Title

Reconfigurable Optical Add-Drop Multiplexers with Servo Control and Dynamic Spectral Power Management Capabilities

Preliminary Class

385

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).

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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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Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (01-10)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Filed Herewith
	Filing Date	Filed Herewith
	First Named Inventor	Jeffrey P. Wilde, et. al
	Art Unit	Unknown
	Examiner Name	Unknown
	Attorney Docket Number	C2393-1101RE2

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	7183633	B2	2007-02-27	Daneman et. al	all
	2	6989921	B2	2006-01-24	Bernstein et. al	all
	3	6810169	B2	2004-10-26	Bouevitch et. al	all
	4	6631222	B1	2003-10-07	Wagener et. al	all
	5	6600851	B2	2003-07-29	Aksyuk et. al	all
	6	6567574	B1	2003-05-20	Ma et. al	all
	7	6498872	B2	2002-12-24	Bouevitch et. al	all
	8	6256430	B1	2001-07-03	Jin et. al	all

EFS Web 2.1.17

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number: Filed Herewith Filing Date: Filed Herewith First Named Inventor: Jeffrey P. Wilde, et. al Art Unit: Unknown Examiner Name: Unknown Attorney Docket Number: C2393-I101RE2

	9	6028689		2000-01-24	Michalicek et. al	all
	10	5414540		1995-05-09	Patel et. al	all
	11	5629790	A	1997-05-01	Neukermans et. al	all
	12	5745271		1998-04-28	Ford et. al	all
	13	5835458	A	1998-11-01	Bischel et. al	all
	14	5960133	A	1999-09-01	Tomlinson	all
	15	5974207	A	1999-10-01	Aksyuk et. al	all
	16	6204946	B1	2001-03-01	Aksyuk et. al	all
	17	6205269	B1	2001-03-01	Morton	all
	18	6222954	B1	2001-04-01	Riza	all
	19	6253135	B1	2001-07-01	Wade	all

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	

Application Number	Filed Herewith
Filing Date	Filed Herewith
First Named Inventor	Jeffrey P. Wilde, et. al
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	C2393-1101RE2

	20	6289155	B1	2001-09-01	Wade	all
	21	6307657	B1	2001-10-23	Ford	all
	22	6418250	B1	2002-07-01	Corbosiero et. al	all
	23	6625346		2003-09-23	Wilde et. al	
	24	6634810	B1	2003-10-21	Ford et. al	all
	25	6898348	B2	2005-05-24	Morozov et. al	all

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20020131691	A1	2002-09-01	Garrett et al.	all
	2	20030043471	A1	2003-03-01	Belser et. al	all

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	Filed Herewith
	Filing Date	Filed Herewith
	First Named Inventor	Jeffrey P. Wilde, et. al
	Art Unit	Unknown
	Examiner Name	Unknown
	Attorney Docket Number	C2393-1101RE2

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] j	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							☐

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NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1		☐

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EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	Filed Herewith
	Filing Date	Filed Herewith
	First Named Inventor	Jeffrey P. Wilde, et. al
	Art Unit	Unknown
	Examiner Name	Unknown
	Attorney Docket Number	C2393-1101RE2

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the 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 the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification 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 the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

XX None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Barry N. Young/	Date (YYYY-MM-DD)	2010-06-14
Name/Print	Barry N. Young	Registration Number	27,744

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	Reconfigurable Optical Add-Drop Multiplexers with Servo Control and Dynamic Spectral Power Management Capabilities
First Named Inventor/Applicant Name:	Jeffrey P. Wilde
Filer:	Barry N. Young
Attorney Docket Number:	C2393-1101RE2

Filed as Large Entity

Reissue (Utility) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility Reissue Basic	1014	1	330	330
Design and utility Reissue Basic	1114	1	540	540
Design and utility Reissue Basic	1314	1	650	650
Pages:				
Claims:				
Reissue claims in excess of 20 for large	1205	48	52	2496
Independent claims reissue large	1204	4	220	880
Miscellaneous-Filing:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**4896**

Electronic Acknowledgement Receipt

EFS ID:	7818212
Application Number:	12815930
International Application Number:	
Confirmation Number:	2344
Title of Invention:	Reconfigurable Optical Add-Drop Multiplexers with Servo Control and Dynamic Spectral Power Management Capabilities
First Named Inventor/Applicant Name:	Jeffrey P. Wilde
Customer Number:	48789
Filer:	Barry N. Young
Filer Authorized By:	
Attorney Docket Number:	C2393-1101RE2
Receipt Date:	15-JUN-2010
Filing Date:	
Time Stamp:	16:13:07
Application Type:	Reissue (Utility)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$4896
RAM confirmation Number	2781
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Transmittal Reissue Application	SB-50_Re_Trnsmtl.pdf	63755 fe839170a310147d5ea82b0e2f99fa49e41e54e4	no	1
Warnings:					
Information:					
2	Fee Worksheet (PTO-875)	SB-56_Fee_Trnsmtl.pdf	52758 cac0c50834bacc0a7a8cf827cefe8e4195e38642	no	1
Warnings:					
Information:					
3		RE39397.pdf	1442861 605df43c28ab6a6c5f0d38225d78cb11ffaafb8d	yes	23
	Multipart Description/PDF files in .zip description				
	Document Description		**Start**	**End**	
	Abstract		1	1	
	Drawings-only black and white line drawings		2	13	
	Specification		14	19	
	Claims		20	23	
Warnings:					
Information:					
4	Drawings-other than black and white line drawings	Figs_1101RE2.pdf	1315713 c37bea86c6b9226e6d75c91eecbb5ff539e4df6b	no	12
Warnings:					
Information:					
5	Oath or Declaration filed	SB-52_Declr_PoA.pdf	417661 6250f6d8cf8cf8448b43b7cd107340e3e0791eb9	no	2
Warnings:					
Information:					
6	Consent of Assignee accompanying the declaration.	SB-53_Consent_Assgnee.pdf	192272 856426b478beccccd1bd1d713a97cc37286557d	no	1
Warnings:					
Information:					
7	Assignee showing of ownership per 37 CFR 3.73(b).	SB-96_Stmt_373b.pdf	209937 8ff706bc700a026d92d047926da84108dca81490	no	1
Warnings:					

Information:					
8	Preliminary Amendment	1101RE2_PA_Status_Support.pdf	62207 2e8579af49b731eef9c317531aae51d4d5e7b1d6	no	19
Warnings:					
Information:					
9	Information Disclosure Statement (IDS) Filed (SB/08)	Sb-08_IDS.pdf	812976 5cf0ac50c5d4983946eb01865fc0ecb8015a9b27	no	5
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
10	Fee Worksheet (PTO-875)	fee-info.pdf	38439 096cd29e1aa9d3b3ea275d67403f01efec378489	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	4608579		

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.

REISSUE PATENT APPLICATION TRANSMITTAL

Address to:		
Mail Stop Reissue **Commissioner for Patents** **P.O. Box 1450** **Alexandria, VA 22313-1450**	Attorney Docket No.	C2393-1101RE2
	First Named Inventor	Jeffrey P. WILDE, et. al
	Original Patent Number	RE39,397 (6,625,346)
	Original Patent Issue Date (Month/Day/Year)	11/14/2006 (9/23/2003)
	Express Mail Label No.	EFS-Web

APPLICATION FOR REISSUE OF: (*Check applicable box*) ☑ Utility Patent ☐ Design Patent ☐ Plant Patent

APPLICATION ELEMENTS (37 CFR 1.173)

1. ☑ Fee Transmittal Form (PTO/SB/56)
2. ☐ Applicant claims small entity status. See 37 CFR 1.27.
3. ☑ Specification and Claims in double column copy of patent format *(amended, if appropriate)*
4. ☑ Drawing(s) *(proposed amendments, if appropriate)*
5. ☑ Reissue Oath/Declaration (original or copy) (37 C.F.R. 1.175) (PTO/SB/51 or 52)
6. ☑ Power of Attorney
7. ☑ Original U.S. Patent currently assigned? ☑ Yes ☐ No
   (If Yes, check applicable box(es))
   - ☑ Written Consent of all Assignees (PTO/SB/53)
   - ☑ 37 CFR 3.73(b) Statement (PTO/SB/96)
8. ☐ CD-ROM or CD-R in duplicate, Computer Program (Appendix) or large table
   ☐ Landscape Table on CD
9. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, items a. – c. are required))*
   a. ☐ Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i ☐ CD-ROM (2 copies) or CD-R (2 copies); **or**
      ii ☐ paper
   c. ☐ Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

10. ☑ Statement of status and support for all changes to the claims. See 37 CFR 1.173(c).
11. ☐ Foreign Priority Claim (35 U.S.C. 119) *(if applicable)*
12. ☑ Information Disclosure Statement (IDS) PTO/SB/08 or PTO-1449
    ☐ Copies of citations attached
13. ☐ English Translation of Reissue Oath/Declaration *(if applicable)*
14. ☑ Preliminary Amendment
15. ☐ Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
16. ☐ Other:

17. CORRESPONDENCE ADDRESS

☑ The address associated with *Customer Number:* 48789 ***OR*** ☐ *Correspondence address below*

Name	Barry N. Young				
Address	200 Page Mill Road; Suite 102				
City	Palo Alto	State	CA	Zip Code	94306
Country	US	Telephone	(650) 326-2701	Email	Byoung@young-iplaw.com

Signature	/Barry N. Young/	Date	June 14, 2010
Name (Print/Type)	Barry N. Young	Registration No. (Attorney/Agent)	27,744

PTO/SB/56 (02-10)
Approved for use through 08/31/2010. 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.

REISSUE APPLICATION FEE TRANSMITTAL FORM

Docket Number (Optional): C2393-1101RE2

Application as Filed – Part 1

	(1) Claims in Patent	(2) Claims Filed in Reissue Application	(3) Number Extra	Small Entity Rate ($)	Small Entity Fee ($)		Other than a Small Entity Rate ($)	Other than a Small Entity Fee ($)
Total Claims (37 CFR 1.16(i))	(A) 67	(B) 68	**** 48 =	x =			x 52 =	2496
Independent Claims (37 CFR 1.16(h))	(C) 6	(D) 7	* 4 =	x =			x 220 =	880
Application Size Fee (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $270 ($135 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).					or		0
			Filing Fee (37 CFR 1.16(e))					330
			Search Fee (37 CFR 1.16(n))					540
			Examination Fee (37 CFR 1.16(r))					650
			Total Filing Fee					4896

Application as Amended – Part 2

	(1) Claims Remaining After Amendment		(2) Highest Number Previously Paid For	(3) Extra Claims Present	Small Entity Rate ($)	Small Entity Fee ($)		Other than a Small Entity Rate ($)	Other than a Small Entity Fee ($)
Total Claims (37 CFR 1.16(i))	***	MINUS	**	=	X =			x =	
Independent Claims (37 CFR 1.16(h))	***	MINUS	*****	=	x =		or	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 $270 ($135 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).								
				Total Additional Fee					

* Enter (D) minus 3, or enter "0" if (D) is less than 3.
** If the "Highest Number of Total Claims Previously Paid For" is less than 20, enter "20" in this space.
*** After any cancellation of claims.
**** Enter (B) – 20, or enter "0" if (B) is less than 20.
***** If the "Highest Number of Independent Claims Previously Paid For" is less than 3, enter "3" in this space.

☐ Applicant claims small entity status. See 37 CFR 1.27.

☐ Please charge Deposit Account No. ______________ in the amount of ______________.

☐ The Director is hereby authorized to charge any additional fees under 37 CFR 1.16 or 1.17 which may be required, or credit any overpayment to Deposit Account No. ______________.

☐ A check in the amount of $ ______________ to cover the filing/additional fee is enclosed.

☒ Payment by credit card. Form PTO-2038 is attached. WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

EFS-Web /Barry N. Young/ — Signature — 6/14/2010 — Date

Barry N. Young — Typed or printed name — 27,744 — Registration Number, if applicable

(650) 326-2701 — Telephone Number

US00RE39397E

(19) **United States**
(12) **Reissued Patent**
Wilde et al.

(10) **Patent Number: US RE39,397 E**
(45) **Date of Reissued Patent: Nov. 14, 2006**

(54) **RECONFIGURABLE OPTICAL ADD-DROP MULTIPLEXERS WITH SERVO CONTROL AND DYNAMIC SPECTRAL POWER MANAGEMENT CAPABILITIES**

(75) Inventors: **Jeffrey P. Wilde**, Morgan Hill, CA (US); **Joseph E. Davis**, Morgan Hill, CA (US)

(73) Assignee: **Capella Photonics, Inc.**, San Jose, CA (US)

(21) Appl. No.: **11/027,586**

(22) Filed: **Dec. 31, 2004**

Related U.S. Patent Documents

Reissue of:
(64) Patent No.: **6,625,346**
Issued: **Sep. 23, 2003**
Appl. No.: **09/938,426**
Filed: **Aug. 23, 2001**

U.S. Applications:
(60) Provisional application No. 60/277,217, filed on Mar. 19, 2001.

(51) **Int. Cl.**
G02B 6/28 (2006.01)

(52) **U.S. Cl.** **385/24**; 385/11; 385/37; 385/34

(58) **Field of Classification Search** 385/11, 385/24, 34, 37
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,629,790 A * 5/1997 Neukermans et al. 359/198
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2002/0131691 A1 * 9/2002 Garrett et al. 385/24
2003/0043471 A1 * 3/2003 Belser et al. 359/634

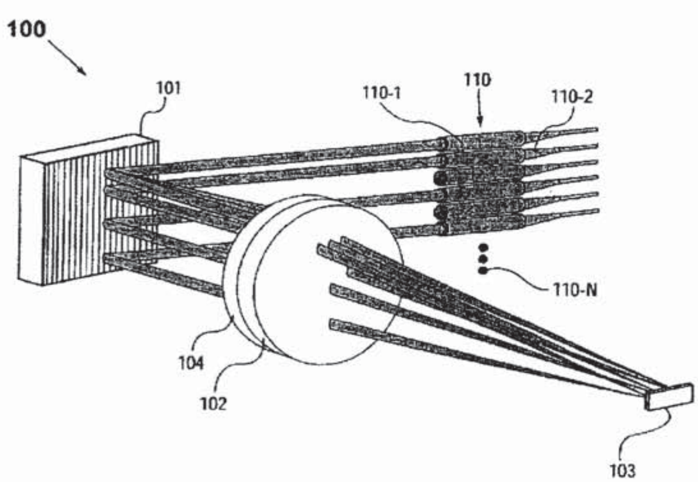
* cited by examiner

Primary Examiner—Brian Healy
(74) *Attorney, Agent, or Firm*—Barry N. Young

(57) **ABSTRACT**

This invention provides a novel wavelength-separating-routing (WSR) apparatus that uses a diffraction grating to separate a multi-wavelength optical signal by wavelength into multiple spectral characters, which are then focused onto an array of corresponding channel micromirrors. The channel micromirrors are individually controllable and continuously pivotable to reflect the spectral channels into selected output ports. As such, the inventive WSR apparatus is capable of routing the spectral channels on a channel-by-channel basis and coupling any spectral channel into any one of the output ports. The WSR apparatus of the present invention may be further equipped with servo-control and spectral power-management capabilities, thereby maintaining the coupling efficiencies of the spectral channels into the output ports at desired values. The WSR apparatus of the present invention can be used to construct a novel class of dynamically reconfigurable optical add-drop multiplexers (OADMs) for WDM optical networking applications.

67 Claims, 12 Drawing Sheets



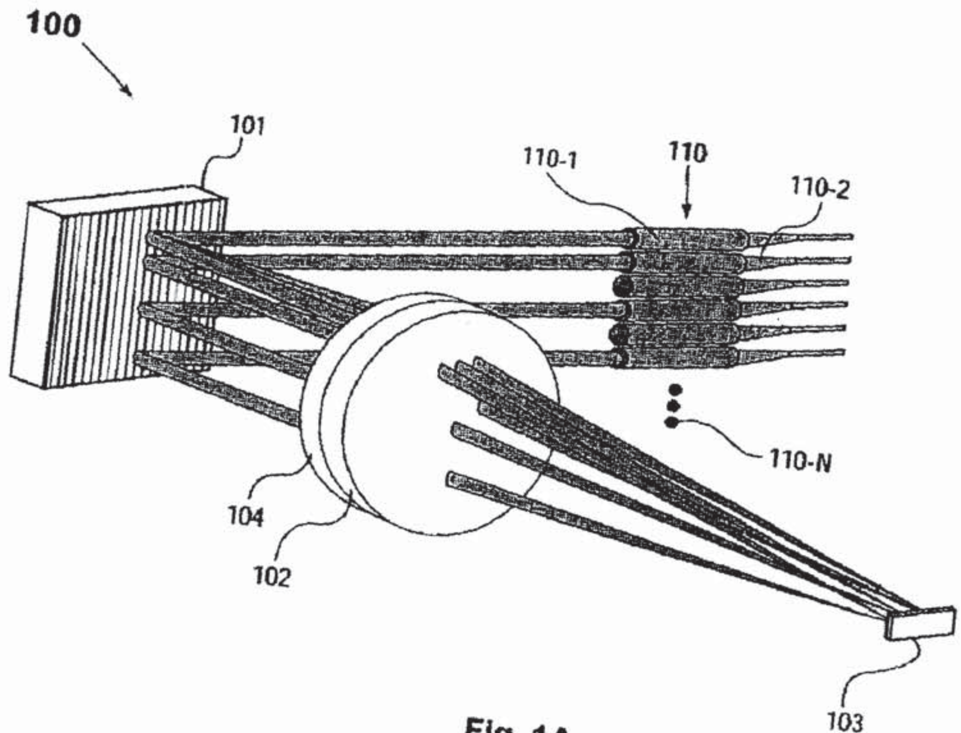


Fig. 1A

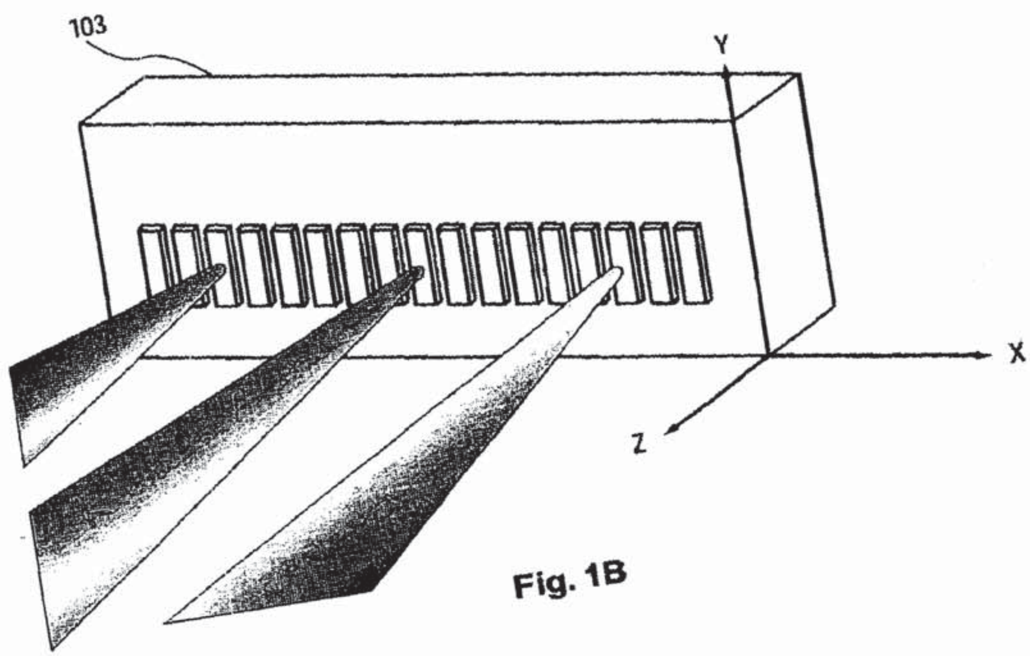


Fig. 1B

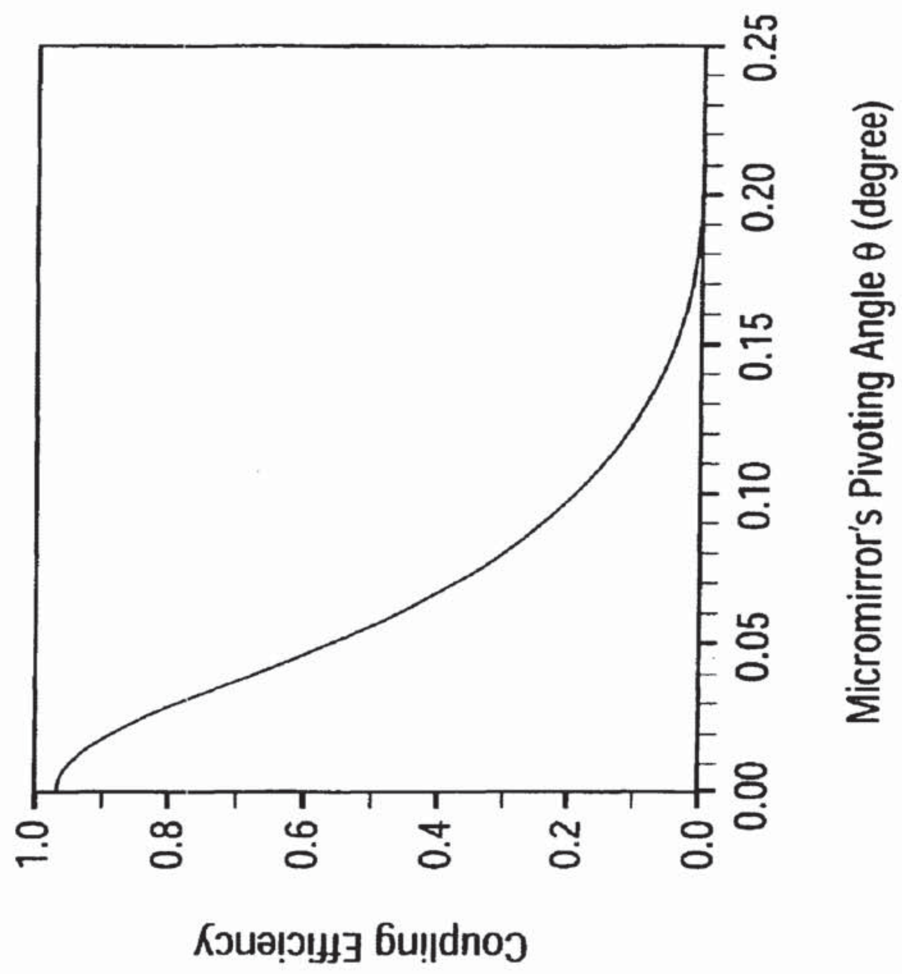

Coupling Efficiency
1.0
0.8
0.6
0.4
0.2
0.0
0.00
0.05
0.10
0.15
0.20
0.25
Micromirror's Pivoting Angle θ (degree)

Fig. 1C

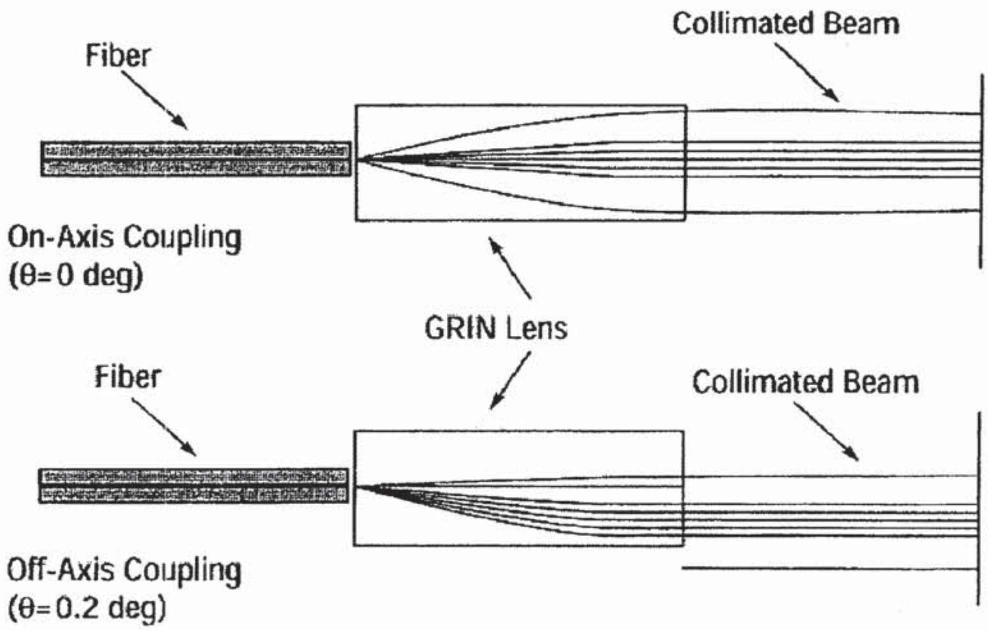

Fiber
Collimated Beam
On-Axis Coupling
(θ=0 deg)
GRIN Lens
Fiber
Collimated Beam
Off-Axis Coupling
(θ=0.2 deg)

Fig. 1D

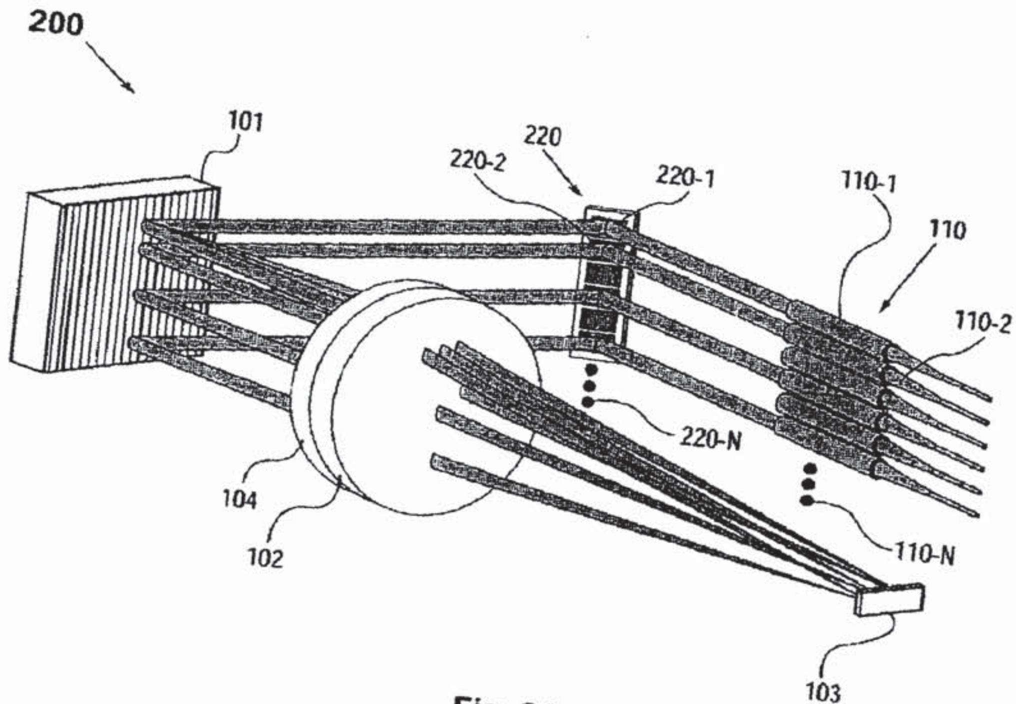


Fig. 2A

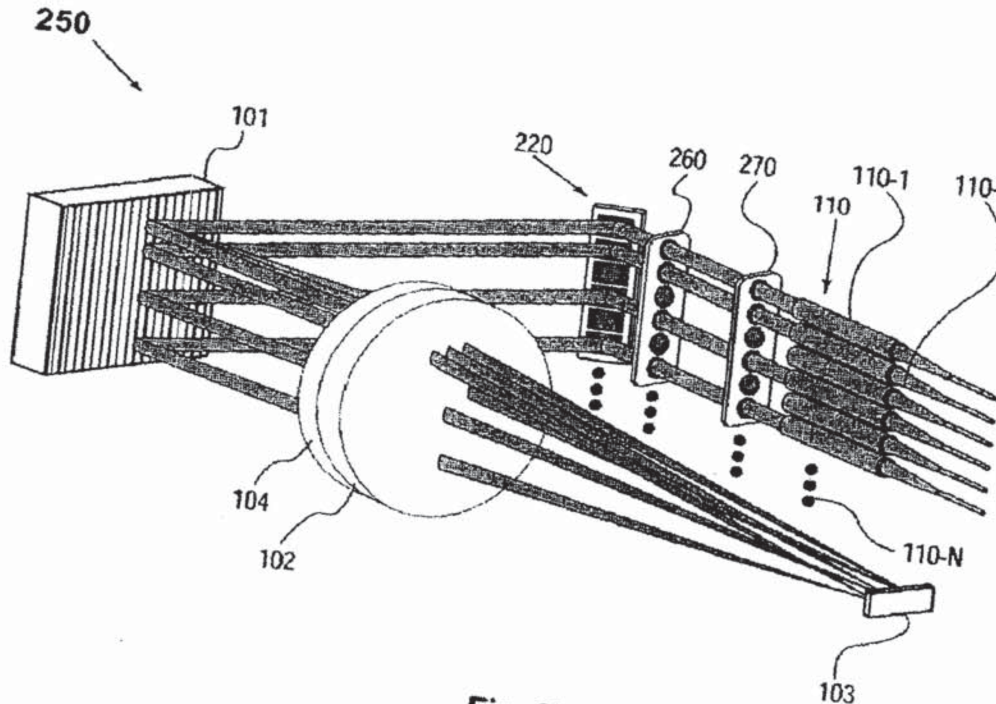


Fig. 2B

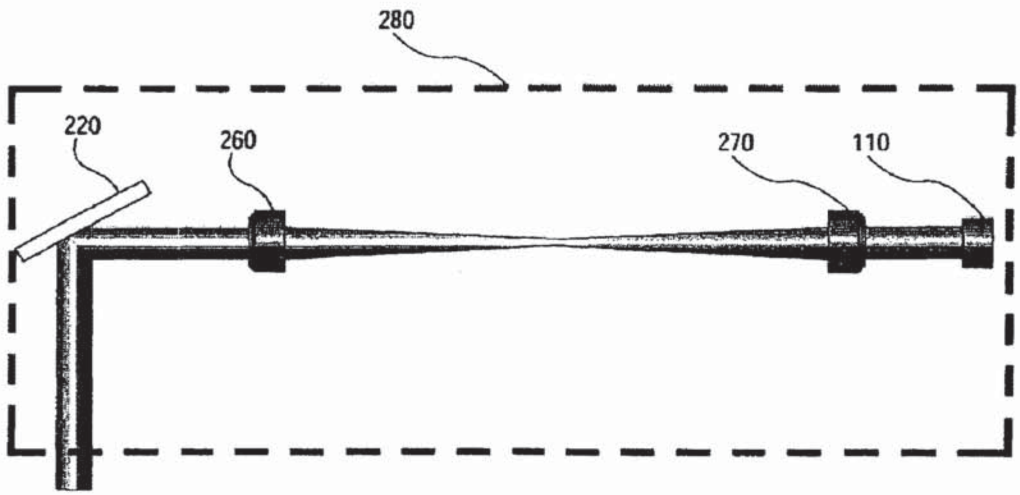


Fig. 2C

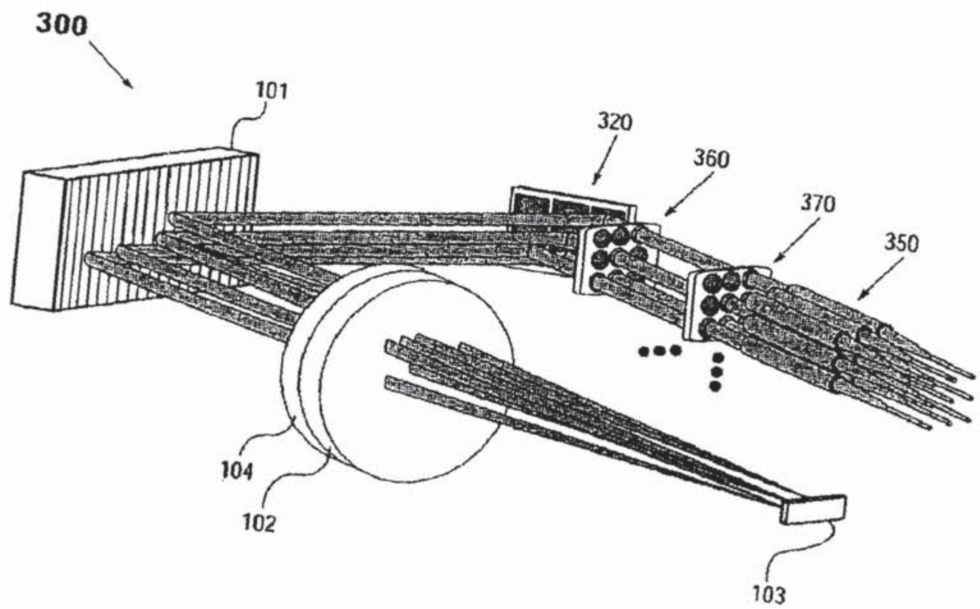


Fig. 3

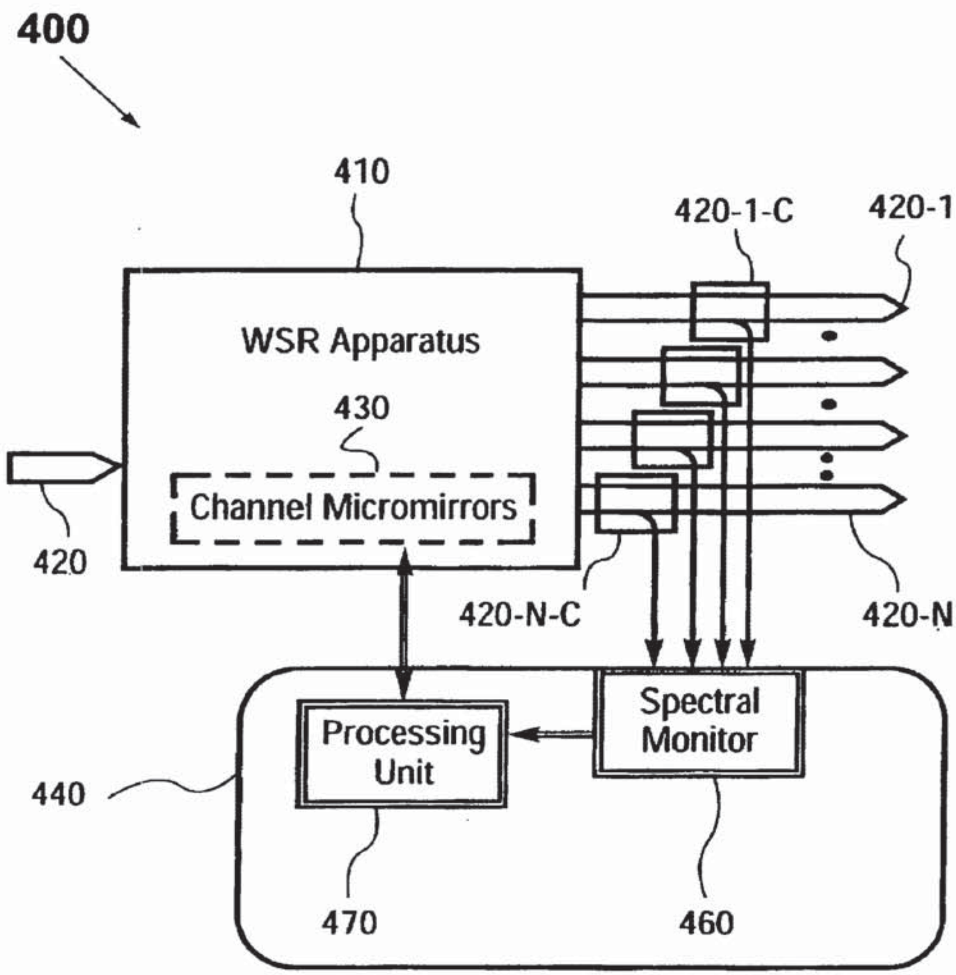

400
410
420-1-C
420-1
WSR Apparatus
430
Channel Micromirrors
420
420-N-C
420-N
Spectral Monitor
Processing Unit
440
470
460

Fig. 4A

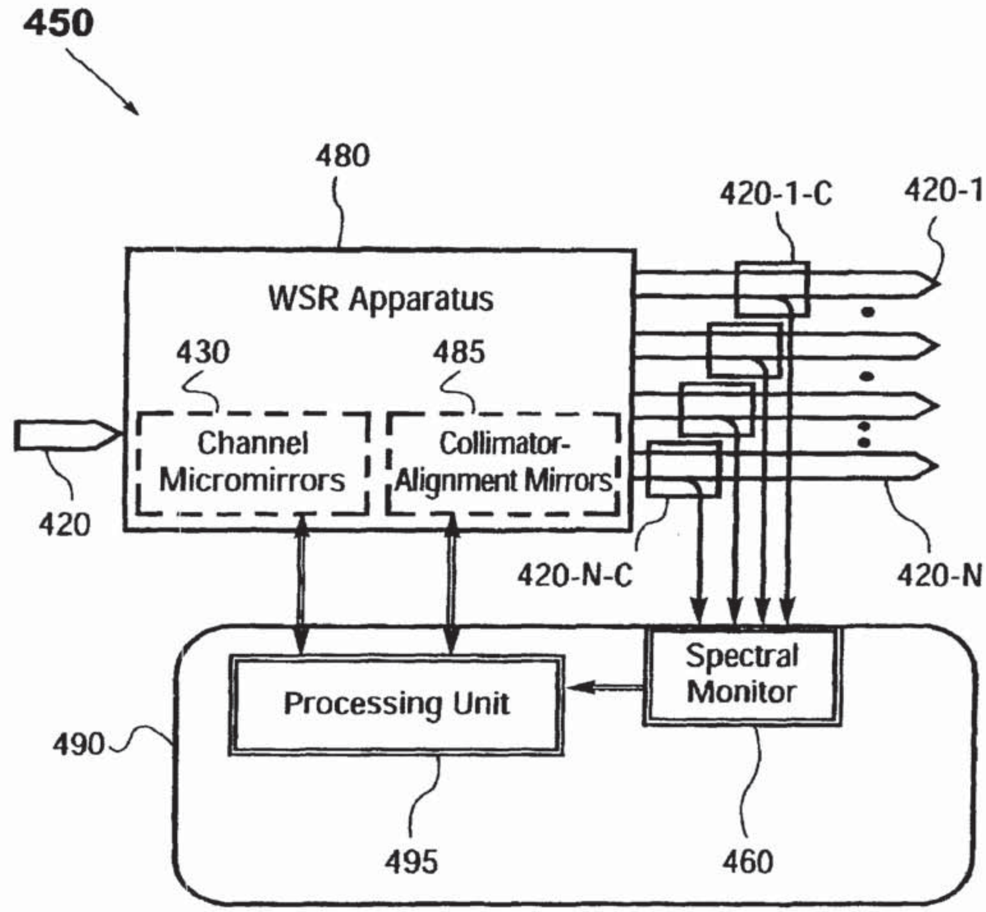

450
480
WSR Apparatus
430
485
Channel Micromirrors
Collimator-Alignment Mirrors
420
420-1-C
420-1
420-N-C
420-N
Spectral Monitor
Processing Unit
490
495
460

Fig. 4B

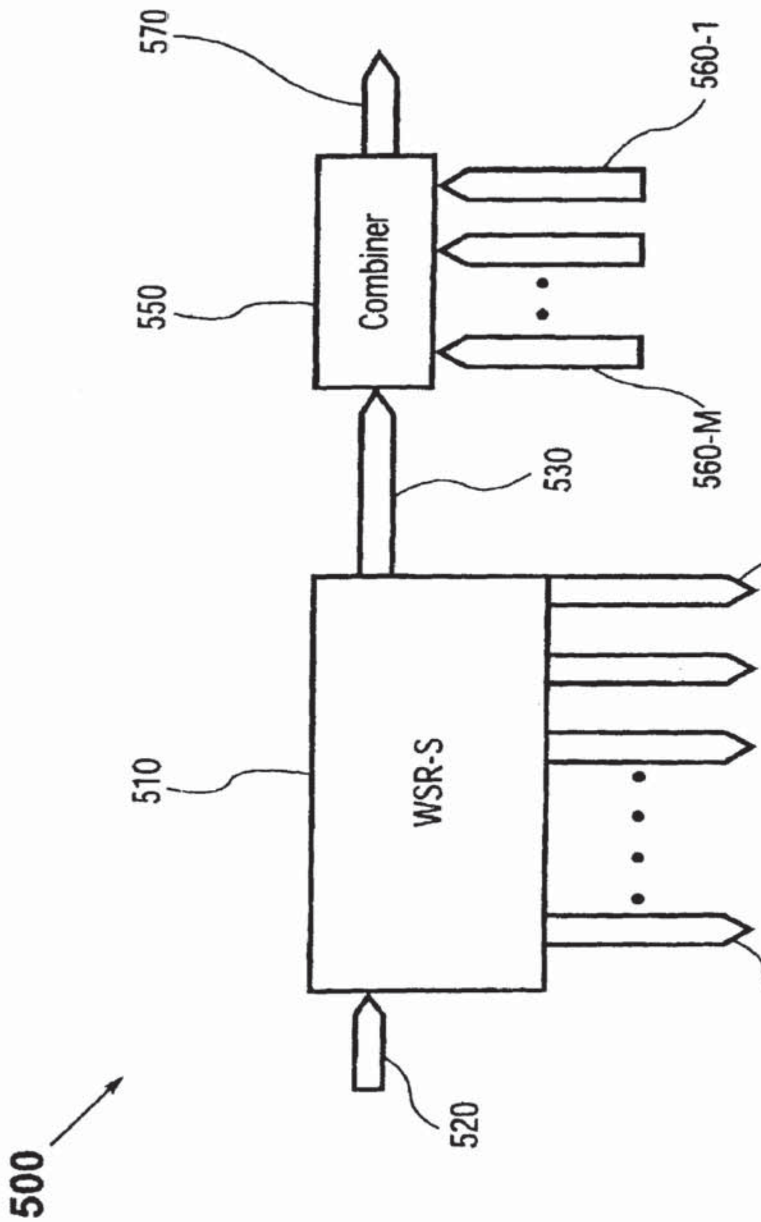


Fig. 5

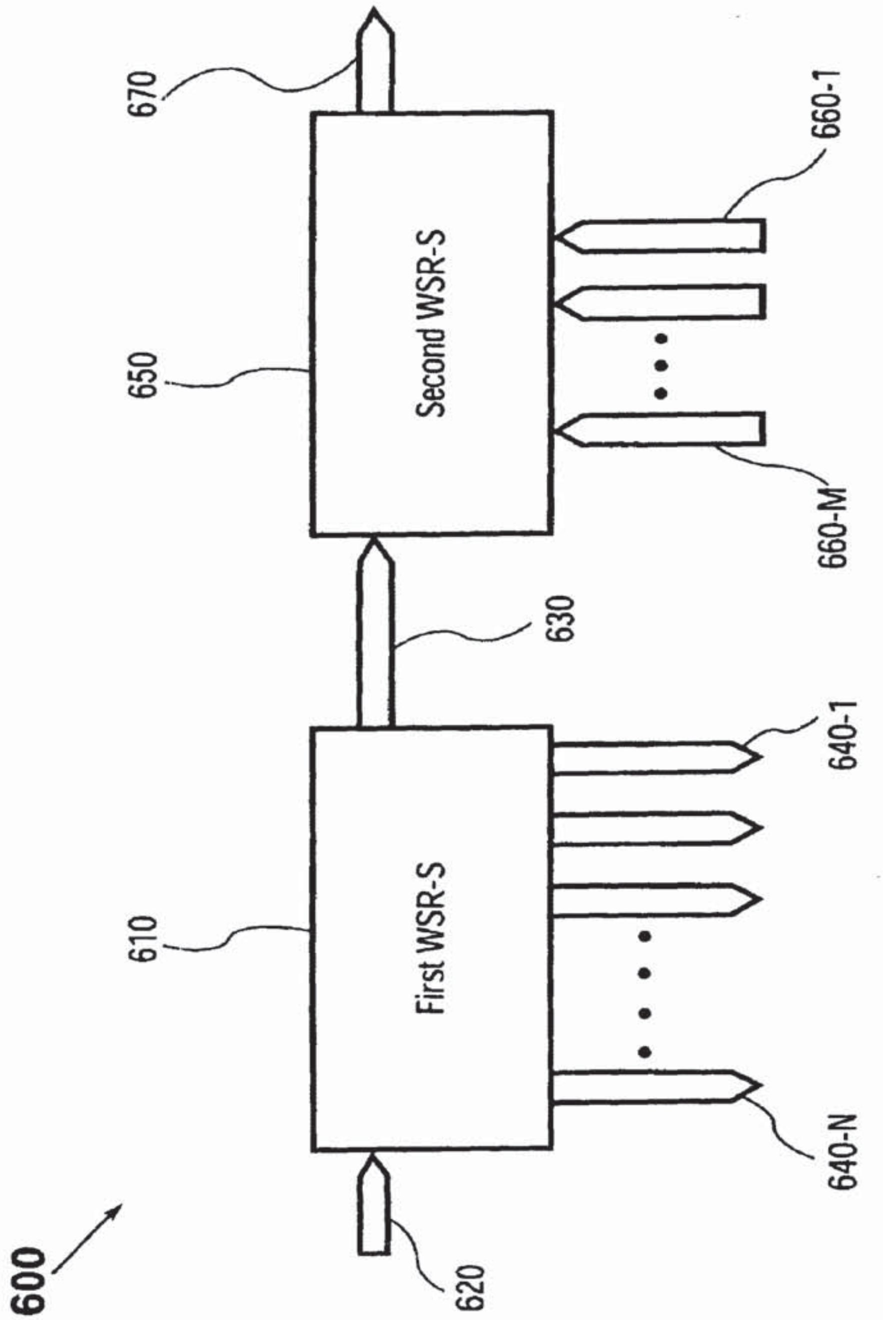

600
610
620
630
650
670
First WSR-S
Second WSR-S
640-1
640-N
660-1
660-M

Fig. 6

RECONFIGURABLE OPTICAL ADD-DROP MULTIPLEXERS WITH SERVO CONTROL AND DYNAMIC SPECTRAL POWER MANAGEMENT CAPABILITIES

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority of U.S. Provisional Patent Application No. 60/277,217, filed Mar. 19, 2001 which is incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates generally to optical communication systems. More specifically, it relates to a novel class of dynamically reconfigurable optical add-drop multiplexers (OADMs) for wavelength division multiplexed optical networking applications.

BACKGROUND

As fiber-optic communication networks rapidly spread into every walk of modern life, there is a growing demand for optical components and subsystems that enable the fiber-optic communications networks to be increasingly scalable, versatile, robust, and cost-effective.

Contemporary fiber-optic communications networks commonly employ wavelength division multiplexing (WDM), for it allows multiple information (or data) channels to be simultaneously transmitted on a single optical fiber by using different wavelengths and thereby significantly enhances the information-bandwidth of the fiber. The prevalence of WDM technology has made optical add-drop multiplexers indispensable building blocks of modern fiber-optic communication networks. An optical add-drop multiplexer (OADM) serves to selectively remove (or drop) one or more wavelengths from a multiplicity of wavelengths on an optical fiber, hence taking away one or more data channels from the traffic stream on the fiber. It further adds one or more wavelength back onto the fiber, thereby inserting new data channels in the same stream of traffic. As such, an OADM makes it possible to launch and retrieve multiple data channels (each characterized by a distinct wavelength) onto and from an optical fiber respectively, without disrupting the overall traffic flow along the fiber. Indeed, careful placement of the OADMs can dramatically improve an optical communication network's flexibility and robustness, while providing significant cost advantages.

Conventional OADMs in the art typically employ multiplexers/demultiplexers (e.g. waveguide grating routers or arrayed-waveguide gratings), tunable filters, optical switches, and optical circulators in a parallel or serial architecture to accomplish the add and drop functions. In the parallel architecture, as exemplified in U.S. Pat. No. 5,974,207, a demultiplexer (e.g., a waveguide grating router) first separates a multi-wavelength signal into its constituent spectral components. A wavelength switching/routing means (e.g., a combination of optical switches and optical circulators) then serves to drop selective wavelengths and add others. Finally, a multiplexer combines the remaining (i.e., the pass-through) wavelengths into an output multi-wavelength optical signal. In the serial architecture, as

exemplified in U.S. Pat. No. 6,205,269, tunable filters (e.g., Bragg fiber gratings) in combination with optical circulators are used to separate the drop wavelength from the pass-through wavelengths and subsequently launch the add channels into the pass-through path. And if multiple wavelengths are to be added and dropped, additional multiplexers and demultiplexers are required to demultiplex the drop wavelengths and multiplex the add wavelengths, respectively. Irrespective of the underlying architecture, the OADMs currently in the art are characteristically high in cost, and prone to significant optical loss accumulation. Moreover, the designs of these OADMs are such that it is inherently difficult to reconfigure them in a dynamic fashion.

U.S. Pat. No. 6,204,946 to Askyuk et al. discloses an OADM that makes use of free-space optics in a parallel construction. In this case, a multi-wavelength optical signal emerging from an input port is incident onto a ruled diffraction grating. The constituent spectral channels thus separated are then focused by a focusing lens onto a linear array of binary micromachined mirrors. Each micromirror is configured to operate between two discrete states, such that it either retrofits its corresponding spectral channel back into the input port as a pass-through channel, or directs its spectral channel to an output port as a drop channel. As such, the pass-through signal (i.e., the combined pass-through channels) shares the same input port as the input signal. An optical circulator is therefore coupled to the input port, to provide necessary routing of these two signals. Likewise, the drop channels share the output port with the add channels. An additional optical circulator is thereby coupled to the output port, from which the drop channels exit and the add channels are introduced into the output ports. The add channels are subsequently combined with the pass-through signal by way of the diffraction grating and the binary micromirrors.

Although the aforementioned OADM disclosed by Askyuk et al. has the advantage of performing wavelength separating and routing in free space and thereby incurring less optical loss, it suffers a number of limitations. First, it requires that the pass-through signal share the same port/fiber as the input signal. An optical circulator therefore has to be implemented, to provide necessary routing of these two signals. Likewise, all the add and drop channels enter and leave the OADM through the same output port, hence the need for another optical circulator. Moreover, additional means must be provided to multiplex the add channels before entering the system and to demultiplex the drop channels after exiting the system. This additional multiplexing/demultiplexing requirement adds more cost and complexity that can restrict the versatility of the OADM thus-constructed. Second, the optical circulators implemented in this OADM for various routing purposes introduce additional optical losses, which can accumulate to a substantial amount. Third, the constituent optical components must be in a precise alignment, in order for the system to achieve its intended purpose. There are, however, no provisions provided for maintaining the requisite alignment; and no mechanisms implemented for overcoming degradation in the alignment owing to environmental effects such as thermal and mechanical disturbances over the course of operation.

U.S. Pat. No. 5,906,133 to Tomlinson discloses an OADM that makes use of a design similar to that of Aksyuk et al. There are input, output, drop and add ports implemented in this case. By positioning the four ports in a specific arrangement, each micromirror, notwithstanding switchable between two discrete positions, either reflects its corresponding channel (coming from the input port) to the output port, or concomitantly reflects its channel to the drop port and an incident add channel to the output port. As such, this OADM is able to perform both the add and drop functions without involving additional optical components (such as optical circulators and in the system of the Aksyuk et al.). However, because a single drop port is designated for all the drop channels and a single add port is designated for all the add channels, the add channels would have to be multiplexed before entering the add port and the drop channels likewise need to be demultiplexed upon exiting from the drop port. Moreover, as in the case of Askyuk et al., there are no provisions provided for maintaining requisite optical alignment in the system, and no mechanisms implemented for combating degradation in the alignment due to environmental effects over the course of operation.

As such, the prevailing drawbacks suffered by the OADMs currently in the art are summarized as follows:

1) The wavelength routing is intrinsically static, rendering it difficult to dynamically reconfigure these OADMs.
2) Add and/or drop channels often need to be multiplexed and/or demultiplexed, thereby imposing additional complexity and cost.
3) Stringent fabrication tolerance and painstaking optical alignments are required. Moreover, the optical alignment is not actively maintained, rendering it susceptible to environmental effects such as thermal and mechanical disturbances over the course of operation.
4) In an optical communication network, OADMs are typically in a ring or cascaded configuration. In order to mitigate the interference amongst OADMs, which often adversely affects the overall performance of the network, it is essential that the power levels of spectral channels entering and exiting each OADM be managed in a systematic way, for instance, by introducing power (or gain) equalization at each stage. Such a power equalization capability is also needed for compensating for nonuniform gain caused by optical amplifiers (e.g., erbium doped fiber amplifiers) in the network. There lacks, however, a systematic and dynamic management of the power levels of various spectral channels in these OADMs.
5) The inherent high cost and heavy optical loss further impede the wide application of these OADMs.

In view of the foregoing, there is an urgent need in the art for optical add-drop multiplexers that overcome the aforementioned shortcomings, in a simple, effective, and economical construction.

SUMMARY

The present invention provides a wavelength-separating-routing (WSR) apparatus and method which employ an array of fiber collimators serving as an input port and a plurality of output ports; a wavelength-separator; a beam-focuser; and an array of channel micromirrors.

In operation, a multi-wavelength optical signal emerges from the input port. The wavelength-separator separates the multi-wavelength optical signal into multiple spectral channels, each characterized by a distinct center wavelength and associated bandwidth. The beam-focuser focuses the spectral channels into corresponding spectral spots. The channel micromirrors are positioned such that each channel micromirror receives one of the spectral channels. The channel micromirrors are individually controllable and movable, e.g., continuously pivotable (or rotatable), so as to reflect the spectral channels into selected ones of the output ports. As such, each channel micromirror is assigned to a specific spectral channel, hence the name "channel micromirror". And each output port may receive any number of the reflected spectral channels.

A distinct feature of the channel micromirrors in the present invention, in contrast to those used in the prior art, is that the motion, e.g., pivoting (or rotation), of each channel micromirror is under analog control such that its pivoting angle can be continouously adjusted. This enables each channel micromirror to scan its corresponding spectral channel across all possible output ports and thereby direct the spectral channel to any desired output ports.

In the WSR apparatus of the present invention, the wavelength-separator may be provided by a ruled diffraction grating, a holographic diffraction grating, an echelle grating, a curved diffraction grating, a dispersing prism, or other wavelength-separating means known in the art. The beam-focuser may be a single lens, an assembly of lenses, or other beam-focusing means known in the art. The channel micromirrors may be provided by silicon micromachined mirrors, reflective ribbons (or membranes), or other types of beam-deflecting means known in the art. And each channel micromirror may be pivotable about one or two axes. The fiber collimators serving as the input and output ports may be arranged in a one-dimensional or two-dimensional array. In the latter case, the channel micromirrors must be pivotable biaxially.

The WSR apparatus of the present invention may further comprise an array of collimator-alignment mirrors, in optical communication with the wavelength-separator and the fiber collimators, for adjusting the alignment of the input multi-wavelength signal and directing the spectral channels into the selected output ports by way of angular control of the collimated beams. Each collimator-alignment mirror may be rotatable about one or two axes. The collimator-alignment mirrors may be arranged in a one-dimensional or two-dimensional array. First and second arrays of imaging lenses may additionally be optically interposed between the collimator-alignment mirrors and the fiber collimators in a telecentric arrangement, thereby "imaging" the collimator-alignment mirrors onto the corresponding fiber collimators to ensure an optimal alignment.

The WSR apparatus of the present invention may further include a servo-control assembly, in communication with the channel micromirrors and the output ports. The servo-control assembly serves to monitor the power levels of the spectral channels coupled into the output ports and further provide control of the channel micromirrors on an individual basis, so as to maintain a predetermined coupling efficiency of each spectral channel in one of the output ports. As such, the servo-control assembly provides dynamic control of the coupling of the spectral channels into the respective output ports and actively manages the power levels of the spectral channels coupling into the output ports. (If the WSR apparatus includes an array of collimator-alignment mirrors as described above, the servo-control assembly may additionally provide dynamic control of the collimator-alignment mirrors.) Moreover, the utilization of such a servo-control assembly effectively relaxes the requisite fabrication tolerances and the precision of optical alignment during assembly of a WSR apparatus of the present invention, and further enables the system to correct for shift in optical alignment over the course of operation. A WSR apparatus incorporating a servo-control assembly thus described is termed a WSR-S apparatus, thereinafter in the present invention.

Accordingly, the WSR-S (or WSR) apparatus of the present invention may be used to construct a variety of optical devices, including a novel class of dynamically reconfigurable optical add-drop multiplexers (OADMs), as exemplified in the following embodiments.

One embodiment of an OADM of the present invention comprises an aforementioned WSR-S (or WSR) apparatus and an optical combiner. The output ports of the WSR-S apparatus include a pass-through port and one or more drop ports, each carrying any number of the spectral channels. The optical combiner is coupled to the pass-through port, serving to combine the pass-through channels with one or more add spectral channels. The combined optical signal constitutes an output signal of the system. The optical combiner may be an N×1 (N≦2) broadband fiber-optic coupler, for instance, which also serves the purpose of multiplexing a multiplicity of add spectral channels to be coupled into the system.

In another embodiment of an OADM of the present invention, a first WSR-S (or WSR) apparatus is cascaded with a second WSR-S (or WSR) apparatus. The output ports of the first WSR-S (or WSR) apparatus include a pass-through port and one or more drop ports. The second WSR-S (or WSR) apparatus includes a plurality of input ports and an exiting port. The configuration is such that the pass-through channels from the first WSR-S apparatus and one or more add channels are directed into the input ports of the second WSR-S apparatus, and consequently multiplexed into an output multi-wavelength optical signal directed into the exiting port of the second WSR-S apparatus. That is to say that in this embodiment, one WSR-S apparatus (e.g., the first one) effectively performs a dynamic drop function, whereas the other WSR-R apparatus (e.g., the second one) carries out a dynamic add function. And there are essentially no fundamental restrictions on the wavelengths that can be added or dropped, other than those imposed by the overall communication system. Moreover, the underlying OADM architecture thus presented is intrinsically scalable and can be readily extended to any number of the WSR-S (or WSR) systems, if so desired for performing intricate add and drop functions in a network environment.

Those skilled in the art will recognize that the aforementioned embodiments provide only two of many embodiments of a dynamically reconfigurable OADM according to the present invention. Various changes, substitutions, and alternations can be made herein, without departing from the principles and the scope of the invention. Accordingly, a skilled artisan can design an OADM in accordance with the present invention, to best suit a given application.

All in all, the OADMs of the present invention provide many advantages over the prior art devices, notably:

1) By advantageously employing an array of channel micromirrors that are individually and continuously controllable, an OADM of the present invention is capable of routing the spectral channels on a channel-by-channel basis and directing any spectral channel into any one of the output ports. As such, its underlying operation is dynamically reconfigurable, and its underlying architecture is intrinsically scalable to a large number of channel counts.
2) The add and drop spectral channels need not be multiplexed and demultiplexed before entering and after leaving the OADM respectively. And there are not fundamental restrictions on the wavelengths to be added or dropped.
3) The coupling of the spectral channels into the output ports is dynamically controlled by a servo-control assembly, rendering the OADM less susceptible to environmental effects (such as thermal and mechanical disturbances) and therefore more robust in performance. By maintaining an optimal optical alignment, the optical losses incurred by the spectral channels are also significantly reduced.
4) The power levels of the spectral channels coupled into the output ports can be dynamically managed according to demand, or maintained at desired values (e.g., equalized at a predetermined value) by way of the servo-control assembly. This spectral power-management capability as an integral part of the OADM will be particularly desirable in WDM optical networking applications.
5) The use of free-space optics provides a simple, low loss, and cost-effective construction. Moreover, the utilization of the servo-control assembly effectively relaxes the requisite fabrication tolerances and the precision of optical alignment during initial assembly, enabling the OADM to be simpler and more adaptable in structure, lower in cost and optical loss.
6) The underlying OADM architecture allows a multiplicity of the OADMs according to the present invention to be readily assembled (e.g., cascaded) for WDM optical networking applications.

The novel features of this invention, as well as the invention itself, will be best understood from the following drawings and detailed description.

BRIEF DESCRIPTION OF THE FIGURES

FIGS. **1A**–**1D** show a first embodiment of a wavelength-separating-routing (WSR) apparatus according to the present invention, and the modeling results demonstrating the performance of the WSR apparatus;

FIGS. **2A**–**2C** depict second and third embodiments of a WSR apparatus according to the present invention;

FIG. **3** shows a fourth embodiment of a WSR apparatus according to the present invention;

FIGS. **4A**–**4B** show schematic illustration of two embodiments of a WSR-S apparatus comprising a WSR apparatus and a servo-control assembly, according to the present invention;

FIG. **5** depicts an exemplary embodiment of an optical add-drop multiplexer (OADM) according to the present invention; and

FIG. **6** shows an alternative embodiment of an OADM according to the present invention.

DETAILED DESCRIPTION

In this specification and appending claims, a "spectral channel" is characterized by a distinct center wavelength and associated bandwidth. Each spectral channel may carry a unique information signal, as in WDM optical networking applications.

FIG. **1A** depicts a first embodiment of a wavelength-separating-routing (WSR) apparatus according to the present invention. By way of example to illustrate the general principles and the topological structure of a wavelength-separating-routing (WSR) apparatus of the present invention, the WSR apparatus **100** comprises multiple input/output ports which may be in the form of an array of fiber collimators **110**, providing an input port **110-1** and a plurality of output ports **110-2** through **110**-N (N≦3); a wavelength-separator which in one form may be a diffraction grating **101**; a beam-focuser in the form of a focusing lens **102**; and an array of channel micromirrors **103**.

In operation, a multi-wavelength optical signal emerges from the input port **110-1**. The diffraction grating **101** angularly separates the multi-wavelength optical signal into multiple spectral channels, which are in turn focused by the focusing lens **102** into a spatial array of distinct spectral spots (not shown in FIG. **1**A) in a one-to-one correspondence. The channel micromirrors **103** are positioned in accordance with the spatial array formed by the spectral spots, such that each channel micromirror receives one of the spectral channels. The channel micromirrors **103** are individually controllable and movable, e.g., pivotable (or rotatable) under analog (or continuous) control, such that, upon reflection, the spectral channels are directed into selected ones of the output ports **110-2** through **110**-N by way of the focusing lens **102** and the diffraction grating **101**. As such, each channel micromirror is assigned to a specific spectral channel, hence the name "channel micromirror". Each output port may receive any number of the reflected spectral channels.

For purposes of illustration and clarity, only a selective few (e.g., three) of the spectral channels, along with the input multi-wavelength optical signal, are graphically illustrated in FIG. **1**A and the following figures. It should be noted, however, that there can be any number of the spectral channels in a WSR apparatus of the present invention (so long as the number of spectral channels does not exceed the number of channel mirrors employed in the system). It should also be noted that the optical beams representing the spectral channels shown in FIG. **1**A and the following figures are provided for illustrative purpose only. That is, their sizes and shapes may not be drawn according to scale. For instance, the input beam and the corresponding diffracted beams generally have different cross-sectional shapes, so long as the angle of incidence upon the diffraction grating is not equal to the angle of diffraction, as is known to those skilled in the art.

In the embodiment of FIG. **1**A, it is preferable that the diffracting grating **101** and the channel micromirrors **103** are placed respectively at the first and second (i.e., the front and back) focal points (on the opposing sides) of the focusing lens **102**. Such a telecentric arrangement allows the chief rays of the focused beams to be parallel to each other and generally parallel to the optical axis. In this application, the telecentric configuration further allows the reflected spectral channels to be efficiently coupled into the respective output ports, thereby minimizing various translational walk-off effects that may otherwise arise. Moreover, the input multi-wavelength optical signal is preferably collimated and circular in cross-section. The corresponding spectral channels diffracted from the diffraction grating **101** are generally elliptical in cross-section; they may be of the same size as the input beam in one dimension and elongated in the other dimension.

It is known that the diffraction efficiency of a diffraction grating is generally polarization-dependent. That is, the diffraction efficiency of a grating in a standard mounting configuration may be considerably higher for P-polarization that is perpendicular to the groove lines on the grating than for S-polarization that is orthogonal to P-polarization, especially as the number of groove lines (per unit length) increases. To mitigate such polarization-sensitive effects, a quarter-wave plate **104** may be optically interposed between the diffraction grating **101** and the channel micromirrors **103**, and preferably placed between the diffraction grating **101** and the focusing lens **102** as is shown in FIG. **1**A. In this way, each spectral channel experiences a total of approximately 90-degree rotation in polarization upon traversing the quarter-wave plate **104** twice. (That is, if a beam of light has P-polarization with first encountering the diffraction grating, it would have predominantly (if not all) S-polarization upon the second encountering, and vice versa.) This ensures that all the spectral channels incur nearly the same amount of round-trip polarization dependent loss.

In the WSR apparatus **100** of FIG. **1**A, the diffraction grating **101**, by way of example, is oriented such that the focused spots of the spectral channels fall onto the channel micromirrors **103** in a horizontal array, as illustrated in FIG. **1**B.

Depicted in FIG. **1**B is a close-up view of the channel micromirrors **103** shown in the embodiment of FIG. **1**A. By way of example, the channel micromirrors **103** are arranged in a one-dimensional array along the x-axis (i.e., the horizontal direction in the figure), so as to receive the focused spots of the spatially separated spectral channels in a one-to-one correspondence. (As in the case of FIG. **1**A, only three spectral channels are illustrated, each represented by a converging beam.) Let the reflective surface of each channel micromirror lie in the x-y plane as defined in the figure and be movable, e.g., pivotable (or deflectable) about the x-axis in an analog (or continuous) manner. Each spectral channel, upon reflection, is deflected in the y-direction (e.g., downward) relative to its incident direction, so to be directed into one of the output ports **110-2** through **110**-N shown in FIG. **1**A.

As described above, a unique feature of the present invention is that the motion of each channel micromirror is individually and continuously controllable, such that its position, e.g., pivoting angle, can be continuously adjusted. This enables each channel micromirror to scan its corresponding spectral channel across all possible output ports and thereby direct the spectral channel to any desired output port. To illustrate this capability, FIG. **1**C shows a plot of coupling efficiency as a function of a channel micromirror's pivoting angle θ, provided by a ray-tracing model of a WSR apparatus in the embodiment of FIG. **1**A. As used herein, the coupling efficiency for a spectral channel is defined as the ratio of the amount of optical power coupled into the fiber core in an output port to the total amount of optical power incident upon the entrance surface of the fiber (associated with the fiber collimator grating serving as the output port). In the ray-tracing model, the input optical signal is incident upon a diffraction grating with 700 lines per millimeter at a grazing angle of 85 degrees, where the grating is blazed to optimize the diffraction efficiency for the "−1" order. The focusing lens has a focal length of 100 mm. Each output port is provided by a quarter-pitch GRIN lens (2 mm in diameter) coupled to an optical fiber (see FIG. **1**D). As displayed in FIG. **1**C, the coupling efficiency varies with the pivoting angle θ, and it requires about a 0.2-degree change in θ for the coupling efficiency to become practically negligible in this exemplary case. As such, each spectral channel may practically acquire any coupling efficiency value by way of controlling the pivoting angle of its corresponding channel micromirror. This is also to say that variable optical attenuation at the granularity of a single wavelength can be obtained in a WSR apparatus of the present invention. FIG. **1**D provides ray-tracing illustrations of two extreme points on the coupling efficiency vs. θ curve of FIG. **1**C; on-axis coupling corresponding to θ=0, where the coupling efficiency is maximum; and off-axis coupling corresponding to θ=0.2 degrees, where the representative collimated beam (representing an exemplary spectral channel) undergoes a significant translational walk-off and renders the coupling efficiency practically negligible. All in all, the exemplary modeling results thus described demonstrate the unique capabilities of the WSR apparatus of the present invention.

FIG. **1**A provides one of many embodiments of a WSR apparatus according to the present invention. In general, the wavelength-separator is a wavelength-separating means that may be a ruled diffraction grating, a holographic diffraction grating, an echelle grating, a dispersing prism, or other types of spectral-separating means known in the art. The beam-focuser may be a focusing lens, an assembly of lenses, or other beam-focusing means known in the art. The focusing function may also be accomplished by using a curved diffraction grating as the wavelength-separator. The channel micromirrors may be provided by silicon micromachined mirrors, reflective ribbons (or membranes), or other types of beam-deflecting elements known in the art. And each micromirror may be pivoted about one or two axes. What is important is that the pivoting (or rotational) motion of each channel micromirror be individually controllable in an analog manner, whereby the pivoting angle can be continuously adjusted so as to enable the channel micromirror to scan a spectral channel across all possible output ports. The underlying fabrication techniques for micromachined mirrors and associated actuation mechanism are well documented in the art, see U.S. Pat. No. 5,629,790 for example. Moreover, a fiber collimator is typically in the form of a collimating lens (such as a GRIN lens) and a ferrule-mounted fiber packaged together in a mechanically rigid stainless steel (or glass) tube. The fiber collimators serving as the input and output ports may be arranged in a one-dimensional array, a two-dimensional array, or other desired spatial pattern. For instance, they may be conveniently mounted in a linear array along a V-groove fabricated on a substrate made of silicon, plastic, or ceramic, as commonly practiced in the art. It should be noted, however, that the input port and the output ports need not necessarily be in close spatial proximity with each other, such as in an array configuration (although a close packing would reduce the rotational range required for each channel micromirror). Those skilled in the art will know how to design a WSR apparatus according to the present invention, to best suit a given application.

A WSR apparatus of the present invention may further comprise an array of collimator-alignment mirrors, for adjusting the alignment of the input multi-wavelength optical signal and facilitating the coupling of the spectral channels into the respective output ports, as shown in FIGS. **2A**–**2B** and **3**.

Depicted in FIG. **2A** is a second embodiment of a WSR apparatus according to the present invention. By way of example, WSR apparatus **200** is built upon and hence shares a number of the elements used in the embodiment of FIG. **1A**, as identified by those labeled with identical numerals. Moreover, a one-dimensional array **220** of collimator-alignment mirrors **220-1** through **220**-N is optically interposed between the diffraction grating **101** and the fiber collimator array **110**. The collimator-alignment mirror **220-1** is designated to correspond with the input port **110-1**, for adjusting the alignment of the input multi-wavelength optical signal and therefore ensuring that the spectral channels impinge onto the corresponding channel micromirrors. The collimator-alignment mirrors **220-2** through **220**-N are designated to the output ports **110-2** through **110**-N in a one-to-one correspondence, serving to provide angular control of the collimator beams of the reflected spectral channels and thereby facilitating the coupling of the spectral channels into the respective output ports according to desired coupling efficiencies. Each collimator-alignment mirror may be rotatable about one axis, or two axes.

The embodiment of FIG. **2A** is attractive in applications where the fiber collimators (serving as the input and output ports) are desired to be placed in close proximity to the collimator-alignment mirror array **220**. To best facilitate the coupling of the spectral channels into the output ports, arrays of imaging lenses may be implemented between the collimator-alignment mirror array **220** and the fiber collimator array **110**, as depicted in FIG. **2B**. By way of example, WSR apparatus **250** of FIG. **2B** is built upon and hence shares many of the elements used in the embodiment of FIG. **2A**, as identified by those labeled with identical numerals. Additionally, first and second arrays **260**, **270** of imaging lenses are placed in a 4-f telecentric arrangement with respect to the collimator-alignment mirror array **220** and the fiber collimator array **110**. The dashed box **280** shown in FIG. **2C** provides a top view of such a telecentric arrangement. In this case, the imaging lenses in the first and second arrays **260**, **270** all have the same focal length f. The collimator-alignment mirrors **220-1** through **220**-N are placed at the respective first (or front) focal points of the imaging lenses in the first array **260**. Likewise, the fiber collimators **110-1** through **110**-N are placed at the respective second (or back) focal points of the imaging lenses in the second array **270**. And the separation between the first and second arrays **260**, **270** of imaging lenses is 2f. In this way, the collimator-alignment mirrors **220-1** through **220**-N are effectively imaged onto the respective entrance surfaces (i.e., the front focal planes) of the GRIN lenses in the corresponding fiber collimators **110-1** through **110**-N. Such a telecentric imaging system substantially eliminates translational walk-off of the collimated beams at the output ports that may otherwise occur as the mirror angles change.

FIG. **3** shows a fourth embodiment of a WSR apparatus according to the present invention. By way of example, WSR apparatus **300** is built upon and hence shares a number of the elements used in the embodiment of FIG. **2B**, as identified by those labeled with identical numerals. In this case, the one-dimensional fiber collimator array **110** of FIG. **2B** is replaced by a two-dimensional array **350** of fiber collimators, providing for an input-port and a plurality of output ports. Accordingly, the one-dimensional collimator-alignment mirror array **220** of FIG. **2B** is replaced by a two-dimensional array **320** of collimator-alignment mirrors, and first and second one-dimensional arrays **260**, **270** of imaging lenses of FIG. **2B** are likewise replaced by first and second two-dimensional arrays **360**, **370** of imaging lenses respectively. As in the case of the embodiment of FIG. **2B**, the first and second two-dimensional arrays **360**, **370** of imaging lenses are placed in a 4-f telecentric arrangement with respect to the two-dimensional collimator-alignment mirror array **320** and the two-dimensional fiber collimator array **350**. The channel micromirror **103** must be pivotable biaxially in this case (in order to direct its corresponding spectral channel to any one of the output ports). As such, the WSR apparatus **300** is equipped to a support a greater number of the output ports.

In addition to facilitating the coupling of the spectral channels into the respective output ports as described above, the collimator-alignment mirrors in the above embodiments also serve to compensate for misalignment (e.g., due to fabricated and assembly errors) in the fiber collimators that provide for the input and output ports. For instance, relative misalignment between the fiber cores and their respective collimating lenses in the fiber collimators can lead to pointing errors in the collimated beams, which may be corrected for by the collimator-alignment mirrors. For these reasons, the collimator-alignment mirrors are preferably rotatable about two axes. They may be silicon micromachined mirrors, for fast rotational speeds. They may also be other types of mirrors or beam-deflecting elements known in the art.

To optimize the coupling of the spectral channels into the output ports and further maintain the optimal optical alignment against environment effects such as temperature variations and mechanical instabilities over the course of operation, a WSR apparatus of the present invention may incorporate a servo-control assembly, for providing dynamic control of the coupling of the spectral channels into the respective output ports on a channel-by-channel basis. A WSR apparatus incorporating a servo-control assembly is termed a WSR-S apparatus, thereinafter in this specification.

FIG. **4**A depicts a schematic illustration of a first embodiment of a WSR-S apparatus according to the present invention. The WSR-S apparatus **400** comprises a WSR apparatus **410** and a servo-control assembly **440**. The WSR **410** may be in the embodiment of FIG. **1**A, or any other embodiment in accordance with the present invention. The servo-control assembly **440** includes a spectral monitor **460**, for monitoring the power levels of the spectral channels coupled into the output ports **420-1** through **420**-N of the WSR apparatus **410**. By way of example, the spectral monitor **460** is coupled to the output ports **420-1** through **420**-N by way of fiber-optic couplers **420-1** through **420**-N-C, wherein each fiber-optic coupler serves to tap off a predetermined fraction of the optical signal in the corresponding output port. The servo-control assembly **440** further includes a processing unit **470**, in communication with the spectral monitor **460** and the channel micromirrors **430** of the WSR apparatus **410**. The processing unit **470** uses the power measurements from the spectral monitor **460** to provide feedback control of the channel micromirrors **430** on an individual basis, so as to maintain a desired coupling efficiency for each spectral channel into a selected output port. As such, the servo-control assembly **440** provides dynamic control of the coupling of the spectral channels into the respective output ports on a channel-by-channel basis and thereby manages the power levels of the spectral channels coupled into the output ports. The power levels of the spectral channels in the output ports may be dynamically managed according to demand, or maintained at desired values (e.g., equalized at a predetermined value) in the present invention. Such a spectral power-management capability is essential in WDM optical networking applications, as discussed above.

FIG. **4**B depicts a schematic illustration of a second embodiment of a WSR-S apparatus according to the present invention. The WSR-S apparatus **450** comprises a WSR apparatus **480** and a servo-control assembly **490**. In addition to the channel micromirrors **430** (and other elements identified by the same numerals as those used in FIG. **4**A), the WSR apparatus **480** further includes a plurality of collimator-alignment mirrors **485**, and may be configured according to the embodiments of FIGS. **2**A, **2**B, **3**, or any other embodiment in accordance with the present invention. By way of example, the servo-control assembly **490** includes the spectral monitor **460** as described in the embodiment of FIG. **4**A, and a processing unit **495**. In this case, the processing unit **495** is in communication with the channel micromirrors **430** and the collimator-alignment mirrors **485** of the WSR apparatus **480**, as well as the spectral monitor **460**. The processing unit **495** uses the power measurements from the spectral monitor **460** to provide dynamic control of the channel micromirrors **430** along with the collimator-alignment mirrors **485**, so to maintain the coupling efficiencies of the spectral channels into the output ports at desired values.

In the embodiment of FIG. **4**A or **4**B, the spectral monitor **460** may be one of spectral power monitoring devices known in the art that is capable of detecting the power levels of spectral components in a multi-wavelength optical signal. Such devices are typically in the form of a wavelength-separating means (e.g., a diffraction grating) that spatially separates a multi-wavelength optical signal by wavelength into constituent spectral components, and one or more optical sensors (e.g., an array of photodiodes) that are configured such to detect the power levels of these spectral components. The processing unit **470** in FIG. **4**A (or the processing unit **495** in FIG. **4**B) typically includes electrical circuits and signal processing programs for processing the power measurements received from the spectral monitor **460** and generating appropriate control signals to be applied to the channel micromirrors **430** (and the collimator-alignment mirrors **485** in the case of FIG. **4**B), so to maintain the coupling efficiencies of the spectral channels into the output ports at desired values. The electronic circuitry and the associated signal processing algorithm/software for such processing unit in a servo-control system are known in the art. A skilled artisan will know how to implement a suitable spectral monitor along with an appropriate processing unit to provide a servo-control assembly in a WSP-S apparatus according to the present invention, for a given application.

The incorporation of a servo-control assembly provides additional advantages of effectively relaxing the requisite fabrication tolerances and the precision of optical alignment during initial assembly of a WSR apparatus of the present invention, and further enabling the system to correct for shift in the alignment over the course of operation. By maintaining an optimal optical alignment, the optical losses incurred by the spectral channels are also significantly reduced. As such, the WSR-S apparatus thus constructed in simpler and more adaptable in structure, more robust in performance, and lower in cost and optical loss. Accordingly, the WSR-S (or WSR) apparatus of the present invention may be used to construct a variety of operable devices and utilized in many applications.

For instance, by directing the spectral channels into the output ports in a one-channel-per-port fashion and coupling the output ports of a WSR-S (or WSR) apparatus to an array of optical sensors (e.g., photodiodes), or a single optical sensor that is capable of scanning across the output ports, a dynamic and versatile spectral power monitor (or channel analyzer) is provided, which would be highly desired in WDM optical networking applications. Moreover, a novel class of optical add-drop multiplexers (OADMs) may be built upon the WSR-S (or WSR) apparatus of the present invention, as exemplified in the following embodiments.

FIG. **5** depicts an exemplary embodiment of an optical add-drop multiplexer (OADM) according to the present invention. By way of example, OADM **500** comprises a WSR-S (or WSR) apparatus **510** and an optical combiner **550**. An input port **520** of the WSR-S apparatus **510** transmits a multi-wavelength optical signal. The constituent spectral channels are subsequently separated and routed into a plurality of output ports, including a pass-through port **530** and one or more drop ports **540-1** through **540**-N ($N \geqq 1$). The pass-through port **530** may receive any number of the spectral channels (i.e., the pass-through spectral channels). Each drop port may also receive any number of the spectral channels (i.e., the drop spectral channels). The pass-through port **530** is optically coupled to the optical combiner **550**, which serves to combine the pass-through spectral channels with one or more add spectral channels provided by one or more add ports **560-1** through **560**-M ($M \geqq 1$). The combined optical signal is then routed into an existing port **570**, providing an output multi-wavelength optical signal.

In the above embodiment, the optical combiner **550** may be a K×1 ($K \geqq 2$) broadband fiber-optic coupler, wherein there are K input-ends and one output-end. The pass-through spectral channels and the add spectral channels are fed into the K input-ends (e.g., in a one-to-one correspondence) and the combined optical signal exits from the output-end of the K×1 fiber-optic coupler as the output multi-wavelength optical signal of the system. Such a multiple-input coupler also serves the purpose of multiplexing a multiplicity of add spectral channels to be coupled into the OADM **500**. If the power levels of the spectral channels in the output multi-wavelength optical signal are desired to be actively managed, such as being equalized at a predetermined value, two spectral monitors may be utilized. As a way of example, the first spectral monitor may receive optical signals tapped off from the pass-through port **530** and the drop ports **540-1** through **540**-N (e.g., by way of fiber-optic couplers as depicted in FIG. **4**A or **4**B). The second spectral monitor receives optical signals tapped off from the exiting port **570**. A servo-control system may be constructed accordingly for monitoring and controlling the pass-through, drop and add spectral channels. As such, the embodiment of FIG. **5** provides a versatile optical add-drop multiplexer in a simple and low-cost assembly, while providing multiple physically separate drop/add ports in a dynamically reconfigurable fashion.

FIG. **6** depicts an alternative embodiment of an optical add-drop multiplexer (OADM) according to the present invention. By way of example, OADM **600** comprises a first WSR-S apparatus **610** optically coupled to a second WSR-S apparatus **650**. Each WSR-S apparatus may be in the embodiment of FIG. **4**A or **4**B. (A WSR apparats of the embodiment of FIG. **1**A, **2**A, **2**B, or **3** may be alternatively implemented.) The first WSR-S apparatus **610** includes an input port **620**, a pass-through port **630**, and one or more drop ports **640-1** through **640**-N (N≧1). The pass-through spectral channels from the pass-through port **630** are further coupled to the second WSR-S apparatus **650**, along with one or more add spectral channels emerging from add ports **660-1** through **660**-M (M≧1). In this exemplary case, the pass-through port **630** and the add ports **660-1** through **660**-M constitute the input ports for the second WSR-S apparatus **650**. By way of its constituent wavelength-separator (e.g., a diffraction grinding) and channel micro-mirrors (not shown in FIG. **6**), the second WSR-R apparatus **650** serves to multiplex the pass-through spectral channels and the add spectral channels, and route the multiplexed optical signal into an exiting port **770** to provide an output signal of the system.

In the embodiment of FIG. **6**, one WSR-S apparatus (e.g., the first WSR-S apparatus **610**) effectively performs dynamic drop function, whereas the other WSR-S apparatus (e.g., the second WSR-S apparatus **650**) carries out dynamic add function. And there are essentially no fundamental restrictions on the wavelengths that can be added or dropped (other than those imposed by the overall communication system). Moreover, the underlying OADM architecture thus presented is intrinsically scalable and can be readily extended to any number of cascaded WSR-S (or WSR) systems, if so desired for performing intricate add and drop functions. Additionally, the OADM of FIG. **6** may be operated in reverse direction, by using the input ports as the output ports, the drop ports as the add ports, and vice versa.

Those skilled in the art will recognize that the aforementioned embodiments provide only two of many embodiments of a dynamically reconfigurable OADM according to the present invention. Those skilled in the art will also appreciate that various changes, substitutions, and alternations can be made herein without departing from the principles and the scope of the invention as defined in the appended claims. Accordingly, a skilled artisan can design an OADM in accordance with the principles of the present invention, to best suit a given application.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions, and alternations can be made herein without departing from the principles and the scope of the invention. Accordingly, the scope of the present invention should be determined by the following claims and their legal equivalents.

What is claimed is:

1. A wavelength-separating-routing apparatus, comprising:

a) multiple fiber collimators, providing an input port for a multi-wavelength optical signal and a plurality of output ports;

b) a wavelength-separator, for separating said multi-wavelength optical signal from said input port into multiple spectral channels;

c) a beam-focuser, for focusing said spectral channels into corresponding spectral spots; and

d) a spatial array of channel micromirrors positioned such that each channel micromirror receives one of said spectral channels, said channel micromirrors being individually and continuously controllable to reflect said spectral channels into selected ones of said output ports.

2. The wavelength-separating-routing apparatus of claim **1** further comprising a servo-control assembly, in communication with said channel micromirrors and said output ports, for providing control of said channel micromirrors and thereby maintaining a predetermined coupling of each reflected spectral channel into one of said output ports.

3. The wavelength-separating-routing apparatus of claim **2** wherein said servo-control assembly comprises a spectral monitor for monitoring power levels of said spectral channels coupled into said output ports, and a processing unit responsive to said power levels for providing control of said channel micromirrors.

4. The wavelength-separating-routing apparatus of claim **3** wherein said servo-control assembly maintains said power levels at a predetermined value.

5. The wavelength-separating-routing apparatus of claim **1** further comprising an array of collimator-alignment mirrors, in optical communication with said wavelength-separator and said fiber collimators, for adjusting an alignment of said multi-wavelength optical signal from said input port and directing said reflected spectral channels into said output ports.

6. The wavelength-separating-routing apparatus of claim **5** wherein each collimator-alignment mirror is rotatable about one axis.

7. The wavelength-separating-routing apparatus of claim **5** wherein each collimator-alignment mirror is rotatable about two axes.

8. The wavelength-separating-routing apparatus of claim **5** further comprising first and second arrays of imaging lenses, in a telecentric arrangement with said collimator-alignment mirrors and said fiber collimators.

9. The wavelength-separating-routing apparatus of claim **1** wherein each channel micromirror is continuously pivotable about one axis.

10. The wavelength-separating-routing apparatus of claim **1** wherein each channel micromirror is pivotable about two axes.

11. The wavelength-separating-routing apparatus of claim **10** wherein said fiber collimators are arranged in a two-dimensional array.

12. The wavelength-separating-routing apparatus of claim **1** wherein each channel micromirror is a silicon micromachined mirror.

13. The wavelength-separating-routing apparatus of claim **1** wherein said fiber collimators are arranged in a one-dimensional array.

14. The wavelength-separating-routing apparatus of claim **1** wherein said beam-focuser comprises a focusing lens having first and second focal points.

15. The wavelength-separating-routing apparatus of claim **14** wherein said wavelength-separator and said channel micromirrors are placed respectively at said first and second focal points of said focusing lens.

16. The wavelength-separating-routing apparatus of claim **1** wherein said beam-focuser comprises an assembly of lenses.

17. The wavelength-separating-routing apparatus of claim **1** wherein said wavelength-separator comprises an element selected from the group consisting of ruled diffraction gratings, halographic diffraction gratings, echelle gratings, curved diffraction gratings, and dispersing gratings.

18. The wavelength-separating-routing apparatus of claim **1** further comprising a quarter-wave plate optically interposed between said wavelength-separator and said channel micromirrors.

19. The wavelength-separating-routing apparatus of claim **1** wherein each output port carries a single one of said spectral channels.

20. The wavelength-separating-routing apparatus of claim **19** further comprising one or more optical sensors, optically coupled to said output ports.

21. A servo-based optical apparatus comprising:

a) multiple fiber collimators, providing an input port for a multi-wavelength optical signal and a plurality of output ports;

b) a wavelength-separator, for separating said multi-wavelength optical signal from said input port into multiple spectral channels;

c) a beam-focuser, for focusing said spectral channels into corresponding spectral spots; and

d) a spatial array of channel micromirrors positioned such that each channel micromirror receives one of said spectral channels, said channel micromirrors being individually controllable to reflect said spectral channels into selected ones of said output ports; and

e) a servo-control assembly, in communication with said channel micromirrors and said output ports, for maintaining a predetermined coupling of each reflected spectral channel into one of said output ports.

22. The servo-based optical apparatus of claim **21** wherein said servo-control assembly comprises a spectral monitor for monitoring power levels of said spectral channels coupled into said output ports, and a processing unit responsive to said power levels for providing control of said channel micromirrors.

23. The servo-based optical apparatus of claim **22** wherein said servo-control assembly maintains said power levels at a predetermined value.

24. The servo-based optical apparatus of claim **21** further comprising an array of collimator-alignment mirrors, in optical communication with said wavelength-separator and said fiber collimators, for adjusting an alignment of said multi-wavelength optical signal from said input port and directing said reflected spectral channels into said output ports.

25. The servo-based optical apparatus of claim **24** further comprising first and second arrays of imaging lenses, in a telecentric arrangement with said collimator-alignment mirrors and said fiber collimators.

26. The servo-based optical apparatus of claim **24** wherein each collimator-alignment mirror is rotatable about at least one axis.

27. The servo-based optical apparatus of claim **21** wherein each channel micromirror is continuously pivotable about at least one axis.

28. The servo-based optical apparatus of claim **21** wherein each channel micromirror is a silicon micromachined mirror.

29. The servo-based optical apparatus of claim **21** wherein said wavelength-separator comprises an element selected from the group consisting of ruled diffraction gratings, holographic diffraction gratings, echelle gratings, curved diffraction gratings, and dispersing prisms.

30. The servo-based optical apparatus of claim **21** wherein said beam-focuser comprises one or more lenses.

31. An optical apparatus comprising:

a) an array of fiber collimators, providing an input port for a multi-wavelength optical signal and a plurality of output ports;

b) a wavelength-separator, for separating said multi-wavelength optical signal from said input port into multiple spectral channels;

c) a beam-focuser, for focusing said spectral channels into corresponding spectral spots;

d) a spatial array of channel micromirrors positioned such that each channel micromirror receives one of said spectral channels, said channel micromirrors being individually and continuously controllable to reflect said spectral channels into selected ones of said output ports; and

e) a one-dimensional array of collimator-alignment mirrors, for adjusting an alignment of said multi-wavelength optical signal from said input port and directing said reflected spectral channels into said output ports.

32. The optical apparatus of claim **31** further comprising a servo-control assembly, in communication with said channel micromirrors, said collimator-alignment mirrors, and said output ports, for providing control of said channel micromirrors along with said collimator-alignment mirrors and thereby maintaining a predetermined coupling of each reflected spectral channel into one of said output ports.

33. The optical apparatus of claim **32** wherein said servo-control assembly comprises a spectral monitor for monitoring power levels of said spectral channels coupled into said output ports, and a processing unit responsive to said power levels for providing control of said channel micromirrors and said collimator-alignment mirrors.

34. The optical apparatus of claim **31** wherein each channel micromirror is continuously pivotable about at least one axis.

35. The optical apparatus of claim **31** wherein each collimator-alignment mirror is rotatable about at least one axis.

36. The optical apparatus of claim **31** further comprising first and second arrays of imaging lenses, in a telecentric arrangement with said collimator-alignment mirrors and said fiber collimators.

37. An optical apparatus comprising:

a) an array of fiber collimators, providing an input port for a multi-wavelength optical signal and a plurality of output ports;

b) a wavelength-separator, for separating said multi-wavelength optical signal from said input port into multiple spectral channels;

c) a beam-focuser, for focusing said spectral channels into corresponding spectral spots;

d) a spatial array of channel micromirrors positioned such that each channel micromirror receives one of said spectral channels, said channel micromirrors being individually and continuously controllable to reflect said spectral channels into selected ones of said output ports; and

e) a two-dimensional array of collimator-alignment mirrors, for adjusting an alignment of said multi-wavelength optical signal from said input port and directing said reflected spectral channels into said output ports.

38. The optical apparatus of claim **37** further comprising a servo-control assembly, in communication with said channel micromirrors, and collimator-alignment mirrors, and said output ports, for providing control of said channel micromirrors along with said collimator-alignment mirrors and thereby maintaining a predetermined coupling of each reflected spectral channel into one of said output ports.

39. The optical apparatus of claim **38** wherein said servo-control assembly comprises a spectral monitor for monitoring power levels of said spectral channels coupled into said output ports, and a processing unit responsive to said power levels for providing control of said channel micromirrors and said collimator-alignment mirrors.

40. The optical apparatus of claim **37** wherein each collimator-alignment mirror is rotatable about at least one axis.

41. The optical apparatus of claim **37** wherein each channel micromirror is continuously pivotable about at least one axis.

42. The optical apparatus of claim **41** wherein each channel micromirrors is pivotable about two axes, and wherein said fiber collimators are arranged in a two-dimensional array.

43. The optical apparatus of claim **37** further comprising first and second arrays of imaging lenses, in a telecentric arrangement with said collimator-alignment mirrors and said fiber collimators.

44. An optical system comprising a wavelength-separating-routing apparatus, wherein said wavelength-separating-routing apparatus includes:

a) an array of fiber collimators, providing an input port for a multi-wavelength optical signal and a plurality of output ports including a pass-through port and one or more drop ports;

b) a wavelength-separator, for separating said multi-wavelength optical signal from said input port into multiple spectral channels;

c) a beam-focuser, for focusing said spectral channels into corresponding spectral spots; and

d) a spatial array of channel micromirrors positioned such that each channel micromirror receives one of said spectral channels, said channel micromirrors being individually and continuously pivotable to reflect said spectral channels into selected ones of said output ports, whereby said pass-through port receives a subset of said spectral channels.

45. The optical system of claim **44** further comprising a servo-control assembly, in communication with said channel micromirrors and said output ports, for providing control of said channel micromirrors and thereby maintaining a predetermined coupling of each reflected spectral channel into one of said output ports.

46. The optical system of claim **45** wherein said servo-control assembly comprises a spectral monitor for monitoring power levels of said spectral channels coupled into said output ports, and a processing unit responsive to said power levels for providing control of said channel micromirrors.

47. The optical system of claim **44** further comprising an array of collimator-alignment mirrors, in optical communication with said wavelength-separator and said fiber collimators, for adjusting an alignment of said multi-wavelength optical signal from said input port and directing said reflected spectral channels into said output ports.

48. The optical system of claim **47** further comprising first and second arrays of imaging lenses, in a telecentric arrangement with said collimator-alignment mirrors and said fiber collimators.

49. The optical system of claim **47** wherein each collimator-alignment mirror is rotatable about at least one axis.

50. The optical system of claim **44** wherein each channel micromirror is pivotable about at least one axis.

51. The optical system of claim **44** wherein each channel micromirror is a silicon micromachined mirror.

52. The optical system of claim **44** wherein said beam-focuser comprises a focusing lens having first and second focal points, and wherein said wavelength-separator and said channel micromirrors are placed respectively at said first and second focal points.

53. The optical system of claim **44** wherein said wavelength-separator comprises an element selected from the group consisting of ruled diffraction gratings, holographic diffraction gratings, echelle gratings, curved diffraction gratings, and dispersing prisms.

54. The optical system of claim **44** further comprising a quarter-wave plate optically interposed between said wavelength-separator and said channel micromirrors.

55. The optical system of claim **44** further comprising an auxiliary wavelength-separating-routing apparatus, including:

a) multiple auxiliary fiber collimators, providing a plurality of auxiliary input ports and an exiting port;

b) an auxiliary wavelength-separator;

c) an auxiliary beam-focuser; and

d) a spatial array of auxiliary channel micromirrors;

wherein said subset of said spectral channels in said pass-through port and one or more add spectral channels are directed into said auxiliary input ports, and multiplexed into an output optical signal directed into said exiting port by way of said auxiliary wavelength-separator, said auxiliary beam-focuser and said auxiliary channel micromirrors.

56. The optical system of claim **55** wherein said auxiliary channel micromirrors are individually pivotable.

57. The optical system of claim **55** wherein each auxiliary channel micromirror is pivotable continuously about at least one axis.

58. The optical system of claim **55** wherein each auxiliary channel micromirror is a silicon micromachined mirror.

59. The optical system of claim **55** wherein said auxiliary wavelength-separator comprises an element selected from the group consisting of ruled diffraction gratings, holographic diffraction gratings, echelle gratings, curved diffraction gratings, and dispersing prisms.

60. The optical system of claim **55** wherein said pass-through port constitutes one of said auxiliary input ports.

61. A method of performing dynamic wavelength separating and routing, comprising:

a) receiving a multi-wavelength optical signal from an input port;

b) separating said multi-wavelength optical signal into multiple spectral channels;

c) focusing said spectral channels onto a spatial array of corresponding beam-deflecting elements, whereby each beam-deflecting element receives one of said spectral channels; and

d) dynamically and continuously controlling said beam-deflecting elements, thereby directing said spectral channels into a plurality of output ports.

62. The method of claim 61 further comprising the step of providing feedback control of said beam-deflecting elements, thereby maintaining a predetermining coupling of each spectral channel directed into one of said output ports.

63. The method of claim 62 further comprising the step of maintaining power levels of said spectral channels directed into said output ports at a predetermining value.

64. The method of claim 61 wherein each spectral channel is directed into a separate output port.

65. The method of claim 61 wherein a subset of said spectral channels is directed into one of said output ports, thereby providing one or more pass-through spectral channels.

66. The method of claim 65 further comprising the step of multiplexing said pass-through spectral channels with one or more add spectral channels, so as to provide an output optical signal.

67. The method of claim 61 wherein said beam-deflecting elements comprise an array of silicon micromachined mirrors.

* * * * *

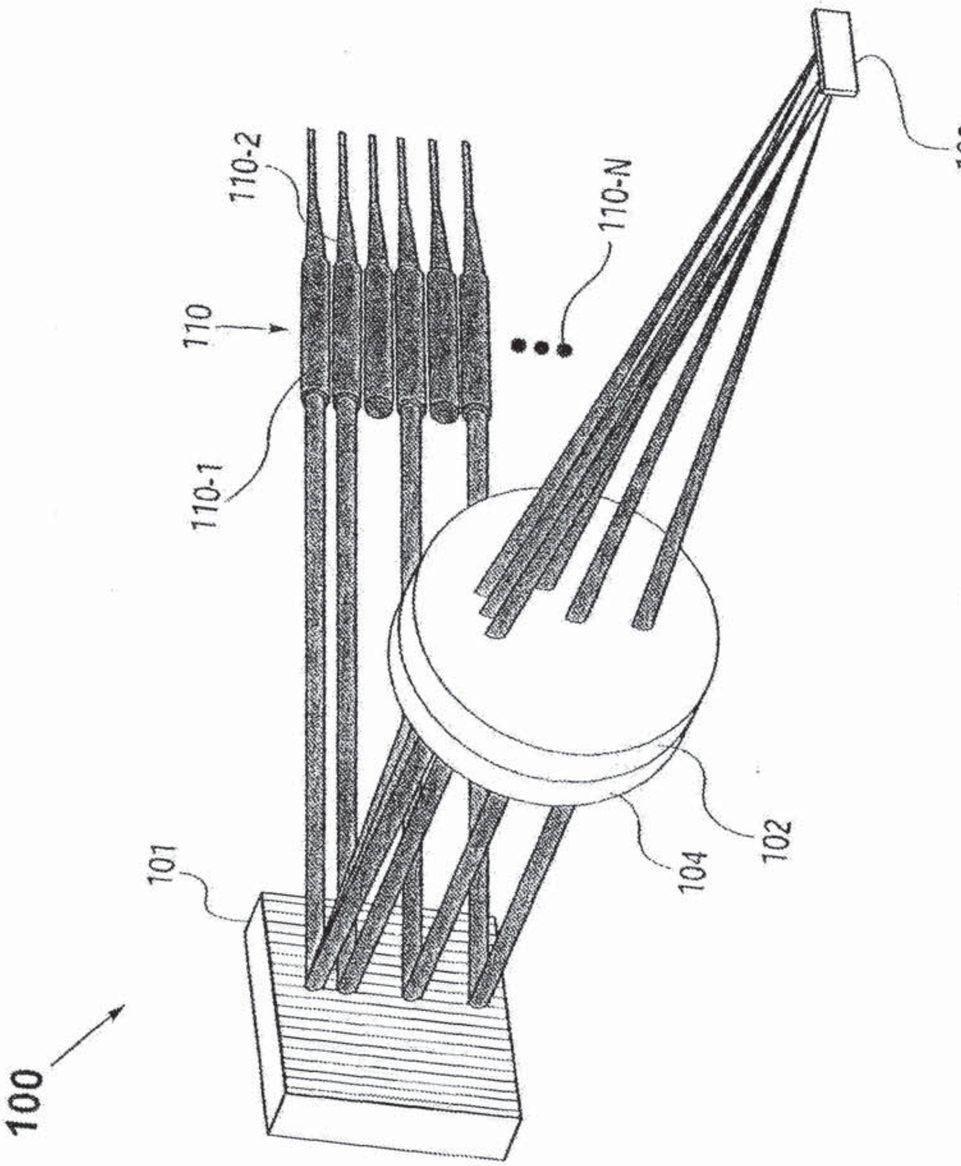


Fig. 1A

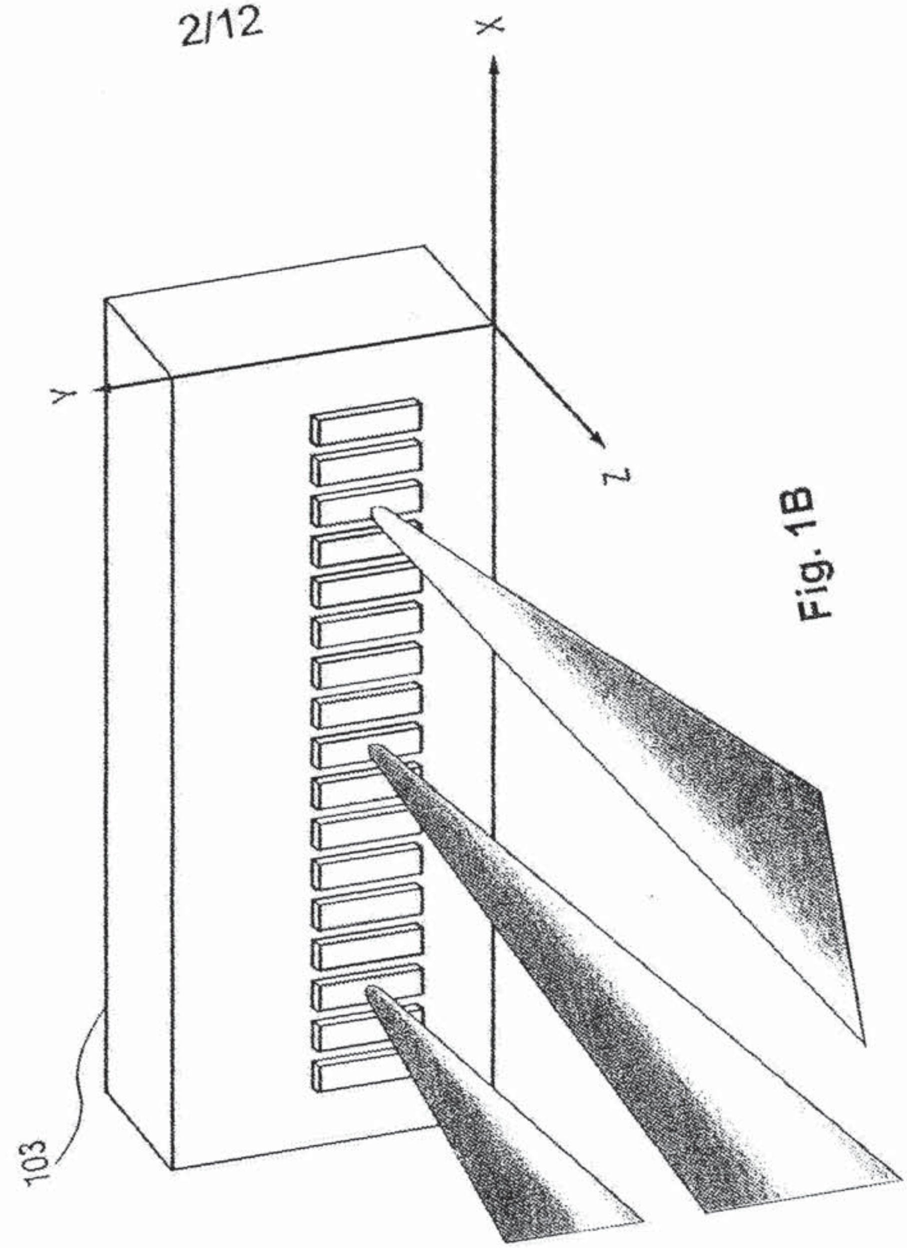


Fig. 1B

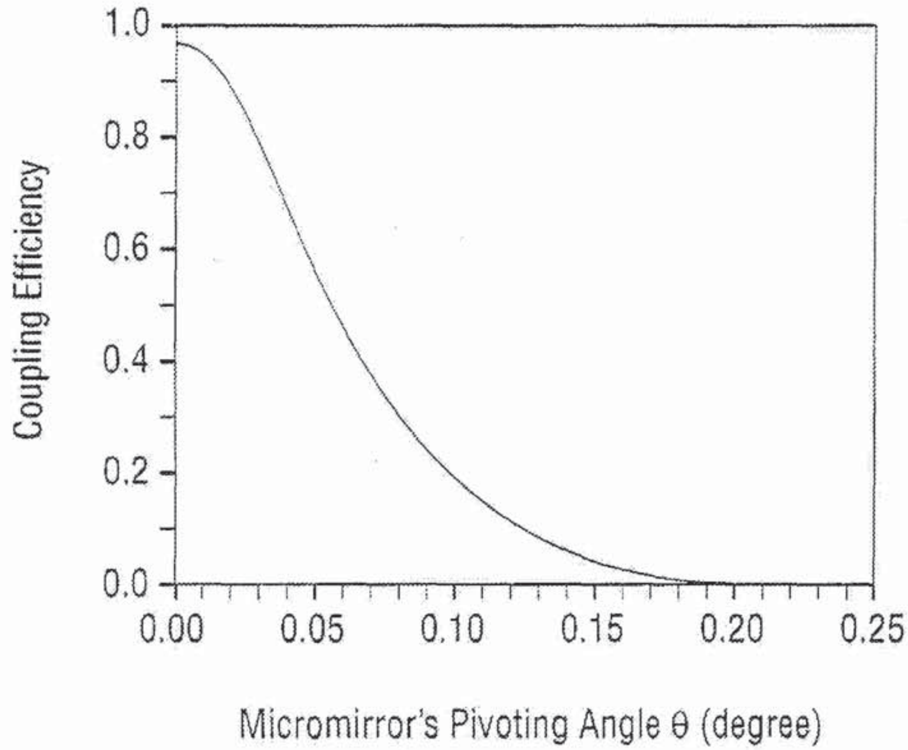

1.0
0.8
0.6
0.4
0.2
0.0
Coupling Efficiency
0.00
0.05
0.10
0.15
0.20
0.25
Micromirror's Pivoting Angle θ (degree)

Fig. 1C

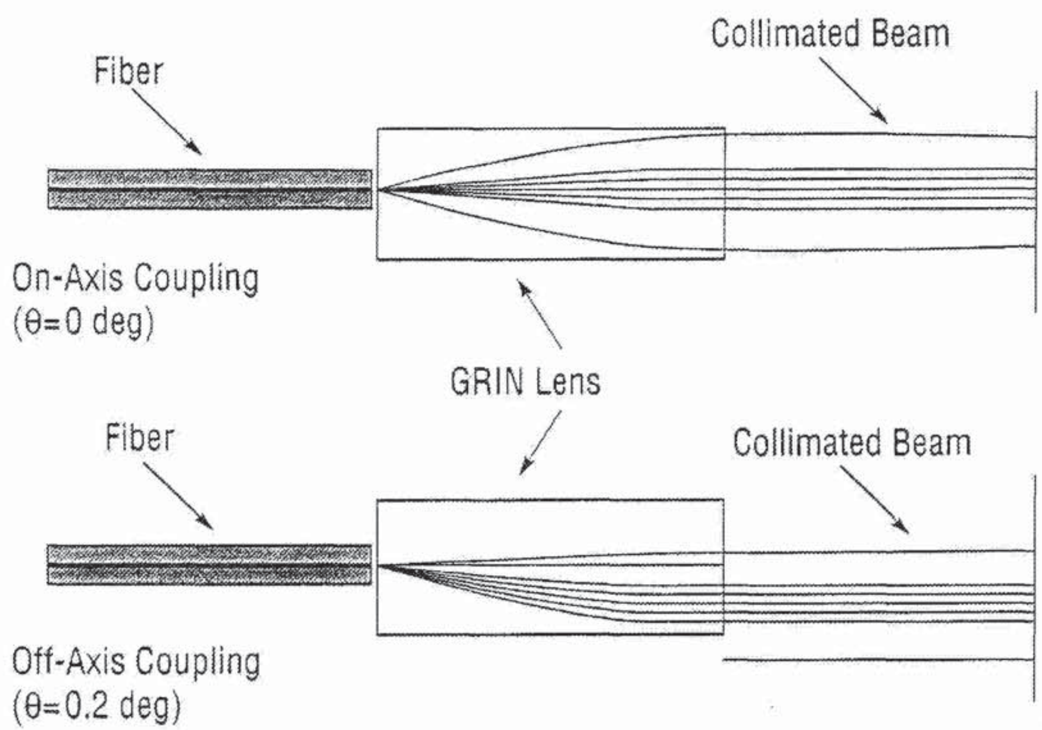

Fiber
Collimated Beam
On-Axis Coupling
(θ=0 deg)
GRIN Lens
Fiber
Collimated Beam
Off-Axis Coupling
(θ=0.2 deg)

Fig. 1D

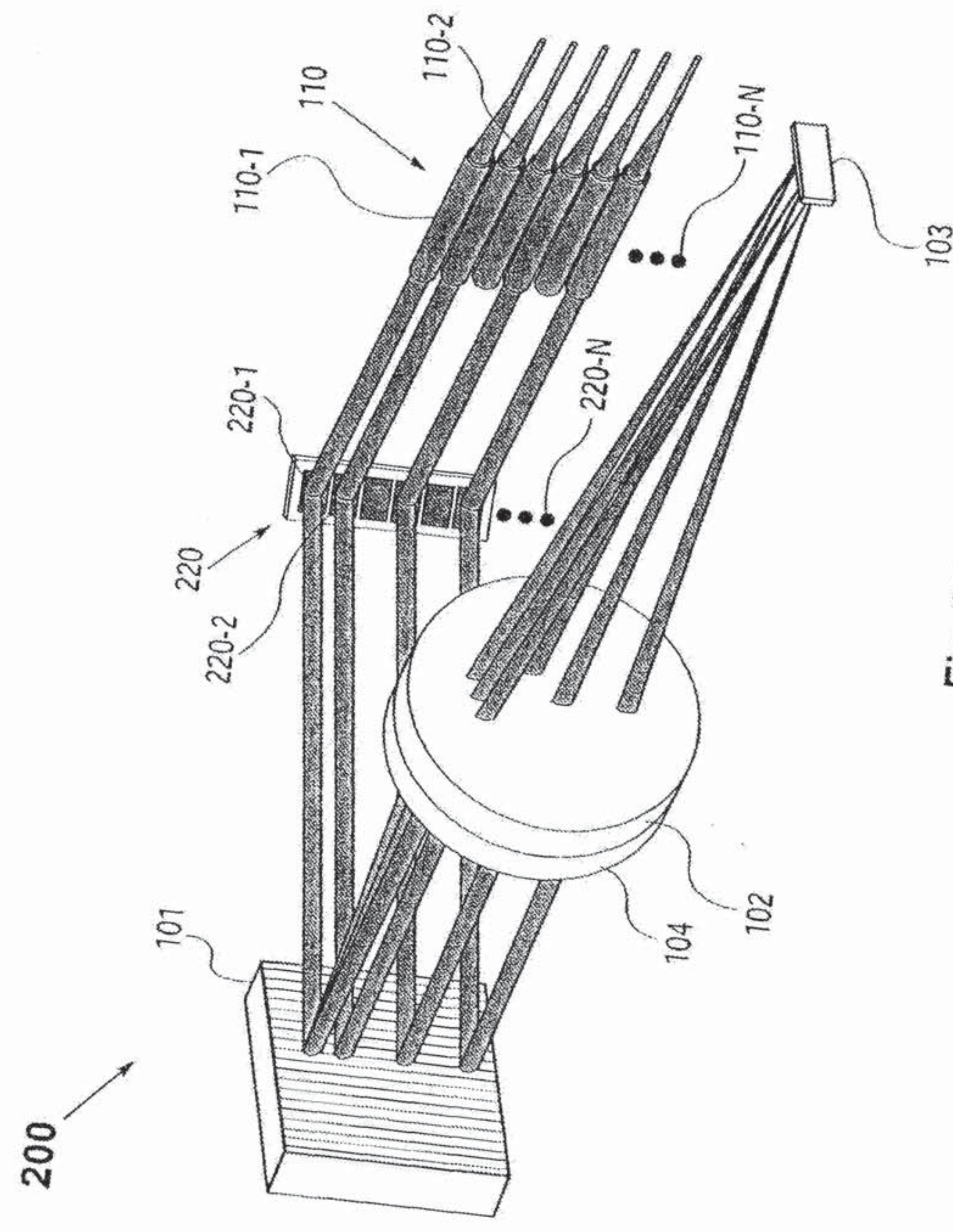


Fig. 2A

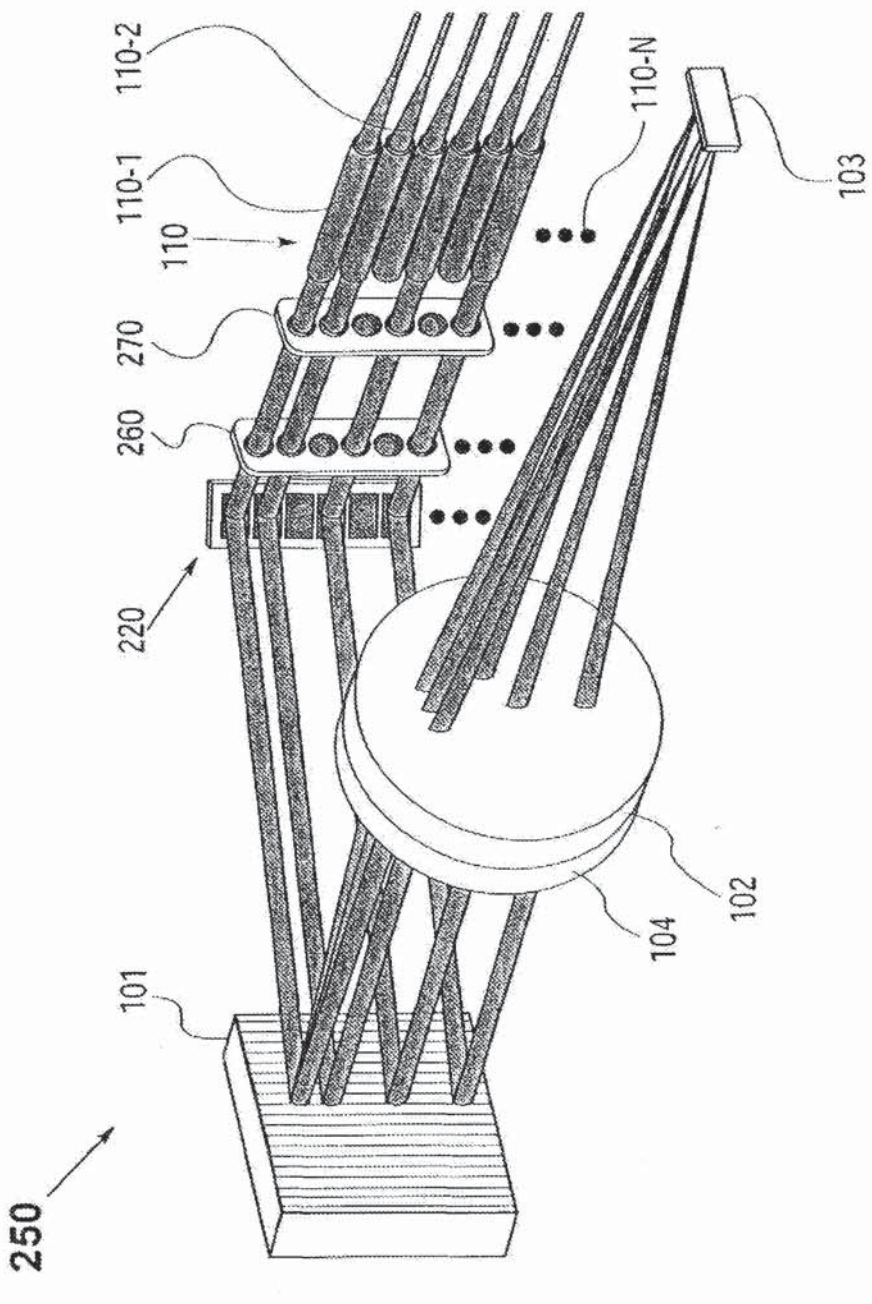


Fig. 2B

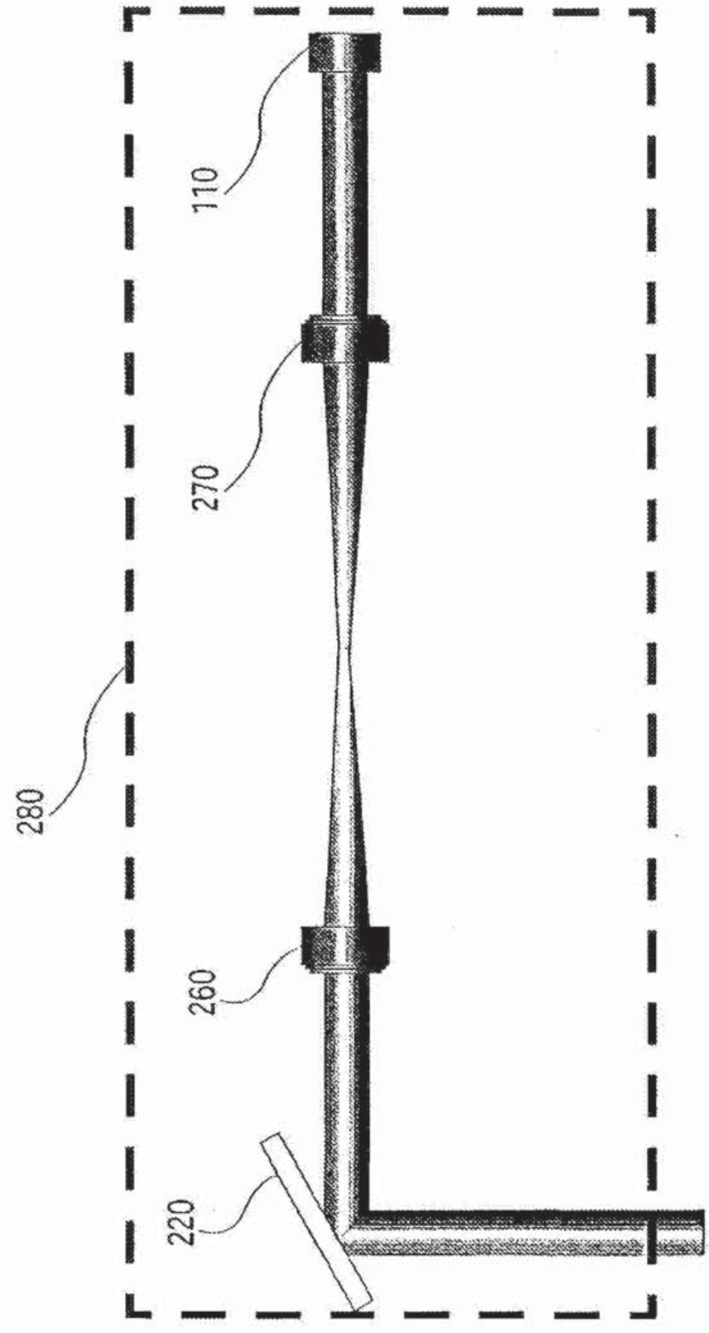


Fig. 2C

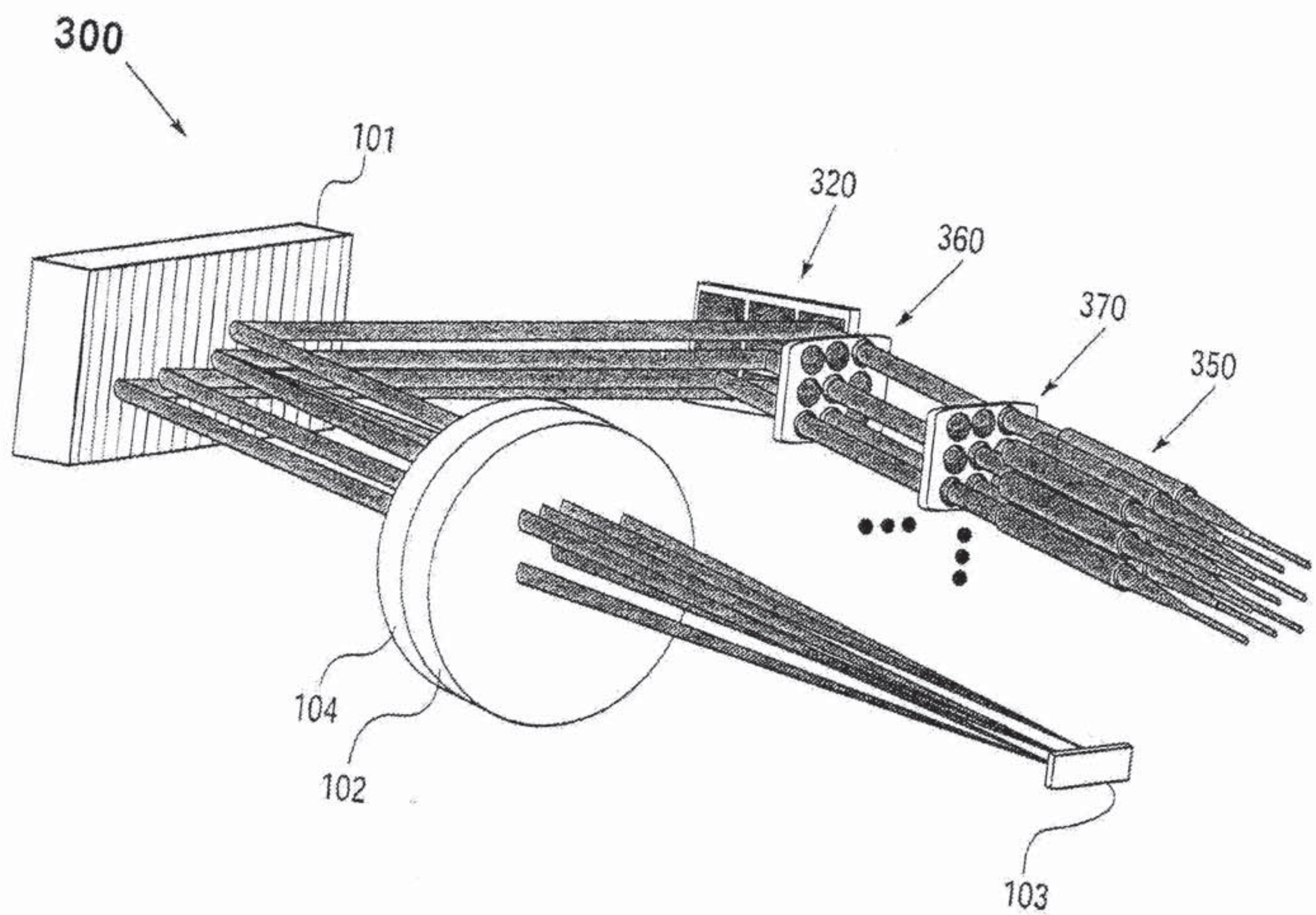
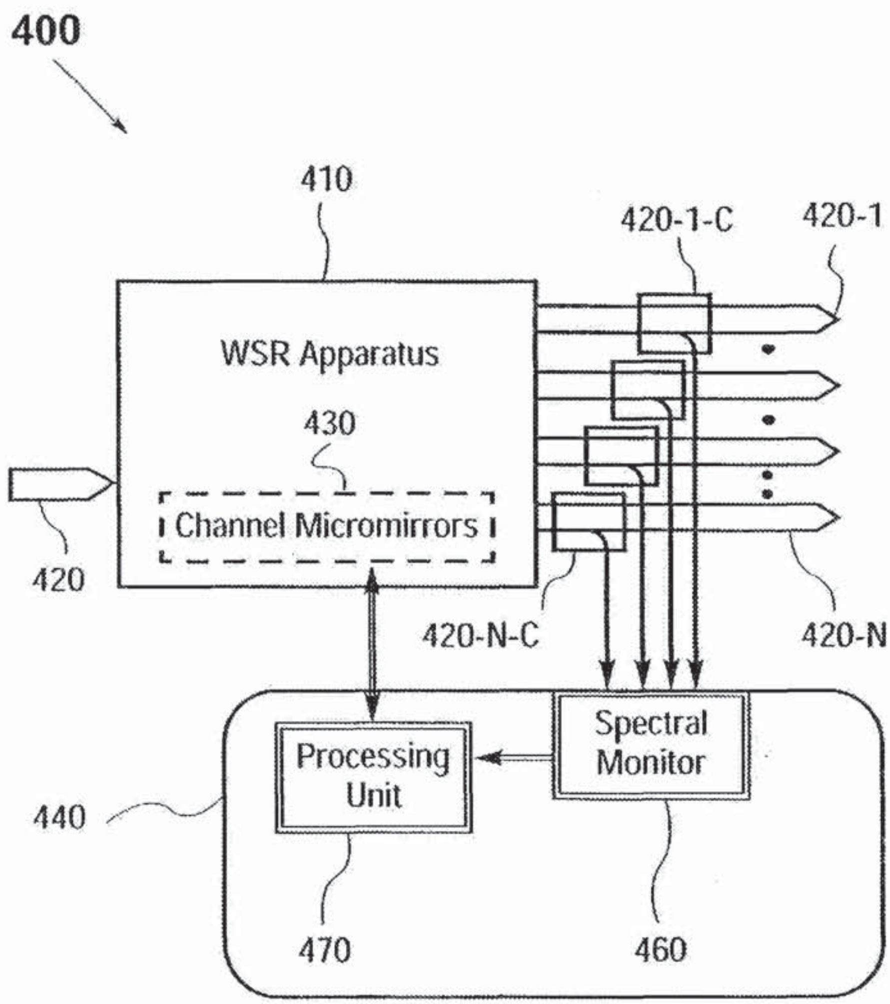


Fig. 3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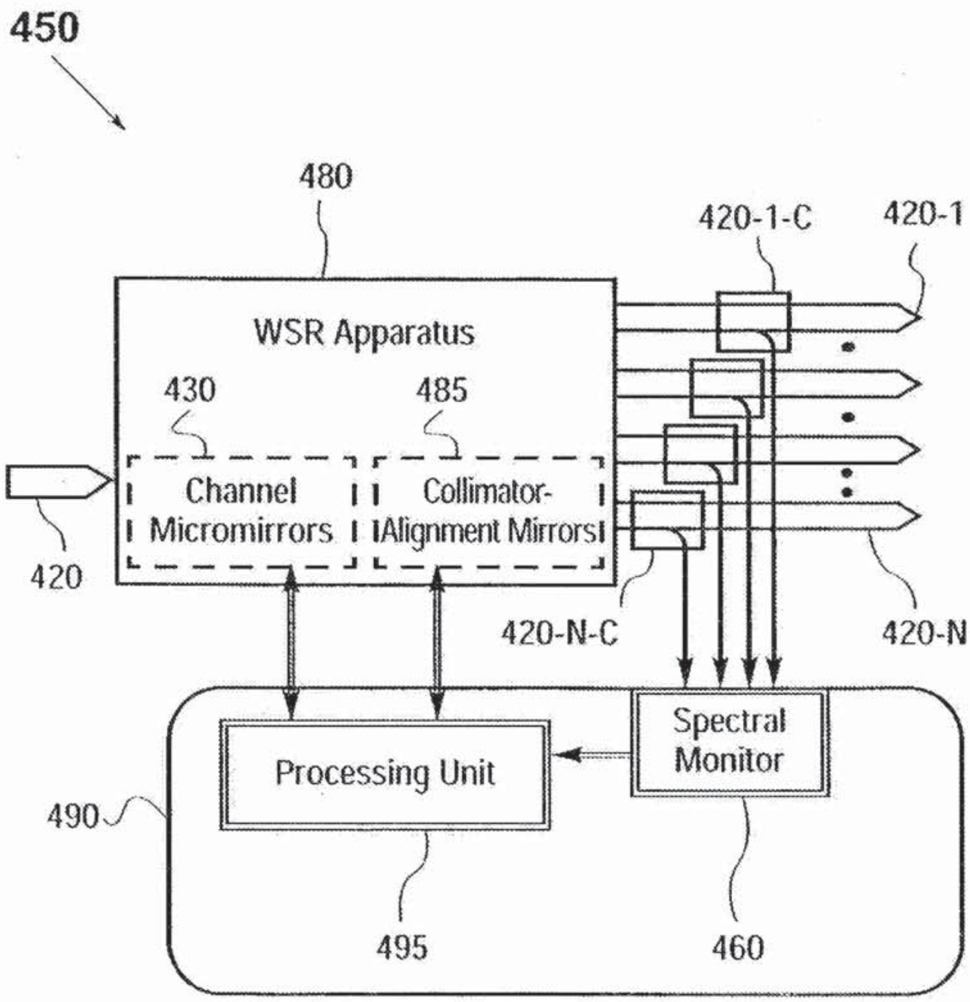
410
420-1-C
420-1
WSR Apparatus
430
Channel Micromirrors
420
420-N-C
420-N
Spectral
Monitor
Processing
Unit
440
470
460

Fig. 4A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420-1
WSR Apparatus
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Channel Micromirrors
Collimator-Alignment Mirrors
420
420-N-C
420-N
Spectral Monitor
Processing Unit
490
495
460

Fig. 4B

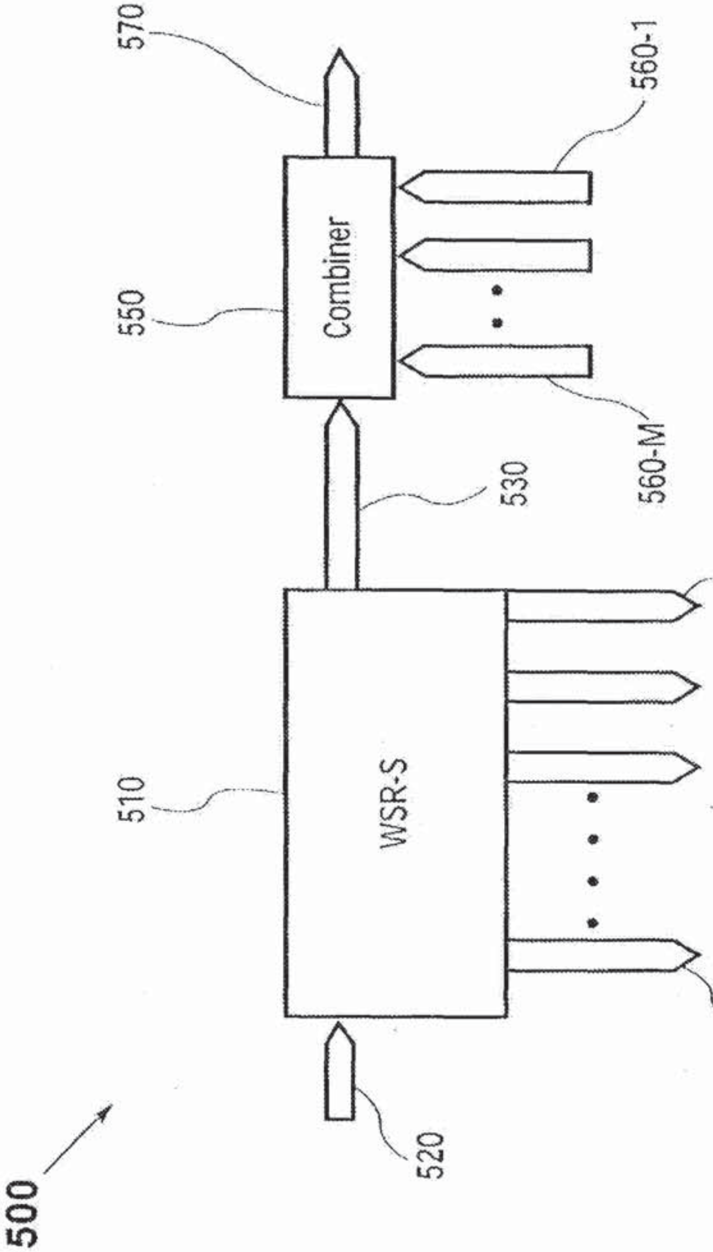

Fig. 5

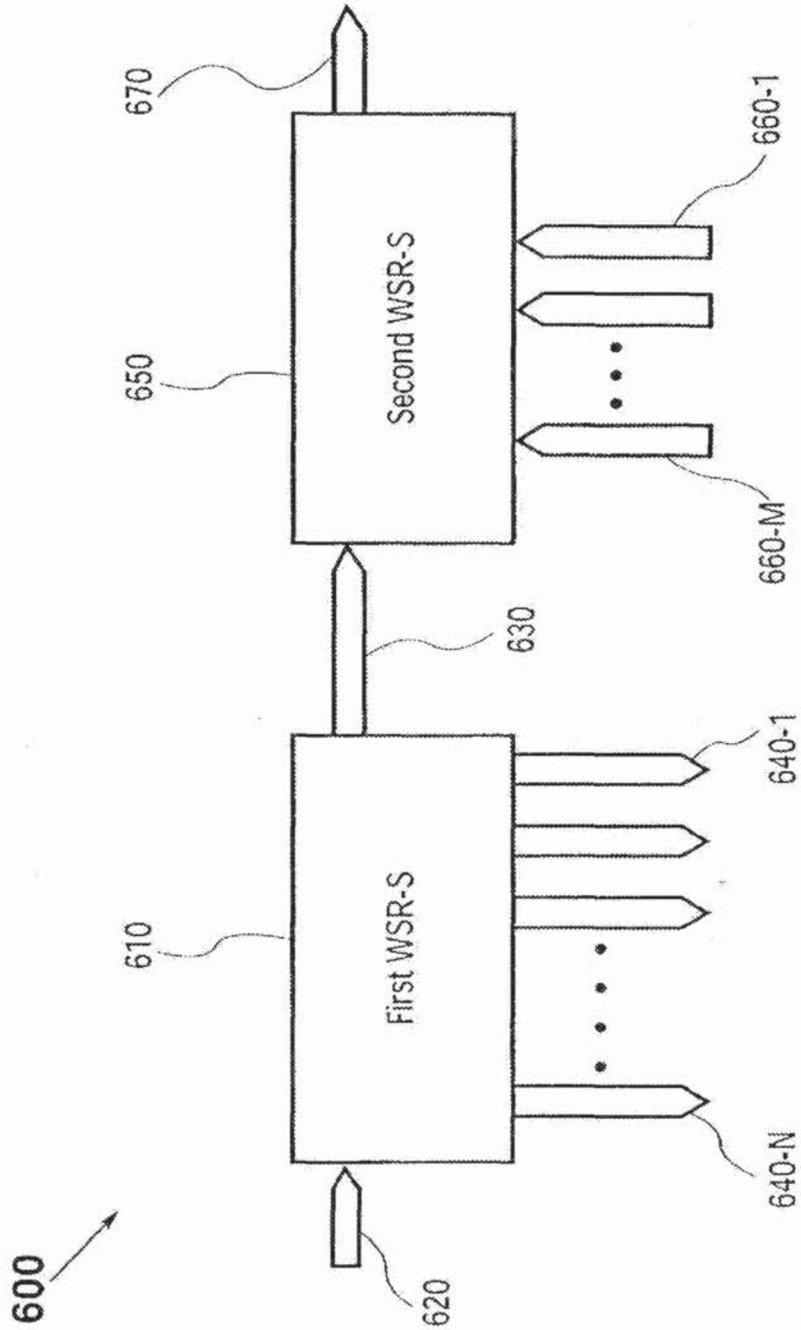
600
620
610
First WSR-S
640-N
640-1
630
650
Second WSR-S
660-M
660-1
670

Fig. 6

PTO/SB/52 (05-08)
Approved for use through 08/31/2010. OMB 0651-0033
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

REISSUE APPLICATION DECLARATION BY THE ASSIGNEE	Docket Number (optional) C2393-1101RE2

I hereby declare that:

The residence, mailing address and citizenship of the inventors are stated below.

I am authorized to act on behalf of the following assignee: Capella Photonics, Inc.

and the title of my position with said assignee is: President and Chief Executive Officer

The entire title to the patent identified below is vested in said assignee.

Inventor Jeffrey P. Wilde	Citizenship US
Residence/Mailing Address 2310 Rockwood Ranch Road; Morgan Hill, CA 95037	
Inventor Joseph E. Davis	Citizenship US
Residence/Mailing Address 18785 St. Marks Avenue; Morgan Hill, CA 95037	
☐ Additional Inventors are named on separately numbered sheets attached hereto.	
Patent Number RE39,397	Date of Patent Issued November 14, 2006

I believe said inventor(s) to be the original and first inventor(s) of the subject matter which is described and claimed in said patent, for which a reissue patent is sought on the invention entitled:

Reconfigurable Optical Add-Drop Multiplexers With Servo Control and Dynamic Spectral Power Management Ca

the specification of which

☑ is attached hereto.

☐ was filed on ______________ as reissue application number ________ / ____________

and was amended on herewith
(If applicable)

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.

☐ I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b). Attached is form PTO/SB/02B (or equivalent) listing the foreign applications.

I verily believe the original patent to be wholly or partly inoperative or invalid, for the reasons described below. (Check all boxes that apply.)

☐ by reason of a defective specification or drawing.

☑ by reason of the patentee claiming more or less than he had the right to claim in the patent.

☐ by reason of other errors.

PTO/SB/52 (05-08)
Approved for use through 08/31/2010. OMB 0651-0033
U.S. Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

REISSUE APPLICATION DECLARATION BY THE ASSIGNEE | Docket Number (Optional) C2393-1101

At least one error upon which reissue is based is described as follows:

Claims 1, 44 and 61 may have claimed more than there was a right to claim in view of the cited prior art. Applicants failed to include an apparatus claim per Claim 68 added herein that corresponds substantially to method Claim 61 as amended herein.

[Attach additional sheets, if needed.]

All errors corrected in this reissue application arose without any deceptive intention on the part of the applicant.

I hereby appoint:

☑ Practitioners associated with Customer Number: 48789

OR

☐ Practitioner(s) named below:

Name	Registration Number

as my/our attorney(s) or agent(s) to prosecute the application identified above, and to transact all business in the United States Patent and Trademark Office connected therewith.

Correspondence Address: Direct all communications about the application to:

☑ The address associated with Customer Number: 48789

OR

☐ Firm or Individual Name	
Address	
City	State / Zip
Country	
Telephone	Email

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

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 18 U.S.C. 1001, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this declaration is directed.

Signature: [signature] | Date: 06/11/10

Full name of person signing (given name, family name): Larry Schwerin

Address of Assignee: 5390 Hellyer Avenue
San Jose, CA 95138

REISSUE APPLICATION: CONSENT OF ASSIGNEE; STATEMENT OF NON-ASSIGNMENT	Docket Number (Optional) C2393-1101RE2

This is part of the application for a reissue patent based on the original patent identified below.

Name of Patentee(s)
Jeffrey P. Wilde, et. al

Patent Number	Date Patent Issued
RE39,397	November 14, 2006

Title of Invention
Reconfigurable Optical Add-Drop Multiplexers with Servo Control and Dynamic Spectral Power Management Cap

1. [✓] Filed herein is a statement under 37 CFR 3.73(b). (Form PTO/SB/96)

2. [ ] Ownership of the patent is in the inventor(s), and no assignment of the patent is in effect.

One of boxes 1 or 2 above must be checked. If multiple assignees, complete this form for each assignee. If box 2 is checked, skip the next entry and go directly to "Name of Assignee".

The written consent of all assignees and inventors owning an undivided interest in the original patent is included in this application for reissue.

The assignee(s) owning an undivided interest in said original patent is/are Capella Photonics, Inc. , and the assignee(s) consents to the accompanying application for reissue.

Name of assignee/inventor (if not assigned)

Signature	Date
[signature]	06/11/10

Typed or printed name and title of person signing for assignee (if assigned)

Larry Schwerin, President and Chief Executive Officer of Assignee, Capella Photonics, Inc.

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: Capella Photonics, Inc.

Application No./Patent No.: RE39,397 Filed/Issue Date: November 14, 2006

Titled: Reconfigurable Optical Add-Drop Multiplexers with Servo Control and Dynamic Spectral Power Management Capabilities

Capella Photonics, Inc. , a Corporation

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.

states that it is:

1. [X] the assignee of the entire right, title, and interest in;

2. [ ] an assignee of less than the entire right, title, and interest in
(The extent (by percentage) of its ownership interest is ________ %); or

3. [ ] the assignee of an undivided interest in the entirety of (a complete assignment from one of the joint inventors was made)

the patent application/patent identified above, by virtue of either:

A. [ ] An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel ________, Frame ________, or for which a copy therefore is attached.

OR

B. [X] A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: Inventors To: Assignee, Capella Photonics, Inc.

The document was recorded in the United States Patent and Trademark Office at
Reel 012118, Frame 0994, or for which a copy thereof is attached.

2. From: ________ To: ________

The document was recorded in the United States Patent and Trademark Office at
Reel ________, Frame ________, or for which a copy thereof is attached.

3. From: ________ To: ________

The document was recorded in the United States Patent and Trademark Office at
Reel ________, Frame ________, or for which a copy thereof is attached.

[ ] Additional documents in the chain of title are listed on a supplemental sheet(s).

[ ] 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] 06/11/10

Signature Date

Larry Schwerin President and CEO

Printed or Typed Name Title

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Reissue of:

Patent No.: RE 39,397

Issued: November 14, 2006

Patentee: Jeffrey P. Wilde, et. al

Reissue Appln. No.: Group Art Unit:

Filed: herewith Examiner:

Title: Reconfigurable Optical Add-Drop Multiplexers with Servo Control and Dynamic Spectral Power Management Capabilities

PRELIMINARY AMENDMENT

and

STATEMENT OF STATUS AND SUPPORT FOR ALL CHANGES TO CLAIMS

Mail Stop REISSUE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

Dear Sir:

Please amend this application as follows:

Amendments to Claims

1. (Amended) A wavelength-separating-routing apparatus, comprising:

a) multiple fiber collimators, providing an input port for a multi-wavelength optical signal and a plurality of output ports;

b) a wavelength-separator, for separating said multi-wavelength optical signal from said input port into multiple spectral channels;

c) a beam-focuser, for focusing said spectral channels into corresponding spectral spots; and

d) a spatial array of channel micromirrors positioned such that each channel micromirror receives one of said spectral channels, said channel micromirrors being pivotal about two axes and being individually and continuously controllable to reflect ~~said~~ corresponding received spectral channels into any selected ones of said output ports and to control the power of said received spectral channels coupled into said output ports.

2. (Original) The wavelength-separating-routing apparatus of claim 1 further comprising a servo-control assembly, in communication with said channel micromirrors and said output ports, for providing control of said channel micromirrors and thereby maintaining a predetermined coupling of each reflected spectral channel into one of said output ports.

3. (Original) The wavelength-separating-routing apparatus of claim 2

wherein said servo-control assembly comprises a spectral monitor for monitoring power levels of said spectral channels coupled into said output ports, and a processing unit responsive to said power levels for providing control of said channel micromirrors.

4. (Original) The wavelength-separating-routing apparatus of claim 3 wherein said servo-control assembly maintains said power levels at a predetermined value.

5. (Original) The wavelength-separating-routing apparatus of claim 1 further comprising an array of collimator-alignment mirrors, in optical communication with said wavelength-separator and said fiber collimators, for adjusting an alignment of said multi-wavelength optical signal from said input port and directing said reflected spectral channels into said output ports.

6. (Original) The wavelength-separating-routing apparatus of claim 5 wherein each collimator-alignment mirror is rotatable about one axis.

7. (Original) The wavelength-separating-routing apparatus of claim 5 wherein each collimator-alignment mirror is rotatable about two axes.

8. (Original) The wavelength-separating-routing apparatus of claim 5 further comprising first and second arrays of imaging lenses, in a telecentric arrangement

with said collimator-alignment mirrors and said fiber collimators.

9. (Original) The wavelength-separating-routing apparatus of claim 1 wherein each channel micromirror is continuously pivotable about one axis.

10. (Original) The wavelength-separating-routing apparatus of claim 1 wherein each channel micromirror is pivotable about two axes.

11. (Original) The wavelength-separating-routing apparatus of claim 10 wherein said fiber collimators are arranged in a two-dimensional array.

12. (Original) The wavelength-separating-routing apparatus of claim 1 wherein each channel micromirror is a silicon micromachined mirror.

13. (Original) The wavelength-separating-routing apparatus of claim 1 wherein said fiber collimators are arranged in a one-dimensional array.

14. (Original) The wavelength-separating-routing apparatus of claim 1 wherein said beam-focuser comprises a focusing lens having first and second focal points.

15. (Original) The wavelength-separating-routing apparatus of claim 14 wherein said wavelength-separator and said channel micromirrors are placed

respectively at said first and second focal points of said focusing lens.

16. (Original) The wavelength-separating-routing apparatus of claim 1 wherein said beam-focuser comprises an assembly of lenses.

17. (Original) The wavelength-separating-routing apparatus of claim 1 wherein said wavelength-separator comprises an element selected from the group consisting of ruled diffraction gratings, halographic diffraction gratings, echelle gratings, curved diffraction gratings, and dispersing gratings.

18. (Original) The wavelength-separating-routing apparatus of claim 1 further comprising a quarter-wave plate optically interposed between said wavelength-separator and said channel micromirrors.

19. (Original) The wavelength-separating-routing apparatus of claim 1 wherein each output port carries a single one of said spectral channels.

20. (Original) The wavelength-separating-routing apparatus of claim 19 further comprising one or more optical sensors, optically coupled to said output ports.

21. (Original) A servo-based optical apparatus comprising:

a) multiple fiber collimators, providing an input port for a multi-wavelength optical signal and a plurality of output ports;

b) a wavelength-separator, for separating said multi-wavelength optical signal from said input port into multiple spectral channels;

c) a beam-focuser, for focusing said spectral channels into corresponding spectral spots; and

d) a spatial array of channel micromirrors positioned such that each channel micromirror receives one of said spectral channels, said channel micromirrors being individually controllable to reflect said spectral channels into selected ones of said output ports; and

e) a servo-control assembly, in communication with said channel micromirrors and said output ports, for maintaining a predetermined coupling of each reflected spectral channel into one of said output ports.

22. (Original) The servo-based optical apparatus of claim 21 wherein said servo-control assembly comprises a spectral monitor for monitoring power levels of said spectral channels coupled into said output ports, and a processing unit responsive to said power levels for providing control of said channel micromirrors.

23. (Original) The servo-based optical apparatus of claim 22 wherein said servo-control assembly maintains said power levels at a predetermined value.

24. (Original) The servo-based optical apparatus of claim 21 further

comprising an array of collimator-alignment mirrors, in optical communication with said wavelength-separator and said fiber collimators, for adjusting an alignment of said multi-wavelength optical signal from said input port and directing said reflected spectral channels into said output ports.

25. (Original) The servo-based optical apparatus of claim 24 further comprising first and second arrays of imaging lenses, in a telecentric arrangement with said collimator-alignment mirrors and said fiber collimators.

26. (Original) The servo-based optical apparatus of claim 24 wherein each collimator-alignment mirror is rotatable about at least one axis.

27. (Original) The servo-based optical apparatus of claim 21 wherein each channel micromirror is continuously pivotable about at least one axis.

28. (Original) The servo-based optical apparatus of claim 21 wherein each channel micromirror is a silicon micromachined mirror.

29. (Original) The servo-based optical apparatus of claim 21 wherein said wavelength-separator comprises an element selected from the group consisting of ruled diffraction gratings, holographic diffraction gratings, echelle gratings, curved diffraction gratings, and dispersing prisms.

30. (Original) The servo-based optical apparatus of claim 21 wherein said beam-focuser comprises one or more lenses.

31. (Original) An optical apparatus comprising:

a) an array of fiber collimators, providing an input port for a multi-wavelength optical signal and a plurality of output ports;

b) a wavelength-separator, for separating said multi-wavelength optical signal from said input port into multiple spectral channels;

c) a beam-focuser, for focusing said spectral channels into corresponding spectral spots;

d) a spatial array of channel micromirrors positioned such that each channel micromirror receives one of said spectral channels, said channel micromirrors being individually and continuously controllable to reflect said spectral channels into selected ones of said output ports; and

e) a one-dimensional array of collimator-alignment mirrors, for adjusting an alignment of said multi-wavelength optical signal from said input port and directing said reflected spectral channels into said output ports.

32. (Original) The optical apparatus of claim 31 further comprising a servo-control assembly, in communication with said channel micromirrors, said collimator-alignment mirrors, and said output ports, for providing control of said channel micromirrors along with said collimator-alignment mirrors and thereby maintaining a predetermined coupling of each reflected spectral channel into one of said output

ports.

33. (Original) The optical apparatus of claim 32 wherein said servo-control assembly comprises

a spectral monitor for monitoring power levels of said spectral channels coupled into said output ports, and

a processing unit responsive to said power levels for providing control of said channel micromirrors and said collimator-alignment mirrors.

34. (Original) The optical apparatus of claim 31 wherein each channel micromirror is continuously pivotable about at least one axis.

35. (Original) The optical apparatus of claim 31 wherein each collimator-alignment mirror is rotatable about at least one axis.

36. (Original) The optical apparatus of claim 31 further comprising first and second arrays of imaging lenses, in a telecentric arrangement with said collimator-alignment mirrors and said fiber collimators.

37. (Original) An optical apparatus comprising:

a) an array of fiber collimators, providing an input port for a multi-wavelength optical signal and a plurality of output ports;

b) a wavelength-separator, for separating said multi-wavelength optical signal from said input port into multiple spectral channels;

c) a beam-focuser, for focusing said spectral channels into corresponding spectral spots;

d) a spatial array of channel micromirrors positioned such that each channel micromirror receives one of said spectral channels, said channel micromirrors being individually and continuously controllable to reflect said spectral channels into selected ones of said output ports; and

e) a two-dimensional array of collimator-alignment mirrors, for adjusting an alignment of said multi-wavelength optical signal from said input port and directing said reflected spectral channels into said output ports.

38. (Original) The optical apparatus of claim 37 further comprising

a servo-control assembly, in communication with said channel micromirrors, and

collimator-alignment mirrors, and said output ports, for providing control of said channel micromirrors along with said collimator-alignment mirrors and thereby maintaining a predetermined coupling of each reflected spectral channel into one of said output ports.

39. (Original) The optical apparatus of claim 38 wherein said servo-control assembly comprises a spectral monitor for monitoring power levels of said spectral channels coupled into said output ports, and a processing unit responsive to said

power levels for providing control of said channel micromirrors and said collimator-alignment mirrors.

40. (Original) The optical apparatus of claim 37 wherein each collimator-alignment mirror is rotatable about at least one axis.

41. (Original) The optical apparatus of claim 37 wherein each channel micromirror is continuously pivotable about at least one axis.

42. (Original) The optical apparatus of claim 41 wherein each channel micromirrors is pivotable about two axes, and wherein said fiber collimators are arranged in a two-dimensional array.

43. (Original) The optical apparatus of claim 37 further comprising first and second arrays of imaging lenses, in a telecentric arrangement with said collimator-alignment mirrors and said fiber collimators.

44. (Amended) An optical system comprising a wavelength-separating-routing apparatus, wherein said wavelength-separating-routing apparatus includes:

a) an array of fiber collimators, providing an input port for a multi-wavelength optical signal and a plurality of output ports including a pass-through port and one or more drop ports;

b) a wavelength-separator, for separating said multi-wavelength optical signal from said input port into multiple spectral channels;

c) a beam-focuser, for focusing said spectral channels into corresponding spectral spots; and

a spatial array of channel micromirrors positioned such that each channel micromirror receives one of said spectral channels, said channel micromirrors being pivotal about two axes and being individually and continuously controllable to reflect ~~said~~ corresponding received spectral channels into any selected ones of said output ports and to control the power of said received spectral channels coupled into said output ports, whereby said pass-through port receives a subset of said spectral channels.

45. (Original) The optical system of claim 44 further comprising a servo-control assembly, in communication with said channel micromirrors and said output ports, for providing control of said channel micromirrors and thereby maintaining a predetermined coupling of each reflected spectral channel into one of said output ports.

46. (Original) The optical system of claim 45 wherein said servo-control assembly comprises a spectral monitor for monitoring power levels of said spectral channels coupled into said output ports, and a processing unit responsive to said power levels for providing control of said channel micromirrors.

47. (Original) The optical system of claim 44 further comprising an array of collimator-alignment mirrors, in optical communication with said wavelength-separator and said fiber collimators, for adjusting an alignment of said multi-wavelength optical signal from said input port and directing said reflected spectral channels into said output ports.

48. (Original) The optical system of claim 47 further comprising first and second arrays of imaging lenses, in a telecentric arrangement with said collimator-alignment mirrors and said fiber collimators.

49. (Original) The optical system of claim 47 wherein each collimator-alignment mirror is rotatable about at least one axis.

50. (Original) The optical system of claim 44 wherein each channel micromirror is pivotable about at least one axis.

51. (Original) The optical system of claim 44 wherein each channel micromirror is a silicon micromachined mirror.

52. (Original) The optical system of claim 44 wherein said beam-focuser comprises a focusing lens having first and second focal points, and wherein said wavelength-separator and said channel micromirrors are placed respectively at said first and second focal points.

53. (Original) The optical system of claim 44 wherein said wavelength-separator comprises an element selected from the group consisting of ruled diffraction gratings, holographic diffraction gratings, echelle gratings, curved diffraction gratings, and dispersing prisms.

54. (Original) The optical system of claim 44 further comprising a quarter-wave plate optically interposed between said wavelength-separator and said channel micromirrors.

55. (Original) The optical system of claim 44 further comprising an auxiliary wavelength-separating-routing apparatus, including:

a) multiple auxiliary fiber collimators, providing a plurality of auxiliary input ports and an exiting port;

b) an auxiliary wavelength-separator;

c) an auxiliary beam-focuser; and

d) a spatial array of auxiliary channel micromirrors;

wherein said subset of said spectral channels in said pass-through port and one or more add spectral channels are directed into said auxiliary input ports, and multiplexed into an output optical signal directed into said exiting port by way of said auxiliary wavelength-separator, said auxiliary beam-focuser and said auxiliary channel micromirrors.

56. (Original) The optical system of claim 55 wherein said auxiliary channel micromirrors are individually pivotable.

57. (Original) The optical system of claim 55 wherein each auxiliary channel micromirror is pivotable continuously about at least one axis.

58. (Original) The optical system of claim 55 wherein each auxiliary channel micromirror is a silicon micromachined mirror.

59. (Original) The optical system of claim 55 wherein said auxiliary wavelength-separator comprises an element selected from the group consisting of ruled diffraction gratings, holographic diffraction gratings, echelle gratings, curved diffraction gratings, and dispersing prisms.

60. (Original) The optical system of claim 55 wherein said pass-through port constitutes one of said auxiliary input ports.

61. (Amended) A method of performing dynamic wavelength separating and routing, comprising:

a) receiving a multi-wavelength optical signal from an input port;

b) separating said multi-wavelength optical signal into multiple spectral channels;

c) focusing said spectral channels onto a spatial array of corresponding beam-deflecting elements, whereby each beam-deflecting element receives one of said spectral channels; and

d) dynamically and continuously controlling said beam-deflecting elements~~,~~ ~~thereby directing~~ in two dimensions to direct said spectral channels into ~~a plurality~~ any selected ones of said output ports and to control the power of the spectral channels coupled into said selected output ports.

62. (Amended) The method of claim 61 further comprising the step of providing feedback control of said beam-deflecting elements~~, thereby maintaining~~ to maintain a predetermining coupling of each spectral channel directed into one of said output ports.

63. (Original) The method of claim 62 further comprising the step of maintaining power levels of said spectral channels directed into said output ports at a predetermining value.

64. (Original) The method of claim 61 wherein each spectral channel is directed into a separate output port.

65. (Original) The method of claim 61 wherein a subset of said spectral channels is directed into one of said output ports, thereby providing one or more pass-through spectral channels.

66. (Original) The method of claim 65 further comprising the step of multiplexing said pass-through spectral channels with one or more add spectral channels, so as to provide an output optical signal.

67. (Original) The method of claim 61 wherein said beam-deflecting elements comprise an array of silicon micromachined mirrors.

68. (New) A wavelength-separating-routing apparatus, comprising:

a) multiple fiber collimators providing an input port for a multi-wavelength optical signal and a plurality of output ports;

b) a wavelength-separator for separating said multi-wavelength optical signal from said input port into multiple spectral channels;

c) a beam-focuser for focusing said spectral channels into corresponding spectral spots; and

e) a spatial array of beam-deflecting elements positioned such that each beam-deflecting element receives a corresponding one of said spectral channels, said beam-deflecting elements being dynamically and continuously controllable in two dimensions to reflect said received spectral channels into any selected ones of said output ports and to control the power of the spectral channels reflected into said selected output ports.

Remarks

Independent apparatus/system Claims 1 and 44 have been amended to recite that the channel micromirrors are "pivotal about two axes" and are individually and continuously controllable to reflect "corresponding received spectral channels into any selected ones of said output ports and to control the power of said received spectral channels coupled into said selected output ports".

Independent method Claim 61 has been amended somewhat similarly to Claims 1 and 44 to recite dynamically and continuously controlling said beam-deflecting elements "in two dimensions to direct said spectral channels into any selected ones of said output ports and to control the power of the spectral channels reflected into said selected output ports".

New Claim 68 adds an independent apparatus claim that corresponds substantially to independent method Claim 61.

The basis for these amendments is in the specification at Col. 3, line 61 – Col. 4, line 26; Col. 7, lines 6-11; Col. 8, lines 24-39; Col. 9, lines 11-17; and Col. 10, lines 48-50.

The amendments correct errors and ensure that the amended claims distinguish over the prior art; and new Claim 68 adds an apparatus claim that corresponds to method Claim 61.

Favorable early consideration of the claims is respectfully requested.

Date: June 11 , 2010

Respectfully Submitted,

/Barry N. Young/

Barry N. Young
Attorney for Assignee
Reg. No. 27,744

Customer No. 48789
Law Offices of Barry N. Young
200 Page Mill Road, Suite 102
Palo Alto, CA 94306-2061
Phone: (650) 326-2701
Fax: (650) 326-2799
byoung@young-iplaw.com

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PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number	Filing Date	
12/815,930	06/15/2010	☐ 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	06/15/2010	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))	* 68	Minus	** 68	= 0	X $ =		OR	X $52=	0
	Independent (37 CFR 1.16(h))	* 7	Minus	***7	= 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:
/DEBORAH NASH/