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PROVISIONAL APPLICATION COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION under 37 CFR 1.53(c).

Docket Number 206692	Type a plus sign (+) inside this box →	+

INVENTOR(S)/APPLICANT(S)

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TITLE OF THE INVENTION (280 characters max)

VARIABLE TRANSMISSION MULTI-WAVELENGTH OPTICAL SWITCH

CORRESPONDENCE ADDRESS

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ENCLOSED APPLICATION PARTS (check all that apply)

☒ Specification Number of Pages: 12 (including any claims and abstract)
☒ Drawings Number of Sheets: 11
☐ Power of Attorney
☐ Assignment
☐ Small Entity Status
☐ Other (specify)

METHOD OF PAYMENT (check one)

☐ A check is enclosed to cover the Provisional filing fee of $150.00.
☒ The Assistant Commissioner is hereby authorized to charge the filing fee of $150.00 to Deposit Account Number 12-1216.
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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government:

☒ No.
☐ Yes, the name of the U.S. Government agency and the Government contract number are:

Respectfully submitted,

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☐ Additional inventors are being named on separately numbered sheets attached hereto.

CERTIFICATION UNDER 37 CFR 1.10

I hereby certify that this correspondence and the documents referred to as attached or enclosed therein are being deposited with the United States Postal Service on September 22, 2000, in an envelope as "EXPRESS MAIL POST OFFICE TO ADDRESSEE" service under 37 CFR 1.10, Mailing Label Number EL643535582US, addressed to Commissioner of Patents and Trademarks, Washington, D.C. 20231.

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PROVISIONAL (Rev 6/29/2000)

Variable Transmission Multi-wavelength Optical Switch

Inventors: Dave Smith, John E. Golub; Fariborz Farhan

Assigned to: MOVAZ Networks, Inc.

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Background of the Invention

In response to the need for increased communications bandwidth, optical fiber systems operating at wavelengths near 1.5 μm are rapidly replacing conventional copper-conductor electronic systems. Advantages of lightwave technology include increased signal bandwidth (10 GHz rates and higher are possible along a single fiber optic channel), immunity to electrical interference and the possibility of system expansion through wavelength division multiplexing (WDM) which superimposes more than one optical carrier on a single fiber channel.

In a conventional, point-to-point, single-channel system, an electrical input signal modulates the output of a semiconductor laser. The resulting lightwave signal is coupled into a single-mode optical fiber that transports it to an optical receiver. En route, one or more optically-pumped, Erbium-doped fiber amplifiers (EDFA's) or other in-line optical amplifiers may be used to compensate for fiber absorption and other losses. Fiber optical components are used for various functions such as traffic distribution and signal routing. Finally, at the receiver, the beam exiting the fiber is focused onto a detector that converts the lightwave signal to an electronic version of the transmitter input signal.

Multiple information signals may also be combined on a single fiber using wavelength division multiplexing (WDM). In this scheme, individual transmitters operate at a different, fixed wavelengths and signals are combined using all-optical multiplexers that couple the light from several input ports into a single output fiber. At the receiver, an optical wavelength separator spatially separates the individual, single-wavelength channels. Various means of multiplexing and demultiplexing multiple optical carriers on a single fiber are disclosed in ---

review paper on WDM technology. Dedicated detectors are then used to convert the information on each channel to an electronic format.

WDM systems offer wide bandwidth capabilities and the possibilities of upgrading system capacity without changing the installed fiber base. At the present time, commercially-available systems can support 40, 2.5GHz channels yielding a total bandwidth of 100 GHz. The optical system components (fibers, amplifiers, lasers and detectors) can support a much larger bandwidth by far and it is expected that future systems will operate at higher data rates (40 GHz, for example) and include 80 or more WDM channels.

Components required for the realization of a multi-wavelength optical network include simple wavelength multiplexers (MUX) and wavelength demultiplexers (DEMUX), add/drop multiplexers (ADM's), optical cross connect switches (OXC's), in-line optical amplifiers and associated gain control technologies, optical performance monitors and wavelength channel power equalizers. Wavelength conversion is another area of active development.

Present-day optical WDM networks are based on components that often disadvantageously utilize the optical-to-electronic-to-optical conversion process for signal regeneration, switching, power equalization and other network functions. System bandwidth and particularly, system upgradability is constrained by the complexity and cost of this pervasive electrical-to-optical conversion requirement. Transparent, all-optical components would effectively address this limitation, facilitating the design of networks in which the optical signal leaving a transmitter would not be converted to the electrical domain until it reached a receiver. A feature of the disclosed invention is that it provides an optically transparent solution to the system requirement for wavelength channel power equalization.

Various WDM components are described in the following as a means of introduction. Wavelength MUX's are used to combine the output beams from a number of single frequency transmitters into a single, wavelength-division-multiplexed signal. DEMUX's perform the inverse function at the receiving stations, physically separating a WDM signal into single frequency beams. Both MUX and DEMUX units may conventionally use fiber or integrated optical components in order to isolate individual WDM channels. A variety of multiplexing techniques using variously, all-fiber components, integrated optical circuits, thin films and diffraction gratings have been developed.

In a typical fiber-optic network application, optical signals occupy a plurality of fiber lines and must be interconnected for signal distribution, multiplexing and demultiplexing of signals from numerous locations, protection routing and other functions. Such coupling and switching of signals amongst fibers is realized by optical switches or crossconnects. Optical cross connect switches (OXC's) provide optical connections between input and output ports that may be reconfigured in response to control signals. In WDM applications, OXC's may be used to connect individual wavelength channels from a single input port to different output ports. If the optical crossconnect further distinguishes among wavelength channels so as to allow redistribution of wavelength content among fibers in a network, this more specific crossconnect is called a wavelength crossconnect.

A variety of crossconnects have been disclosed using a number of different optical technologies. Cross connect designs include devices based on optical interferometry (Mach-Zehnder and directional coupler switch arrays, SOA-based switches, AO, EO and liquid crystal switches, thermo-optical (silica-on-silicon) and polymer optical waveguide switches and optomechanlical switches including those based on MEMS (micro-electro-mechanical systems).

US Patent #6,097,859 to Solgaard (*Solgaard*), et.al. discloses a multiwavelength cross-connect switch based on an array of MEMS mirrors. In this device, optical WDM signals are received by a plurality of input ports. An input lens system collimates these beams and directs them to a diffraction grating that reflects different wavelength channels at different angles while preserving the spatial separation of the individual input ports. The resulting two-dimensional array of beams (the width equals number of input beams and the height equals the number of wavelength channels) is imaged onto an array of electronically-actuated micro-mirrors (MEMS array). Each beam is reflected by an individual micro-mirror at an angle that is a function of the applied voltage.

In a first embodiment of Solgaard's patent, the electronically-controlled elements of a second micro-mirror array redirect the beams from the first MEMS device to an output optical system. Single-wavelength beams are reflected by the second array and recombined into WDM outputs signals by a second grating. Optical lenses on either side of the grating collimate the beams from the MEMS array and couple the WDM beams to the output ports of the switch. According to *Solgaard* the output optical system may be a mirror-image of the input system. By adjusting the voltage on the two MEMS arrays, a variable connection between input and output ports may be established for each wavelength channel in the system. These connections are, however, subject to the constraint that no two inputs in a single wavelength channel may be connected to a single output.

In alternative embodiments, a planar fold mirror is used to eliminate the second MEMS array and output optical system. A fold mirror can be used to reduce the lens and diffraction grating component count and to make a more compact geometry. In this case, for an NxN fiber wavelength crossconnect, 2NxW mirrors are required, where W is the number of wavelength channels being switched.

Optical add/drop multiplexers (OADM's) allow selected wavelength channels to be added or dropped from a WDM lightwave signal. In its simplest embodiment, an OADM has 4 ports - 'input' , 'output', 'add' and 'drop'. Typically, an optical trunk line enters the switch via the 'input' port and exits at the 'output'. Individual wavelength channels may be switched from the 'input' to the 'drop' port or from the 'add' port to the 'output'. Connectivity may or may not be provided between the 'add' and 'drop' ports. Note that the OADM is an application-specific example of a general 2x2 fiber-optic wavelength switch, which is the lowest reasonable port-count wavelength crossconnect (WXC). Larger port-count WXC's allow one of several add inputs to be switched to the output while the input signal is connected to one of several drop ports.

US Patent 5,960,133 to Tomlinson (*Tomlinson*) discloses a MEMS-based ADM switch that also uses a grating to separate the inputs into spatially-distinct, single wavelength beams. In contrast to the Solgaard switch, however, in Tomlinson the beams are switched by a single reflection from a MEMS array.

The overall WDM network performance is optimized when the power on individual wavelength channels is uniform across the channel spectrum. Factors contributing to the inequality of WDM channel powers include source power nonuniformity, different path routing of the channels which comprise the WDM spectrum, differential wavelength-channel gain in optical amplifiers, wavelength-dependent loss along the fiber path and within the components which comprise the overall network.

Generally, the lowest channel power determines the system performance in terms of crosstalk and signal-to-noise ratio, so it is necessary to adapt the system to accommodate the weakest channel. The preferred method is to equalize channel powers to that lowest channel power level.

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