0
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	**0**

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/ZURIASHWORK ZENEBE/

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

21005 7590 10/16/2012

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

EXAMINER	
BEN, LOHA	
ART UNIT	PAPER NUMBER
2872	

DATE MAILED: 10/16/2012

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

TITLE OF INVENTION: OPTICAL PROCESSING

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1770	$300	$0	$2070	01/16/2013

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

21005 7590 10/16/2012

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

TITLE OF INVENTION: OPTICAL PROCESSING

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1770	$300	$0	$2070	01/16/2013

EXAMINER	ART UNIT	CLASS-SUBCLASS
BEN, LOHA	2872	359-279000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
   - ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
   - ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
   (1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
   (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
   1____________________
   2____________________
   3____________________

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
- ☐ Issue Fee
- ☐ Publication Fee (No small entity discount permitted)
- ☐ Advance Order - # of Copies ______________

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ☐ A check is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number ________ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.
- ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature ____________________ Date ____________________

Typed or printed name ____________________ Registration No. ____________________

UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

21005 7590 10/16/2012

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

EXAMINER	
BEN, LOHA	
ART UNIT	PAPER NUMBER
2872	

DATE MAILED: 10/16/2012

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 02/11)

TS0002547

Privacy Act Statement

The Privacy Act of 1974 (**P.L. 93-579**) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	**Application No.** 12/710,913	**Applicant(s)** HOLMES, MELANIE	
	Examiner LOHA BEN	**Art Unit** 2872	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *Applicant's Amendments dated 07/27/2012*.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *1-13 and 23-100*.
4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☒ All b) ☐ Some* c) ☐ None of the:
   1. ☒ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
6. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
   1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
7. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☒ Examiner's Amendment/Comment
8. ☒ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

EXAMINER'S AMENDMENT

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

The application has been amended as follows:

In the Specification

In paragraph [0131]: on line 1, the phrase "FIG. 13. . . diagram" has been replaced with -- FIGS. 13a and 13b show schematic diagrams --, and after "SLM", -- , assuming 1-D routing -- has been inserted.

In paragraph [0417]: on line 2, "13, 13a" has been replaced with – 13a, 13b --.

REASONS FOR ALLOWANCE

The following is an examiner's statement of reasons for allowance: References of record, taken singly or in combination, fail to teach or fairly suggest: (1) the optical processor of independent claims 1 and 30 that has a reflective SLM, a dispersive device and a focusing device, wherein the SLM has **an array of controllable elements** configured and function in the manner now presented in the respective claims 1 and 30; (2) the optical processor of independent claim 38 that has a reflective SLM, a dispersive device and a focusing device, wherein the SLM has **a two-dimensional array of controllable elements** configured and function in the manner now presented in the claim; (3) the method of operating an optical processor of independent claim 23, having the same elements as the ones called for in claims 1 and 30 above, and having the steps as now presented in the claim; (4) the method of operating an optical processor of independent claims 32 and 41, having the same elements as the ones called for in claim 38 above, and having the steps as now presented in the respective claims 32 and 41; (5) the method of controlling input light of independent claim 26 using the same elements as those of the processor called for in claims 1 and 30 above, as now characterized in the claim; (6) the method of directing light of independent claim 27 using the same elements as those of the processor called for in claims 1 and 30 above, as now characterized in the claim; and (7) the method as now presented in independent claim 29 using the same elements as those called for in claims 1 and 30 above.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled “Comments on Statement of Reasons for Allowance.”

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to LOHA BEN whose telephone number is (571)272-2323. The examiner can normally be reached on M-SAT, generally from 12:01 p.m. to 8:00 p.m.

If attempts to reach the examiner by telephone are unsuccessful, the examiner’s supervisor, Ricky Mack, can be reached on M-F, at (571) 272-2333. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

October 2, 2012

/Loha Ben/
Primary Examiner, Art Unit 2872

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12710913	HOLMES, MELANIE
	Examiner	**Art Unit**
	LOHA BEN	2872

SEARCHED

Class	Subclass	Date	Examiner
359	3,9,11,237-239,279,556,558,559,566	05/04/2011	LB
385	15-18,22,31,43,129,133,146,147,901	05/04/2011	LB
356	326,328	05/04/2011	LB
362	26,602	05/04/2011	LB
369	103	05/04/2011	LB
359	All updated plus 24,29	05/24/2012	LB
385	All updated	05/24/2012	LB
356	All updated	05/24/2012	LB
362	All updated	05/24/2012	LB
369	All updated plus 44.29,100	05/24/2012	LB
398	49,79	05/24/2012	LB

SEARCH NOTES

Search Notes	Date	Examiner
WEST & EAST	05/04/2011	LB
WEST	10/15/2011	LB
WEST	01/22/2012	LB
WEST & EAST	05/24/2012	LB
WEST	05/25/2012	LB

INTERFERENCE SEARCH

Class	Subclass	Date	Examiner
See WEST	See WEST	05/04/2011	LB
See WEST	See WEST	10/15/2011	LB
See WEST	See WEST	05/24/2012	LB

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

BIB DATA SHEET

CONFIRMATION NO. 9661

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
12/710,913	02/23/2010 **RULE**	359	2872	3274.1003-004

APPLICANTS

Melanie Holmes, Suffolk, UNITED KINGDOM;

** **CONTINUING DATA** *************************

This application is a CON of 11/978,258 10/29/2007 PAT 8,089,683
which is a CON of 11/515,389 09/01/2006 PAT 7,612,930
which is a DIV of 10/487,810 09/10/2004 PAT 7,145,710
which is a 371 of PCT/GB02/04011 09/02/2002

** **FOREIGN APPLICATIONS** *************************

UNITED KINGDOM 0121308.1 09/03/2001

** **IF REQUIRED, FOREIGN FILING LICENSE GRANTED** **

03/04/2010

	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
Foreign Priority claimed ☑ Yes ☐ No 35 USC 119(a-d) conditions met ☑ Yes ☐ No Verified and Acknowledged /LOHA BEN/ Examiner's Signature ☑ Met after Allowance /LB/ Initials	UNITED KINGDOM	36	~~20~~ 91	~~3~~ 9

ADDRESS

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133
UNITED STATES

TITLE

OPTICAL PROCESSING

FILING FEE RECEIVED		
6990	FEES: Authority has been given in Paper No.__________ to charge/credit DEPOSIT ACCOUNT No.__________ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other __________ ☐ Credit

Index of Claims	Application/Control No. 12710913	Applicant(s)/Patent Under Reexamination HOLMES, MELANIE
	Examiner LOHA BEN	Art Unit 2872

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	08/17/2010	05/04/2011	10/15/2011	01/23/2012	05/26/2012	10/02/2012			
1	1	÷	=	=	=	=	=			
2	2	÷	=	=	=	=	=			
3	3	÷	=	=	=	=	=			
19	4	÷	=	=	=	=	=			
20	5	÷	=	=	=	=	=			
21	6	÷	=	=	=	=	=			
22	7	÷	=	=	=	=	=			
23	8	÷	=	=	=	=	=			
24	9	÷	=	=	=	=	=			
25	10	÷	=	=	=	=	=			
26	11	÷	=	=	=	=	=			
27	12	÷	=	=	=	=	=			
28	13	÷	=	=	=	=	=			
	14	÷	N	-	-	-	-			
	15	÷	N	-	-	-	-			
	16	÷	N	-	-	-	-			
	17	÷	N	-	-	-	-			
	18	÷	N	-	-	-	-			
	19	÷	N	-	-	-	-			
	20	÷	N	-	-	-	-			
	21	÷	N	-	-	-	-			
	22	÷	N	-	-	-	-			
60	23	÷	=	=	=	=	=			
61	24	÷	=	=	=	=	=			
62	25	÷	✓	=	=	=	=			
63	26	÷	=	=	=	=	=			
66	27	÷	=	=	=	=	=			
67	28	÷	=	=	=	=	=			
71	29	÷	✓	=	=	=	=			
72	30	÷	=	=	=	=	=			
29	31					=	=			
73	32					=	=			
74	33					=	=			
75	34					=	=			
64	35					=	=			
68	36					=	=			

Index of Claims	Application/Control No. 12710913	Applicant(s)/Patent Under Reexamination HOLMES, MELANIE
	Examiner LOHA BEN	Art Unit 2872

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	08/17/2010	05/04/2011	10/15/2011	01/23/2012	05/26/2012	10/02/2012			
69	37					=	=			
76	38					=	=			
30	39					=	=			
31	40					=	=			
91	41					=	=			
65	42					=	=			
70	43					=	=			
77	44					=	=			
32	45					=	=			
33	46					=	=			
34	47					=	=			
35	48					=	=			
36	49					=	=			
58	50					=	=			
37	51					=	=			
38	52					=	=			
39	53					=	=			
40	54					=	=			
41	55					=	=			
42	56					=	=			
59	57					=	=			
43	58					=	=			
44	59					=	=			
45	60					=	=			
46	61					=	=			
47	62					=	=			
48	63					=	=			
49	64					=	=			
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51	66					=	=			
52	67					=	=			
53	68					=	=			
56	69					=	=			
57	70					=	=			
54	71					=	=			
55	72					=	=			

Index of Claims	Application/Control No. 12710913	Applicant(s)/Patent Under Reexamination HOLMES, MELANIE
	Examiner LOHA BEN	Art Unit 2872

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	08/17/2010	05/04/2011	10/15/2011	01/23/2012	05/26/2012	10/02/2012			
4	73					=	=			
5	74					=	=			
6	75					=	=			
7	76					=	=			
8	77					=	=			
9	78					=	=			
10	79					=	=			
11	80					=	=			
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83	93					=	=			
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85	95					=	=			
86	96					=	=			
87	97					=	=			
88	98					=	=			
89	99					=	=			
90	100					=	=			

Issue Classification

Application/Control No.	Applicant(s)/Patent Under Reexamination
12710913	HOLMES, MELANIE
Examiner	**Art Unit**
LOHA BEN	2872

ORIGINAL

CLASS	SUBCLASS
359	279

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				
359	9	11	238	615	
369	103				
356	326				

INTERNATIONAL CLASSIFICATION

CLAIMED					NON-CLAIMED
G	0	2	F	1 / 01 (2006.01.01)	
G	0	3	H	1 / 08 (2006.01.01)	

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1		17	74	33	36	49	50	65	12	81	87	97		
2	2		18	75	34	58	50	51	66	13	82	88	98		
3	3		19	64	35	37	51	52	67	14	83	89	99		
19	4		20	68	36	38	52	53	68	15	84	99	100		
20	5		21	69	37	39	53	56	69	16	85				
21	6		22	76	38	40	54	57	70	17	86				
22	7	60	23	30	39	41	55	54	71	18	87				
23	8	61	24	31	40	42	56	55	72	78	88				
24	9	62	25	91	41	59	57	4	73	79	89				
25	10	63	26	65	42	43	58	5	74	80	90				
26	11	66	27	70	43	44	59	6	75	81	91				
27	12	67	28	77	44	45	60	7	76	82	92				
28	13	71	29	32	45	46	61	8	77	83	93				
	14	72	30	33	46	47	62	9	78	84	94				
	15	29	31	34	47	48	63	10	79	85	95				
	16	73	32	35	48	49	64	11	80	86	96				

NONE (Assistant Examiner)	(Date)	Total Claims Allowed: 91
/LOHA BEN/ Primary Examiner.Art Unit 2873 (Primary Examiner)	20121002 (Date)	O.G. Print Claim(s): 1 / O.G. Print Figure: 29

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

21005 7590 10/16/2012
HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	02/23/2010	Melanie Holmes	3274.1003-004	9661

TITLE OF INVENTION: OPTICAL PROCESSING

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1770	$300	$0	$2070	01/16/2013

EXAMINER	ART UNIT	CLASS-SUBCLASS
BEN, LOHA	2872	359-279000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
   - ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
   - ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
   (1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
   (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
   1 Hamilton, Brook, Smith & Reynolds, P.C.
   2 ____
   3 ____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Thomas Swan & Co. Ltd.
(B) RESIDENCE: (CITY and STATE OR COUNTRY): Consett, United Kingdom

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
- ☒ Issue Fee
- ☒ Publication Fee (No small entity discount permitted)
- ☐ Advance Order - # of Copies ____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ☐ A check is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number 08-0380 (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.
- ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature [signature] Date 11/13/12

Typed or printed name Timothy J. Meagher Registration No. 39,302

Electronic Acknowledgement Receipt

EFS ID:	14211599
Application Number:	12710913
International Application Number:	
Confirmation Number:	9661
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Customer Number:	21005
Filer:	Timothy J. Meagher/Julie Kertyzak
Filer Authorized By:	Timothy J. Meagher
Attorney Docket Number:	3274.1003-004
Receipt Date:	13-NOV-2012
Filing Date:	23-FEB-2010
Time Stamp:	15:04:13
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$2070
RAM confirmation Number	1698
Deposit Account	080380
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	32741003004IF.pdf	168732 fb116a42059ce02956032bacd0903d77c13bf734	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	31668 455d4e585e3d6db746381f8998534ecd8dd9e340	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	200400		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Electronic Patent Application Fee Transmittal

Application Number:	12710913
Filing Date:	23-Feb-2010
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Filer:	Timothy J. Meagher/Julie Kertyzak
Attorney Docket Number:	3274.1003-004

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl issue fee	1501	1	1770	1770
Publ. Fee- early, voluntary, or normal	1504	1	300	300

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**2070**

TS0002563

Please replace the paragraph at page 19, lines 4 through 14, with the following amended paragraph:

[0158] Referring to FIG. 1, an integrated SLM 200 for modulating light 201 of a selected wavelength, e.g. 1.5 μm, consists of a pixel electrode array 230 formed of reflective ~~aluminium~~ aluminum. The pixel electrode array 230, as will later be described acts as a mirror, and disposed on it is a quarter-wave plate 221. A liquid crystal layer 222 is disposed on the quarter-wave plate 221 via an alignment layer (not shown) as is known to those skilled in the art of liquid crystal structures. Over (as shown) the liquid crystal layer 222 are disposed in order a second alignment layer 223, a common ITO electrode layer 224 and an upper glass layer 225. The common electrode layer 224 defines an electrode plane. The pixel electrode array 230 is disposed parallel to the common electrode plane 224. It will be understood that alignment layers and other intermediate layers will be provided as usual. They are omitted in FIG. 1 for clarity.

lines 21 through page 91, line 1

Please replace the paragraph on page 90, ~~lines 13 through 23,~~ with the following amended paragraph:

[0457] FIG. 23 shows a first to fourth routing modules 720, 730, 740 and 750. The first and fourth modules each have one input 721, 751, a through output 722, 752, a cross-connect output 723,753 and a number of drop outputs~~721~~ 724, 754. The second and third modules 730,740 each have respective single output 731,741, a number of add inputs 732,742 a cross-connect input 733,743 and a through input 734, 744. The through output 722 of the first module 720 is connected to the through input 734 of the second module 730, and the through output 752 of the fourth module 750 is connected to the through input 744 of the third module 740. The cross-connect output 723 of the first module 720 is connected to the cross-connect input 743 of the third module 740, and the cross-connect output 753 of the fourth module 750 is connected to the cross-connect input 733 of the second module 730.

Change(s) applied
to document,
/K.C./
11/28/2011

Change(s) applied
to document,
/K.C./
11/28/2011

Amendments to the Specification

lines 2 through 9

Please replace the paragraph at page 1, ~~lines 1 through 9~~, entitled "RELATED APPLICATIONS" with the following amended paragraph:

This application is a continuation of U.S. Application No. 11/978,258, filed October 29, 2007, which is a continuation of U.S. Application No. 11/515,389, filed September 1, 2006, now issued Patent 7,612,930, which is a divisional of U.S. Application No. 10/487,810, now issued Patent 7,145,710, which is the U.S. National Stage of International Application No. PCT/GB02/04011, filed September 2, 2002, and published in English. This application claims priority under 35 U.S.C. § 119 or 365 to Great Britain Application No. 0121308.1, filed September 3, 2001. The entire teachings of the above application(s) are incorporated herein by reference.

Please replace the paragraph at page 4, lines 25 through 29, through page 5, lines 1 and 2, with the following amended paragraph:

[0022] Clearly in most situations more than one of these control types will be needed-for example in a routing device (such as a switch, filter or add/drop multiplexer) primary changes of direction are likely to be needed to cope with changes of routing as part of the main system but secondary correction will be needed to cope with effects such as temperature and ageing. Additionally, such systems may also need to control power, and to allow sampling (both of which may in some cases be achieved by direction changes).

Please replace the paragraph at page 6, lines 19 through 26, with the following amended paragraph:

[0040] According to a second aspect of the invention, there is provided an optical device comprising an SLM and a control circuit, the SLM having a two-dimensional array of controllable phase-modulating elements and the control circuit having a store constructed and arranged to hold plural items of control data, the control circuit being constructed and arranged to delineate groups of individual phase-modulating elements, to select, from stored control data, control data for each group of phase-modulating elements, and to generate from the respective selected control data a respective hologram at each group of phase-modulating elements,

Mail room date: 06/14/2010

Substitute for form 1449B/PTO	ATTORNEY DOCKET NO.	APPLICATION NO.	
SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT IN AN APPLICATION	3274.1003-004	12/710,913	
	FIRST NAMED INVENTOR Melanie Holmes	FILING DATE February 23, 2010	
LISTING OF REFERENCES **June 14, 2010** (Use several sheets if necessary)	EXAMINER ~~XXXXXXX~~ LOHA BEN	CONFIRMATION NO. 9661	GROUP ~~XXXX~~ 2873

U.S. PATENT DOCUMENTS

Examiner's Initials	Ref. No.	DOCUMENT NUMBER Number-Kind Code (if known)	ISSUE DATE / PUBLICATION DATE MM-DD-YYYY	NAME OF PATENTEE OR APPLICANT OF CITED DOCUMENT
/L.B./	A31	6,879,426 B1	04-12-2005	Weiner
	A32	6,950,609 B2	09-27-2005	Marom
	A33	6,738,540 B2	05-18-2004	Marom
	A34	6,657,770 B2	12-02-2003	Marom, et al.
	A35	6,795,182 B2	09-21-2004	Rakuljic, et al.
Change(s) applied	A36	6,804,428 B1	~~12-14-2001~~ October 12, 2004	Garrett, et al.
to document,	A37	7,177,496 B1	~~12-27-2001~~ February 13, 2007	Polynkin, et al.
/N.W.S./ /L.B./ 12/1/2011	A38	6,275,623	~~07-12-1999~~ August 14, 2001	Brophy, et al.

We are not listing separately any prior U.S. Patent Office communications regarding the cited application(s) because the Examiner has access to any such actions through PAIR.

EXAMINER	DATE CONSIDERED
/Loha Ben/	05/04/2011

989678_1

CONSIDERED: /L.B./

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/710,913	12/18/2012	8335033	3274.1003-004	9661

21005 7590 11/28/2012

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.
530 VIRGINIA ROAD
P.O. BOX 9133
CONCORD, MA 01742-9133

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Melanie Holmes, Suffolk, UNITED KINGDOM;

IR103 (Rev. 10/09)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Patentee:	Melanie Holmes		
Application No.	12/710,913	Filed:	February 23, 2010
Patent No.:	8,335,033 B2	Issued:	December 18, 2012
Title:	Optical Processing		

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to Commissioner for Patents, P.O. Box 1450 Alexandria, VA 22313-1450, or is being facsimile transmitted to the United States Patent and Trademark Office on:

__________ Date __________ Signature

__________ Typed or printed name of person signing certificate

REQUEST FOR CERTIFICATE OF CORRECTION

Commissioner for Patents
Office of Patent Publication
ATTN: Certificate of Correction Branch
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

Pursuant to 35 U.S.C. § 254, we hereby request that a Certificate of Correction be issued for the above-referenced U.S. Letters Patent to correct errors as shown on the attached PTO/SB/44 form.

Since the errors were made by the U.S. Patent and Trademark Office and not by Patentee or Patentee's Attorney/Agent, it is understood that there are no additional fees are due for the requested Certificate of Correction.

Respectfully submitted,
HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By /Timothy J. Meagher, Reg. No. 39302/
Timothy J. Meagher
Registration No.: 39,302
Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133
Dated: February 5, 2013

PTO/SB/44 (09-07)
Approved for use through 08/31/2013. OMB 0651-0033
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.
(Also Form PTO-1050)

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,335,033 B2

APPLICATION NO.: 12/710,913

ISSUE DATE : December 18, 2012

INVENTOR(S) : Melanie Holmes

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In Column 62, Claim 41, line 42, delete "SIM" and insert -- SLM --

MAILING ADDRESS OF SENDER (Please do not use customer number below):

Hamilton, Brook, Smith & Reynolds, P.C.
530 Virginia Road, P.O., Box 9133
Concord, MA 01742-9133

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Acknowledgement Receipt

EFS ID:	14879764
Application Number:	12710913
International Application Number:	
Confirmation Number:	9661
Title of Invention:	OPTICAL PROCESSING
First Named Inventor/Applicant Name:	Melanie Holmes
Customer Number:	21005
Filer:	Timothy J. Meagher/Amy McGrew
Filer Authorized By:	Timothy J. Meagher
Attorney Docket Number:	3274.1003-004
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Time Stamp:	15:38:44
Application Type:	Utility under 35 USC 111(a)

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Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Request for Certificate of Correction	32741003004ReqCertCorr.pdf	53913 e3938bfae2246a9f2890cd05bf92adb2dee5df01	no	1

Warnings:

Information:

2	Miscellaneous Incoming Letter	32741003004SB44.pdf	164302 1df17cfaa148acf16654f1f1548a5561da4a5253	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	218215	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,335,033 B2
APPLICATION NO. : 12/710913
DATED : December 18, 2012
INVENTOR(S) : Melanie Holmes

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In Column 62, Claim 41, line 42, delete "SIM" and insert -- SLM --

Signed and Sealed this
Nineteenth Day of March, 2013

Teresa Stanek Rea
Acting Director of the United States Patent and Trademark Office