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(54) **Title**: METHOD AND SYSTEM FOR SWITCHING OPTICAL CHANNELS

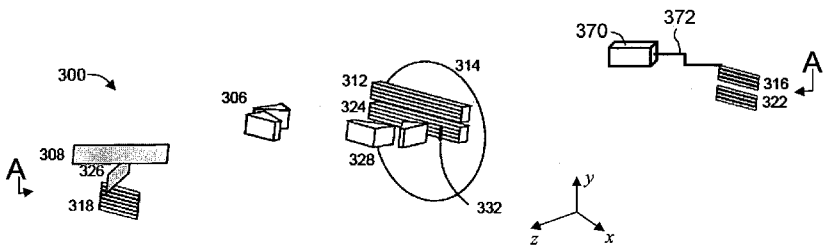


FIG. 3A

(57) **Abstract**: An optical switching system is disclosed. The system comprises: input optics, for receiving light from at least one input optical port and separating the light into a plurality of optical channels to assign a separate optical path to each channel of each input optical port. The system further comprises an input steering array and an output steering array arranged such that the input steering array is imaged onto the output steering array, wherein the input steering array is configured to receive the separated light and steer each optical channel to an individual element of the output steering array. The system further comprises output optics, for receiving the optical channels from the output steering array and coupling the optical channels into at least one output optical port.

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METHOD AND SYSTEM FOR SWITCHING OPTICAL CHANNELS

RELATED APPLICATION

This application claims the benefit of priority from U.S. Patent Application No. 61/253,962, filed on October 22, 2009 the contents of which are hereby incorporated by reference as if fully set forth herein.

FIELD AND BACKGROUND OF THE INVENTION

The present invention, in some embodiments thereof, relates to optical switching and, more particularly, but not exclusively, to switching of optical channels among multiple input and output fibers.

Optical telecommunication employs optical systems for switching, filtering, multiplexing and demultiplexing of optical signals. For example, in wavelength division multiplexing (WDM) telecommunication, multiple optical channels, each having a unique range of wavelengths, carry modulated optical signals in a single optical fiber between a transmitter and a receiver, thereby increasing the transmission capacity of the communication. The transmitter uses an optical multiplexer to combine multiple channels into the fiber for transmission, and the receiver uses an optical demultiplexer to separate the optical channels for detection.

When WDM channels have to be routed at network nodes from one transport fiber to another, it is advantageous to do this routing in an all-optical fashion, i.e., without detecting the signal and retransmitting it. A routing functionality at network nodes is performed by a system called an optical cross-connect system.

One type of optical cross-connect system employs a single large port-count cross-connect that is not wavelength-selective, a demultiplexer and a multiplexer. In operation, the demultiplexer separates the WDM channels, the cross-connect performs the routing and the multiplexer which recombines the WDM channels at their respective rout thereafter.

Another type of optical cross-connect system employs a few wavelength-selective switches (WSS), which either distribute wavelengths from one fiber to multiple output fibers, or combine wavelengths from multiple fibers to a single output fiber. WSS are typically based on switching finite bandwidths of dispersed light, typically with

micro-electro-mechanical system (MEMS) micromirrors or with liquid-crystals (LC) Spatial Light Modulators. Such configurations have the advantage that their passbands are typically broader than the solution employing discrete multiplexer and demultiplexer pair, which imply that the WDM channel experiences less filtering effects, thereby reducing cumulative degradation of the signals.

Systems of WSS are known in the art. Typically, such systems employ a combination of a grating and a lens for spatially dispersing or combining the input light, and an array of beam steering elements which performs the switching operation. The spectral characteristics of such systems are generally satisfactory because they switch continuous spectral bands belonging to individual channels [D. M. Marom, et al, 2005, "Wavelength-Selective 1×K Switches using Free-Space Optics and MEMS Micromirrors: Theory, Design, and Implementation," IEEE J. Lightwave Technol., Vol. 23, No. 4, pp. 1620-30].

Additional background art includes U.S. Patent Nos. 7,649,670, 7,333,688, 7,376,311, 7,283,709, 7,231,106, 7,126,250, 7,016,098, 6,984,917, 6,867,920, 6,738,540, 6,097,859, 6,289,145 and 6,327,398.

SUMMARY OF THE INVENTION

According to some embodiments of the invention the present invention there is provided an optical switching system. The system comprises: input optics, for receiving light from at least one input optical port and separating the light into a plurality of optical channels to assign a separate optical path to each channel of each input optical port. The system further comprises an input steering array and an output steering array arranged such that the input steering array is imaged onto the output steering array. The input steering array is configured to receive the separated light and steer each optical channel to an individual element of the output steering array. The system further comprises output optics, for receiving the optical channels from the output steering array and coupling the optical channels into at least one output optical port.

According to some embodiments of the invention the present invention there is provided an optical switching system. The system comprises: input optics, for receiving light from at least one input optical port and separating the light into a plurality of optical channels to assign a separate optical path to each channel of each input optical

port; and output optics, for combining optical paths into at least one output optical port. The system also comprises an optical path steering arrangement for dynamically steering any optical path into any optical output port. The optical path steering arrangement has an input steering array and an output steering array, arranged such that the input steering array is imaged onto the output steering array. The input steering array is configured to receive light via the optical paths and steer each optical channel to an individual element of the output steering array.

According to some embodiments of the invention the at least one input optical port comprises a plurality of input optical ports.

According to some embodiments of the invention the at least one output optical port comprises a plurality of output optical ports.

According to some embodiments of the invention the input steering array and the output steering array engage the same plane.

According to some embodiments of the invention the optical path steering arrangement comprises a redirector array configured for providing spatial shifts subsequently to the steering by the input steering array.

According to some embodiments of the invention the redirector array comprises a plurality of redirector elements, each configured for redirecting a light beam impinging thereon by a predetermined redirection angle which is different from any redirection angle corresponding to any other redirector element of the redirector array.

According to some embodiments of the invention the redirector array is a reflective redirector array.

According to some embodiments of the invention the redirector array is a refractive redirector array.

According to some embodiments of the invention the input optics comprises an input diffractive optical element for separating the light according to wavelength and an input optical tilter array for separating the light according to the at least one input optical port.

According to some embodiments of the invention the output optics comprises an output optical tilter array for tilting the steered light so as to align light beams according to the at least one output optical port, and an output diffractive optical element for coupling optical channels according to the alignment.

According to some embodiments of the invention the input optics comprise an anamorphic prism optics constituted for expanding the input light along a first direction.

According to some embodiments of the invention the output optics comprise an anamorphic prism optics for contacting the coupled optical channel along the first direction.

According to some embodiments of the invention the system further comprises a controller configured for controlling the input steering array according to a predetermined imaging scenario between the input steering array and output steering array.

According to some embodiments of the invention the controller is configured for detuning at least one of the input steering array and the output steering array.

According to an aspect of some embodiments of the present invention there is provided an optical communication system, comprising at least one input waveguide, for propagating incoming wavelength division multiplexed light, at least one output waveguide for propagating outgoing wavelength division multiplexed light and a wavelength-selective cross-connect (WSXC) system. The WSXC system comprises at least some components and technical features of the optical switching system as delineated above and further exemplified hereinunder.

According to an aspect of some embodiments of the present invention there is provided a method of optical switching, comprising: directing light constituting a plurality of optical channels into at least one input optical port an optical switching system having a controller, operating the controller according to a predetermined imaging scenario, and receiving light from the at least one output optical port. The optical switching system comprises at least some components and technical features of the optical switching system as delineated above and further exemplified hereinunder

According to an aspect of some embodiments of the present invention there is provided a method of optical switching. The method comprises: receiving light constituting N optical channels in each of K input optical ports and separating the light according to the optical channels along a first direction and according to the input optical ports along a second direction. The method further comprises focusing the separated light onto a plurality of focal spots defining a first array and imaging each focal spot onto an image focal spot to define a second array. In various exemplary

embodiments of the invention an order along the second direction is different among the second array and the first array. The method further comprises steering light beams away from the second array to couple the beams into K output optical ports, wherein all beams corresponding to image focal spots having the same location along the second direction are coupled to the same output optical port.

According to some embodiments of the invention the first array and the second array engage the same plane.

According to some embodiments of the invention the separating according to the optical channels is effected by diffraction, and the separating according to the input optical port is effected by refraction.

According to some embodiments of the invention the beams are coupled by tilting each beam along the second direction according to a respective output optical port, and diffracting the tilted beams along the first direction.

According to some embodiments of the invention the method further comprises, prior to the separation, expanding the received light along the first direction.

According to some embodiments of the invention the coupling comprises contracting the beams along the first direction.

According to some embodiments of the invention the method further comprises, employing at least one detuning procedure for generally equalizing power levels of all channels for a given output optical port.

According to some embodiments of the invention the focusing comprises, providing spatial shifts to each individual light beam.

According to some embodiments of the invention the spatial shifts are provided by a redirector array which comprises a plurality of redirector elements, each configured for redirecting a light beam impinging thereon by a predetermined redirection angle which is different from any redirection angle corresponding to any other redirector element of the redirector array.

According to some embodiments of the invention the spatial shifts are provided by reflections.

According to some embodiments of the invention the spatial shifts are provided by refractions.

According to some embodiments of the invention the present invention there is provided an optical switching system. The system comprises: input imaging optics, for receiving light from at least one input optical port and imaging the light onto first dispersed plane, to separate received light according to wavelength channels of each input optical port; and output imaging optics, for receiving light from a second dispersed plane, where the second dispersed plane has light separated according to wavelength channels, and imaging the light onto at least one output optical port. The system further comprises an optical path steering arrangement for dynamically steering dispersed light from the first dispersed plane to the second dispersed plane. The optical path steering arrangement has an input steering array and an output steering array arranged such that input steering array is imaged onto the output steering array optionally and preferably with an intermediate redirector plane assigning deterministic shifts in the imaging. The input optical ports are imaged onto a first dispersed plane with input imaging optics, the optical path steering arrangement images first dispersed plane onto the second dispersed plane in a dynamic fashion, and the second dispersed plane is imaged onto output ports with output imaging optics, for switching wavelength channels from any input optical port to any output optical port.

Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the invention, exemplary methods and/or materials are described below. In case of conflict, the patent specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and are not intended to be necessarily limiting.

Implementation of the method and/or system of embodiments of the invention can involve performing or completing selected tasks manually, automatically, or a combination thereof. Moreover, according to actual instrumentation and equipment of embodiments of the method and/or system of the invention, several selected tasks could be implemented by hardware, by software or by firmware or by a combination thereof using an operating system.

For example, hardware for performing selected tasks according to embodiments of the invention could be implemented as a chip or a circuit. As software, selected tasks

according to embodiments of the invention could be implemented as a plurality of software instructions being executed by a computer using any suitable operating system. In an exemplary embodiment of the invention, one or more tasks according to exemplary embodiments of method and/or system as described herein are performed by a data processor, such as a computing platform for executing a plurality of instructions. Optionally, the data processor includes a volatile memory for storing instructions and/or data and/or a non-volatile storage, for example, a magnetic hard-disk and/or removable media, for storing instructions and/or data. Optionally, a network connection is provided as well. A display and/or a user input device such as a keyboard or mouse are optionally provided as well.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the invention. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced.

In the drawings:

FIG. 1 is a schematic illustration of a conventional system of wavelength-selective switches;

FIG. 2 is a schematic illustration of a conventional wavelength-selective cross-connect;

FIGs. 3A-F are schematic illustrations of a wavelength-selective optical cross-connect system, according to various embodiments of the present invention;

FIG. 4 is a schematic illustration of exemplary layouts of steering arrays according to some embodiments of the present invention;

FIG. 5 is a schematic illustration showing imaging between two steering arrays for a particular beam from a particular input port according to some embodiments of the present invention;

FIGs. 6A-D are, in serial continuation, a schematic illustration of a wavelength-selective optical cross-connect system, in embodiments of the invention in which the system comprises refractive steering array; and

FIG. 7 is a schematic illustration of an optical communication system, according to some embodiments of the present invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS OF THE INVENTION

The present invention, in some embodiments thereof, relates to optical switching and, more particularly, but not exclusively, to switching of optical channels among multiple input and output fibers.

For purposes of better understanding some embodiments of the present invention, as illustrated in FIGs. 3-7 of the drawings, reference is first made to the construction and operation of conventional optical switching systems as illustrated in FIGs. 1 and 2.

FIG. 1 is a schematic illustration of a typical system **100** of WSS. Light from an input fiber **110** is spatially dispersed by a grating **130** and lens **140** combination. Channels from the dispersed light are independently beam steered by individual beam steering element enumerated **152-1** through **152-N**, in a switching array **150**. For each WDM channel, there is a separate steering element **152** (FIG. 1 shows a single channel switched by beam steering element **152-2**). The steered light, which consists of the bandwidth captured by the respective beam steering element, is then back propagated through lens **140** and grating **130** to one of the output fibers **160**-1 through **160**-K. The tilt imposed by beam steering element **152**-x of array 150 determines the output fiber. The channel passband characteristic is determined by the resolving power of the optical arrangement (lens **140** and grating **130**), and is maximized when switching array **150** is placed at the lens back focal plane, where the spectral spots are focused. This means that both the input and output fibers are imaged onto beam steering array **150**, ensuring that bandwidth captured by each beam steering element **152-x** is switched from the input fiber **110** to the selected output fiber **160**. The WSS shown in FIG. 1 thus distribute WDM channels from a single fiber **110** to a plurality of fibers **160**. Also known are systems of WSS operated in reverse, combining WDM channels from a plurality of

input fibers to a single output fiber. The optics in such systems is revered relative to the optics shown in FIG. 1, but the principle of operation is similar.

Attempts have also been made to devise systems that receive optical input from several fibers, and route the individual WDM channels from each fiber to several output fibers. Such systems are referred to as wavelength-selective cross-connect (WSXC).

FIG. 2 is a schematic illustration of a conventional WSXC **200**. WSXC **200** employ the basic WSS architecture described above, and additionally have the light from each fiber (both input and output) incident on its own row of beam steering elements. Shown in FIG. 2 are several input fibers, designated **220-1** through **220-K**, and several output fibers, designated **230-1** through **230-K**. Input fibers **220** carry N optical channels to be routed to the output fibers **230**. WSXC **200** includes a beam steering elements **210** which contains 2K rows of beam steering elements, each row having N elements. An optical path is established by two beam steering elements. The steering element receives a beam with particular wavelength from a particular input fiber, and steers that particular beam towards the corresponding beam steering element of the same wavelength of output fiber. The second beam steering element realigns the beam such that it is efficiently coupled to the output fiber.

It is recognized by the present inventor that this solution has a drawback in that the two beam steering elements cannot be simultaneously placed at the lens back focal plane where the spectral spots are focused. Thus, clipping by the beam steering elements' edges becomes pronounced and the channel passband characteristics are deteriorated.

The present inventor discovered an optical switching technique which is devoid of the above limitations.

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details of construction and the arrangement of the components and/or methods set forth in the following description and/or illustrated in the drawings and/or the Examples. The invention is capable of other embodiments or of being practiced or carried out in various ways.

FIGs. 3A-F are schematic illustrations of an optical switching system **300**, according to various exemplary embodiments of the present invention. FIG. 3A is a

perspective view system **300** without showing the beam traces of the preferred embodiment, FIG. 3B is a top view illustrating the beam traces from input fiber to a spatially dispersed plane, FIGs. 3C, 3E and 3F are side views illustrating several optional embodiments for facilitating optical switching between input and output ports with Fig. 3C being the preferred embodiment, and FIG. 3D is a secondary top view illustrating the beam traces from a secondary spatially dispersed plane to the output fibers. Also shown in FIGs. 3A-F is a three-dimensional Cartesian coordinate system *x-y-z*, conveniently selected such that the *x-z* plane is parallel to FIGs. 3B and 3D and the *y-z* plane is parallel to FIGs. 3C, 3E and 3F. For example, the *y-z* plane can be a vertical plane and the *x-z* plane can be a horizontal plane. It is to be understood, however, that system **300** is operative in any orientation with respect to the gravity, and the terms "vertical" and "horizontal" are not to be construed as limiting.

System **300** can serve as a WSXC, which receives N optical channels on each of its K_i input ports, and routes the individual optical channels from each input port to one of K_o output ports, where each of K_i, K_o and N is an integer number, preferably, but not necessarily, larger than 1. Thus, for example, when $K_i=K_o=K$, the WSXC of the present embodiments has K! switching permutations per channel. Typical values for K_i and K_o include, without limitation, any integer number from 2 to N, and typical values for N include, without limitation, any integer number from 10 to 200. It is expected that during the life of a patent maturing from this application wavelength division multiplexing technology will allow use of many more channels per optical waveguide and the scope of the invention is intended to include all such advances in the technology *a priori*. Thus, In some embodiments of the present invention N is even larger than 200.

In the representative example illustrated in FIGs. 3B-F the number of optical channels shown is 3. These channels are referred to herein collectively as channels **350** and individually as channels **350-1**, **350-2** and **350-3**. It is to be understood that any other number of channels is not excluded from the scope of the present invention. The input ports are typically stacked along the *y* direction. For clarity of presentation the input ports are only shown collectively at **302** (see FIG. 3B). Similarly, the output ports are typically stacked along the *y* direction, and are only shown collectively at **334** (see FIG. 3D).

System **300** comprises input optics which receive light from one or more input optical ports **302** and separates the light into a plurality of optical channels **350** to assign a separate optical path to each channel of each input optical port. Broadly speaking, the input optics separates the light according to optical channels **350** along the *x* direction and according to input optical ports **302** along the *y* direction, thus forms $K_i \times N$ separate optical paths. The separation according to the optical channel is typically effected by diffraction, but can be achieved by means of refraction as well. Separating according to the input optical port is typically effected by refraction or reflection. In principle, any optical arrangement that separates the light to $K_i \times N$ separate optical paths, wherein the separation according to input port is along one direction and the separation according to channel is along another direction is suitable for at least some embodiments of the present invention.

In the representative illustration of FIGs. 3A-D the input optics comprises an input diffractive optical element **308** which separate the light according to the wavelength or optical channel, and an input optical tilter array **312** which separates the light according to the input optical port.

Element **308** can be for example, a diffraction grating. Element **308** can operate in transmission mode, in which case the light experiences diffraction by passing through element **308**, or, as illustrated in FIG. 3B, in reflective mode in which case the light experiences diffraction while being reflected off element **308**. Also contemplated, are embodiments in which the separation according to optical channels is performed by other dispersive elements, including, without limitation, a prism which is known to deflect different wavelengths of light at different angles. Further contemplated is a combination of grating and prism or any other optical element, such as, but not limited to, such as a volume hologram, capable of deflecting the light at wavelength-dependent angles.

Input optical tilter array **312** is an arrangement of optical tilter elements along the *y* direction, wherein each tilter element in the array applies a slightly different tilt to a beam incident thereon. The tilt applied by the individual tilter elements is preferably fixed and corresponds to the respective input port. Thus, tilter array **312** preferably includes K_i tilter elements each being aligned with a respective input port. In these embodiments, tilter array **312** provides K_i different tilt angels along the *y* direction

(one unique tilt angle per input port). The tilter elements can be of any type known in the art and they can operate either in reflective mode in which case the respective beam is tilted while being reflected off the respective tilter element, or, as illustrated in FIGs. 3B-C, in transmission mode, in which case the respective beam is tilted by passing through the respective tilter element. Representative examples of tilter elements include micro-prisms, micro-mirrors, diffractive elements and the like.

In some embodiments, the input optics also comprises an anamorphic optics **306**, positioned in the optical path of the input light before the diffractive optical element **308**. Anamorphic optics can be, for example, an anamorphic prism optics. An anamorphic prism is a device which allows for the magnification of a beam size along one axis while leaving the beam unchanged along another other axis. Alternatively, anamorphic optics **306** can be embodied as a cylindrical lens pair. As shown in FIG. 3B, optics **306** provides a one-dimensional expansion of the input light in the *x*-*z* plane. Such expansion facilitates better separation between different optical channels along the *x* direction, thus enhancing the spectral resolving power as the number of grating periods being illuminated is larger. Optionally, the input optics also comprises K_i input collimator lens systems **304**, one collimator lens system for each input port. Each lens system **304** is preferably positioned at or in proximity to the respective input port for collimating the input light prior to the diffraction and tilting and optional expansion. Thus, reference sign **304** corresponds to a stack or array of lens systems arranged along the *y* direction.

In various exemplary embodiments of the invention system **300** comprises an input steering array **316** and an output steering array **322** arranged such that array **316** is imaged onto array **322**.

As used herein, a first object is said to be "imaged" onto a second object if the two objects are positioned such that a light beam passing from one object to the other object is focused both on the first object and on the second object.

Imaging of one object onto another is typically established by a focusing optical element such as a lens or a lens system. In the representative illustration of FIGs. 3C, 3E and 3F each of input steering array **316** and output steering array **322** engages the focal plane of a lens system **314**, which can be a single lens or an arrangement of lenses. FIG. 3C illustrates an embodiment in which lens system **314** is a single lens, FIG. 3E

illustrates an embodiment in which lens system **314** comprises two lenses, and FIG. 3F illustrates an embodiment in which lens system **314** comprises four lenses. Other configurations for lens system **314** are not excluded from the scope of the present invention, provided that array **316** is imaged by lens system **314** onto array **322**. In various exemplary embodiments of the invention the length of the optical path between arrays **316** and **322** is $4f$ where f is the focal length of lens system **314**. These $4f$ embodiments are further detailed hereinunder. Other optical path lengths between arrays **316** and **322** (*e.g.*, $6f$, $8f$, *etc.*) are not excluded from the scope of the present invention.

Each of arrays **322** and **316** is a two-dimensional array of individual beam steering elements, arranged along the x and y direction. Representative examples of possible layouts for arrays **322** and **316** are illustrated in FIG. 4. Each of arrays **316** and **322** is further divided to rows along the x direction and columns along the y direction, where the number of rows of array **316** equals K_i, the number of rows of array **322** equals K_o, and the number of columns in both array **316** and **322** equals N. The rows of array **316** are labeled **316-1** through **316-K_i**, the rows of array **322** are labeled **322-1** through **322-K_o**, and the columns are labeled by the channel number **Ch. 1** through **Ch. N**. Each individual beam steering element is identified by a three-number reference numeral according to the format Array-Row-Column. The beam steering elements can be reflective or refractive. The beam steering elements can be implemented by tilting micromirrors, *e.g.*, micromirrors fabricated using MEMS technology, by linear phase gradients written into liquid crystal (LC), spatial light modulators (SLM), and the like. Beam steering elements suitable for the present embodiments are found, for example, in U.S. Patent Nos. 7,403,322, 6,867,920 and 7,333,688, the contents of which are hereby incorporated by reference.

In operation, the light, after being separated by the input optics (*e.g.*, by means of diffractive optical element **308** and tilter array **312**) is focused by lens system **314** onto a plurality of focal spots on array **316**, each focal spots engages a different steering element of array **316**. Array **316** steers the individual light beams, preferably dynamically for an active switch functionality, such that each focal spot is imaged onto an image focal spot on array **322**, wherein each image focal spot engages a different steering element of array **322**. The imaging is optionally and preferably such that the

order of the spots along the *y* direction at array **316** is different from the order of the image spots along the *y* direction at array **322**. For example, array **316** can steer a light beam from element **316-1-1** (namely an element of array **316** at the first row and the first column) to element **322-2-1** (namely an element of array **322** at the second row and the first column). Such steering, as will be explained below, results in routing the first channel of the first input port to the second output port. In various exemplary embodiments of the invention the spatial shifts for switching are achieved by a redirector array **318**. These embodiments are described hereinunder.

Array **316** steers the light beams "dynamically" in the sense that the steering angle prescribed by a particular steering element of array **316** to a particular optical beam is controllable, *e.g.*, by means of a controller **370**. For example, when array **316** is a MEMS wherein each steering element is a rotatable micromirror, controller **370** can transmits control signals to the MEMS, *e.g.*, via communication line **372**, and the MEMS can rotate the micromirrors responsively to the control signals. Similarly, when array **316** comprises linear phase gradients written into LC SLM, controller **370** can transmits control signals so as to vary the phase pattern on the LC. All these operations are well-known to those skilled in the art of optics.

Array **322** dynamically steers the beam away from array **322** in the direction of output optics described below. The principles of operations of array **322** are similar to the principles of operations of array **316**.

The output optics receive the steered optical channels and couples them into output optical port(s) **334**. The output optics can be similar to the input optics described above except that the optical function is reversed. For example, the output optics can comprise an output optical tilter array **324** which tilts the steered beams so as to align the beams according to the output optical port(s), and an output diffractive optical element **326** which couples the optical channels according to the alignment. In other words, the output optics (*e.g.*, tilter array **324** and element **326**) ensure that all beams corresponding to image focal spots having the same location along the *y* direction are coupled to the same output optical port.

Output optical tilter array **324** is an arrangement of optical tilter elements along the *y* direction, wherein each tilter element in the array applies a slightly different tilt to a beam incident thereon. Tilter array **324** preferably includes K_o tilter elements each

providing a tilt corresponding to a respective output port. In these embodiments, tilter array **324** provides K_o different tilt angels along the *y* direction (one unique tilt angle per output port). The tilter elements can be of any type known in the art and they can operate either in reflective mode in which case the respective beam is tilted while being reflected off the respective tilter element, or, as illustrated in FIGs. 3B-C, in transmission mode, in which case the respective beam is tilted by passing through the respective tilter element. Representative examples of tilter elements include micro-prisms, micro-mirrors and the like.

In various exemplary embodiments of the invention output diffraction optical element **326** is the same as input diffractive optical element **308**, except that it is flipped along the *x* direction. These embodiments allow utilization of separate locations for the input ports **304** and output ports **334**.

In some embodiments, the output optics also comprises an anamorphic optics **328**, positioned in the light path of the steered beam after diffractive optical element **326**. Anamorphic optics **328** can be, for example, an anamorphic prism pair or a pair of cylindrical lenses. As shown in FIG. 3D, optics **328** provides a one-dimensional contraction of the steered light in the *x-z* plane. Such contraction facilitates the in-coupling of the beam into the respective output port. Optionally and preferably, the one-dimensional contraction provided by anamorphic prism optics **326** matches the one-dimensional expansion provided by anamorphic prism optics **306**.

Optionally, the output optics also comprises K_o input collimator lens systems **332**, one lens system for each output port. Each lens system is preferably positioned at or in proximity to the respective output port for focusing the input light into the output port. Thus, reference sign **332** corresponds to a stack or array of lens systems arranged along the *y* direction.

Following is a more detailed description of the optical paths between input steering array **316** and output steering array **322**, according to some embodiments of the present invention. Each of arrays **316** and **322** can independently be reflective or refractive. FIGs. 3A-F illustrate embodiments of the present invention in which both arrays **316** and **322** are reflective arrays, and FIG. 6 illustrate an embodiment of the present invention in which both arrays **316** and **322** are refractive arrays. The following description is for a non-limiting embodiment in which arrays **316** and **322** are reflective.

A description of the optical paths between array **316** and array **322** in an embodiment in which these arrays are both refractive is provided hereinunder.

With specific reference to FIG. 3C, in some exemplary embodiments of the invention arrays **316** and **322** engage the back focal plane of lens system **314**. In alternative embodiments, illustrated in FIGs. 3E and 3F, array **316** and array **322** engage focal planes of different lenses of system **314**. Without loss of generality, the following description is for the embodiment in which system **314** includes one lens.

FIG. 3C illustrates input beams **364**, corresponding to one of the input ports **302** (not shown in FIG. 3C, see FIG. 3B). For clarity of presentation, beams from other input ports (in preferred embodiments in which $K_i > 1$) are not shown, but the ordinarily skilled person, provided with the details described herein would know how to add more beams to FIG. 3C. Generally, as stated a given input port provides more than one optical channel. These channels that are separated along the x direction by the input optics as described above. Thus, beams **364** represent multiple optical channels that are separated along the x direction, hence not explicitly shown in FIG. 3C (see channels **350-1**, **350-2** and **350-3** in FIGs. 3B and 2D).

After striking diffractive element **308**, each of beams **364** traverse input tilter array **312**, which applies to beams **364**, as stated, a tilt which is specific to the respective input port. The tilt angle, however, is preferably the same to all channels of the respective input port. Thus, each of beams **364** is tilted with respect to the y direction by the same angle. Once tilted, beams **364** and pass through lens system **314** which focuses beams **364** onto input steering array **316** at its back focal plane (or the back focal plane of one of the lenses of system **314**). The tilt applied by tilter array **312** prevents overlap at the lens back focal plane. Beams **364** thus collectively strike a single row of array **316**, wherein each individual beam of beams **364** strikes one steering element within that row. In other words, the tilt applied by tilter array **312** ensure that each of beams **364** strikes the correct row of array **316**, and the spatial dispersion applied by diffractive optical element **308** ensures that each of beams **364** strikes the correct column of array **316** (the rows and columns of array **316** are shown in FIG. 4).

The beam steering elements at the respective row of array **316** steer beams **364** by reflection toward lens system **314**. The beams exiting array **316** are designated **366**.

Notice that the steering angles prescribed by array **316** are not necessarily the same for all channels. In the representative example that is schematically illustrated in FIG. 3C, the row of array **316** which receives beams **364** prescribes four different steering angles with respect to the *y* axis, and therefore beams **366** are shown as four lines separated along the *y* direction.

Notice further that each of the four lines that represent beams **366** may, in principle, correspond to more than one beam since array **316** can prescribe the same steering angle to two different channels. However, since the channels are separated along the *x* direction, multiple channels for each of the lines the represent beams **366** are now shown. For example, consider a simple situation in which the number of channels, *N*, provided by a particular input port is 5. These 5 channels, denoted Ch1 through Ch5, are respectively focused on 5 different steering elements **322-1-1**, ..., **322-1-5** arranged along a particular row of array **316**. Suppose that these five steering elements prescribe four different steering angles, θ_1, ... θ_4, where θ_1 is prescribed by both **322-1-1** and **322-1-2**, θ_2 is prescribed by **322-1-3**, θ_3 is prescribed by **322-1-4**, and θ_4 is prescribed by **322-1-5**. In this situation, one of the four lines the represent beams **366** corresponds to channels Ch1 and Ch2 (separated along the *x* direction) while each of the other three lines correspond to one of the channels Ch3, Ch4 and Ch5.

Beams **366** pass through lens system **314**, and are incident on a redirector array **318**. The angles prescribed by the individual steering elements at the respective row of array **316** determine the position along the *y* axis of each of beams **366** at redirector array **318** and the choice of redirection angle of array **318**. Array **318** serves for fulfilling space-variant imaging arrangements between **316** and **322**. The number of space-variant imaging operation which can be applied by array **318** can be Ki+Ko-1.

Redirector array **318** preferably has multiple elongated redirector elements arranged in rows extending along the *x* direction and stacked along the *y* direction. Thus, beams **366** are incident on one or more of the elongated redirector elements of array **318** which are dynamically selected by the angles prescribed by array **316**. In the representative example illustrated in FIG. 3C, array **316** selects (for the respective input port) four different elongated redirector elements of array **318**. The redirector elements of array **318** are arranged such that each redirector element redirects a light beam at a slightly different angle. Redirector array **318** is preferably a static optical element,

wherein each elongated redirector elements impart a unique and predetermined angle to the respective beam.

Redirector array **318** can be a reflector array, in which case each redirector element is a reflective element with a unique tile which reflects a light beam at a slightly different angle. This embodiment is illustrated in FIG. 3C. A representative example for a reflector array suitable for the present embodiments includes, without limitation, an array of micromirrors. Redirector array **318** can alternatively be a refractive array, in which case each redirector element is a refractive element which refracts a light beam at a slightly different angle. This embodiment is illustrated in FIGs. 6B and 6C. A representative example for a refractor array suitable for the present embodiments includes, without limitation, an array of microprisms.

Once redirected by the respective refractor elements of redirector array **318**, beams **366** back propagate through lens system **314** onto steering array **322**. Thus, the beam steering elements of array **316** are independently imaged by lens system **314** onto the beam steering elements of array **322**.

The beam steering elements of array **322** (one per optical channel per output port, see FIG. 4) dynamically steer beams **366** upon reflection towards lens system **314** and output tilter array **324**. The steering angles prescribed by array **322** are in accordance with the desired input-output switching scheme.

The steering angle of a given mirror of array **322** preferably ensures that the beam steered by it arrives at the respective tilter element of tilter array **324** corresponding to output port. Beams **366** are now aligned along the *y* direction for efficient coupling to output ports **334**. Combining along the *x* direction of several channels into one output port can be effected by output diffractive element **326**, as further detailed hereinabove. Thus, the above description demonstrates switching to four distinct output ports.

The imaging between beam steering arrays **316** and **322** for a particular beam from a particular input port is better illustrated in FIG. 5, which is a partial side view of system **300**. FIG. 5 considers a beam **502** from input port **1**, and shows beam **502** after it has been diffracted (by input diffractive **308**, not shown, see FIG. 3B) at the front focal plane **P5-1** of lens system **314**. Beam **502** is refracted by a respective element of tilter array **312**, and after lens system **314** the beam, now designated **504**, is focused at the

back focal plane **P5-2** of lens system **314** onto input steering array **316**. In the representative example shown in FIG. 5, beam **504** incidents on steering element **316-1-4** of array **316**. Thus, in this non-limiting example, beam **504** constitutes optical channel No. 4. Each steering element array **316** can, as stated, dynamically change the reflected beam direction. Beam **504** can be steered by element **316-1-4** into the direction **506-A** (shown as a solid line) or the direction **506-B** (shown as a dot-dash line).

Consider firstly a scenario in which the resulting steered beam is in the direction **506A**. Steered beam **506A** traverses lens **314**, resulting in a beam **508A**. Beam **508A** propagates towards the front focal plane **P5-1** of lens system **314** and impinges on redirector element (reflective or refractive) **318A** of redirector array **318**. Array **318** is preferably positioned at plane **P5-1**. Redirector element **318A** is therefore selected by steering angle prescribed by element **316-1-4**. The beam being redirected (reflected or refracted) by redirector element **318A**, designated **510A** is converted by lens system **314** to a beam **512A** which is focused onto array **322** at focal plane **P5-2**. In the representative example shown in FIG. 5, focused beam **512A** incidents on element **322-1-4** of array **322**. Thus, in this scenario, element **316-1-4** is imaged onto element **322-1-4**. Continuing with this scenario, element **322-1-4** steers the beam to produce a steered beam **514A** propagating towards a respective tilter element of tilter array **324** which realign the beam resulting in a realign beam **516A**. Beam **516A** is realigned to allow its efficient coupling into output port 1. Thus, in this scenario, the fourth optical channel of the first input port is routed to the first output port.

Consider secondly a scenario in which the resulting steered beam is in the direction **506B**. Steered beam **506B** traverses lens **314**, resulting in a beam **508B**, which propagates towards the front focal plane **P5-1** of lens system **314** and impinges on redirector element **318B** of redirector array **318**. Thus, in this scenario element **316-1-4** selects refractive element **318B**. The beam being redirected by reflector element **318B**, designated **510B**, is converted by lens system **314** to a beam **512B** which is focused onto element **322-2-4** of array **322**. Thus, in this scenario, element **316-1-4** is imaged onto element **322-2-4**. Element **322-2-4** steers the beam to produce a steered beam **514B** propagating towards another tilter element of tilter array **324** which realign the beam resulting in a beam **516B**, realigned to allow its efficient coupling into output port 2.

Thus, in this scenario, the fourth optical channel of the first input port is routed to the second output port.

Note that because of the inversion property of the above described imaging process, the spatial dispersion along the x direction (not shown in FIG. 5) is flipped. In these embodiments, the aforementioned mutual flip relation between diffractive optical elements **308** and **326** maintains separation between input ports **302** and output ports **304**.

Following is a description of the optical paths between array **316** and array **322** in an embodiment in which these arrays are both refractive. This embodiment is illustrated, in serial continuation, in FIGs. 6A-D.

FIGs. 6A, 6B, and 6D are schematic illustrations of a top view of system **300**, whereas 6C is a side view of section 6B. The optical paths from input ports **302** to array **316** are shown in FIG. 6A, from array **316** to array **322** are shown in FIGs. 6B and 6C (the former from the top, the latter from the side), and from array **322** to output port **334** is shown in FIG. 6D. Thus, FIGs. 6B and 6C should be understood as a continuation of FIG. 6A, and FIG. 6D should be understood as a continuation of FIGs. 6B and 6C.

In the embodiment illustrated in FIGs. 6A-D, lens system **314** comprises four lens systems designated **314A**, **314B**, **314C** and **314D**. Referring to FIG. 6A, array **316** engages the back focal plane of lens system **314A**. The input beams, after striking diffractive element **308**, traverse input tilter array **312**, which applies to the beams a tilt as further detailed hereinabove. Once tilted, the beams pass through lens system **314A** which focuses them onto input steering array **316** at its back focal plane.

Referring to FIG. 6B, the beam steering elements at the respective row of array **316** steer the beams by refraction toward lens system **314B**. The beams pass through lens system **314B**, and are incident on redirector array **318**. In the present embodiment, array **318** is a refractor array. The angles prescribed by the individual steering elements at the respective row of array **316** determine the elongated redirector elements on which the beams incident. Thus, the elongated redirector elements of array **318** are dynamically selected by the angles prescribed by array **316**. Once redirected by the respective refractor elements, the beams propagate through lens system **314C** onto steering array **322**. Thus, the beam steering elements of array **316** are independently

imaged onto the beam steering elements of array **322** by a lens system which includes multiple individual lens systems (**314A, 314B** and **314C** in the present example).

Referring to FIG. 6D, the beam steering elements of array **322** (one per optical channel per output port) steer the beams by refraction towards lens system **314D** and output tilter array **324**. The steering angles prescribed by array **322** are in accordance with the desired input-output switching scheme. The steering angle of a given mirror of array **322** preferably ensures that the beam steered by it arrives at the respective tilter element of tilter array **324** corresponding to output port. The beams are now aligned for efficient coupling to output ports **334**. Output diffractive element **326** combines several channels into one output port, as further detailed hereinabove.

While the embodiments above are described with a particular emphasis to a configuration in which arrays **316, 318** and **322** are all reflective, and a configuration in which arrays **316, 318** and **322** are all refractive, it is to be understood that more detailed reference to these configurations is not to be interpreted as limiting the scope of the invention in any way. Thus, any of arrays **316, 318** and **322** can independently be reflective or refractive, and some embodiments of the present invention contemplate combination of refractive and reflective arrays.

It is expected that during the life of a patent maturing from this application many relevant optical steering elements will be developed and the scope of the term beam steering element is intended to include all such new technologies *a priori*.

FIG. 6 is a schematic partial illustration of an optical communication system **600**, according to some embodiments of the present invention. Shown in FIG. 6 is the switching node part of system **600**. System **600** comprises at least one, more preferably a plurality of input waveguides **602**, for propagating incoming wavelength division multiplexed light; at least one, more preferably a plurality of output waveguides **604**, for propagating outgoing wavelength division multiplexed light; and a WSXC system **606**. In various exemplary embodiments of the invention system **606** comprises system **300** described above. In some embodiments of the present invention system **606** is system **300**. WSXC system **606** can be connected to waveguides **602** and **604** by means of output and input ports such as ports **304** and **334** described above. Waveguides **602** and **604** can be of any type which is suitable for guiding wavelength division multiplexed light. For example, waveguides **602** and **604** can be optical fibers or they can be

embedded waveguides, such as waveguides of Planar Light Circuits (PLC) or other arrays. WSXC system **606** perform optical switching to allow wavelength division multiplexed optical data arriving from K_i input waveguides routed to K_o output waveguides. The wavelength division multiplexed optical data are denoted in FIG. 7 by $\lambda^{(p)}_q$, where p is an input waveguide index (p = 1, 2, ..., K_i), and q is a channel index (q = 1, 2, ..., N). WSXC system **606** is capable of routing any channel $\lambda^{(p)}_q$ from any input waveguide to any output waveguide, as further detailed hereinabove.

The word "exemplary" is used herein to mean "serving as an example, instance or illustration." Any embodiment described as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments and/or to exclude the incorporation of features from other embodiments.

The word "optionally" is used herein to mean "is provided in some embodiments and not provided in other embodiments." Any particular embodiment of the invention may include a plurality of "optional" features unless such features conflict.

The terms "comprises", "comprising", "includes", "including", "having" and their conjugates mean "including but not limited to".

The term "consisting of means "including and limited to".

The term "consisting essentially of" means that the composition, method or structure may include additional ingredients, steps and/or parts, but only if the additional ingredients, steps and/or parts do not materially alter the basic and novel characteristics of the claimed composition, method or structure.

As used herein, the singular form "a", "an" and "the" include plural references unless the context clearly dictates otherwise. For example, the term "a compound" or "at least one compound" may include a plurality of compounds, including mixtures thereof.

Throughout this application, various embodiments of this invention may be presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the invention. Accordingly, the description of a range should be considered to have specifically disclosed all the possible subranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed subranges such as

from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Whenever a numerical range is indicated herein, it is meant to include any cited numeral (fractional or integral) within the indicated range. The phrases "ranging/ranges between" a first indicate number and a second indicate number and "ranging/ranges from" a first indicate number "to" a second indicate number are used herein interchangeably and are meant to include the first and second indicated numbers and all the fractional and integral numerals therebetween.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention. To the extent that section headings are used, they should not be construed as necessarily limiting.

WHAT IS CLAIMED IS:

1. An optical switching system, comprising:

input optics, for receiving light from at least one input optical port and separating said light into a plurality of optical channels to assign a separate optical path to each channel of each input optical port;

output optics, for combining optical paths into at least one output optical port; and

an optical path steering arrangement for dynamically steering any optical path into any optical output port, said optical path steering arrangement having an input steering array and an output steering array arranged such that input steering array is imaged onto said output steering array, wherein said input steering array is configured to receive light via said optical paths and steer each optical channel to an individual element of said output steering array.

2. The system according to claim 1, wherein said at least one input optical port comprises a plurality of input optical ports.

3. The system according to any of claims 1 and 2, wherein said at least one output optical port comprises a plurality of output optical ports.

4. The system according to any of claims 1-3, wherein said input steering array and said output steering array engage the same plane.

5. The system according to any of claims 1-4, wherein said optical path steering arrangement comprises a redirector array configured for providing spatial shifts subsequently to said steering by said input steering array.

6. The system according to claim 5, wherein said redirector array comprises a plurality of redirector elements, each configured for redirecting a light beam impinging thereon by a predetermined redirection angle which is different from any redirection angle corresponding to any other redirector element of said redirector array.

7. The system according to claim 5, wherein said redirector array is a reflective redirector array.

8. The system according to claim 5, wherein said redirector array is a refractive redirector array.

9. The system according to any of claims 1-8, wherein said input optics comprises an input diffractive optical element for separating said light according to wavelength and an input optical tilter array for separating said light according to said at least one input optical port.

10. The system according to any of claims 1-9, wherein said output optics comprises an output optical tilter array for tilting said steered light so as to align light beams according to said at least one output optical port, and an output diffractive optical element for coupling optical channels according to said alignment.

11. The system according to any of claims 1-10, wherein said input optics comprise an anamorphic prism optics constituted for expanding said input light along a first direction.

12. The system according to claim 11, wherein said output optics comprise an anamorphic prism optics for contacting said coupled optical channel along said first direction.

13. The system according to any of claims 1-12, further comprising a controller configured for controlling said input steering array according to a predetermined imaging scenario between said input steering array and output steering array.

14. The system according to claim 13, wherein said controller is configured for detuning at least one of said input steering array and said output steering array.

15. An optical communication system, comprising at least one input waveguide, for propagating incoming wavelength division multiplexed light, at least one output waveguide for propagating outgoing wavelength division multiplexed light and a wavelength-selective cross-connect (WSXC) system, wherein said WSXC system comprises the system according to any of claims 1-14.

16. A method of optical switching, comprising:

directing light constituting a plurality of optical channels into at least one input optical port of the system according to any of claims 13 and 14;

operating said controller according to said predetermined imaging scenario; and

receiving light from said at least one output optical port.

17. A method of optical switching, comprising:

receiving light constituting N optical channels in each of K input optical ports;

separating said light according to said optical channels along a first direction and according to said input optical ports along a second direction;

focusing said separated light onto a plurality of focal spots defining a first array;

imaging each focal spot onto an image focal spot to define a second array, wherein an order along said second direction is different among said second array and said first array; and

steering light beams away from said second array to couple said beams into K output optical ports, wherein all beams corresponding to image focal spots having the same location along said second direction are coupled to the same output optical port.

18. The method according to claim 17, wherein said first array and said second array engage the same plane.

19. The method according to any of claims 17 and 18, wherein said separating according to said optical channels is effected by diffraction, and said separating according to said input optical port is effected by refraction.

20. The method according to any of claims 17-19, wherein said beams are coupled by tilting each beam along said second direction according to a respective output optical port, and diffracting said tilted beams along said first direction.

21. The method according to any of claims 17-20, further comprising, prior to said separation, expanding said received light along said first direction.

22. The method according to any of claims 17-21, wherein said coupling comprises contracting said beams along said first direction.

23. The method according to any of claims 17-22, further comprising employing at least one detuning procedure for generally equalizing power levels of all channels for a given output optical port.

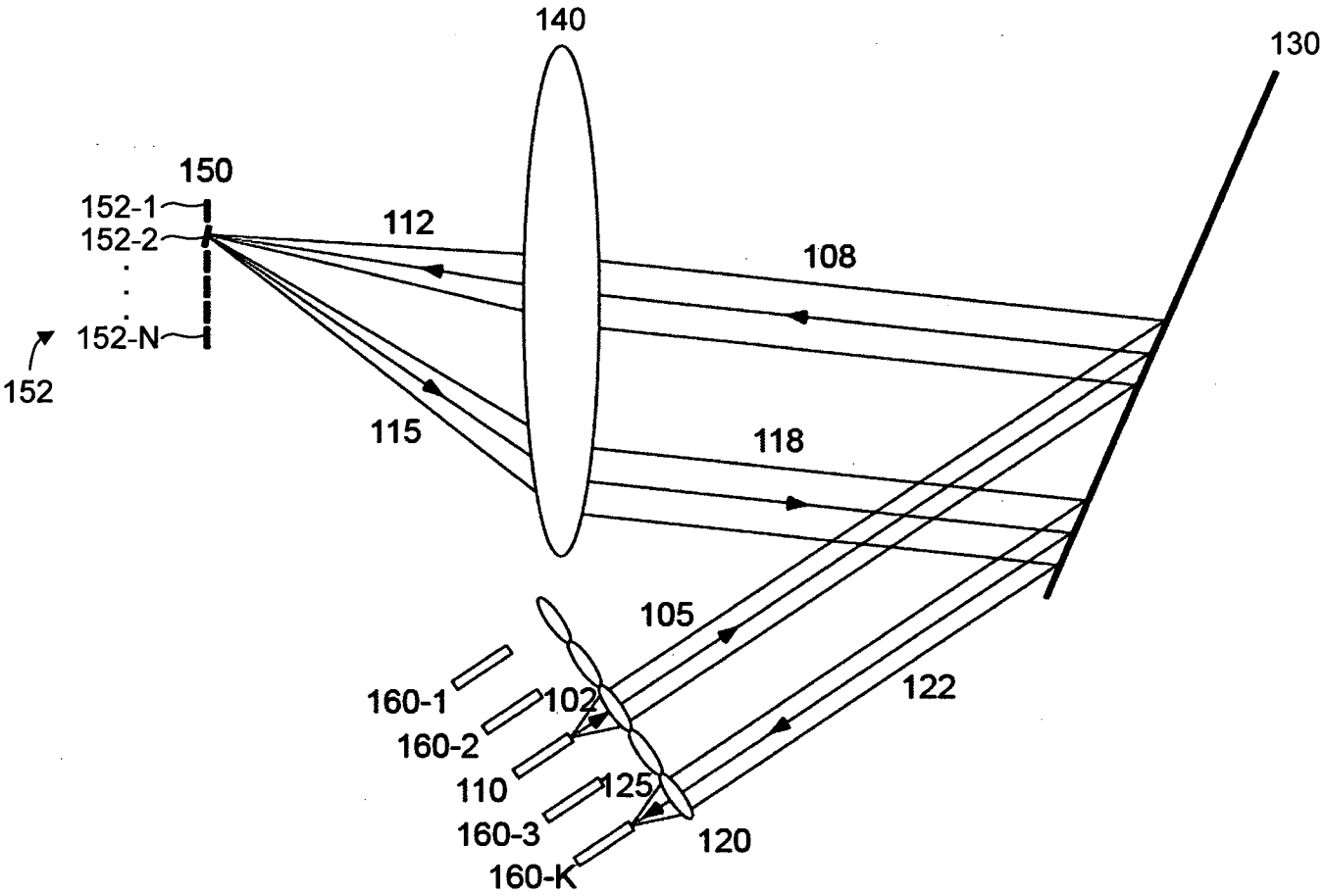


FIG. 1 (Prior Art)

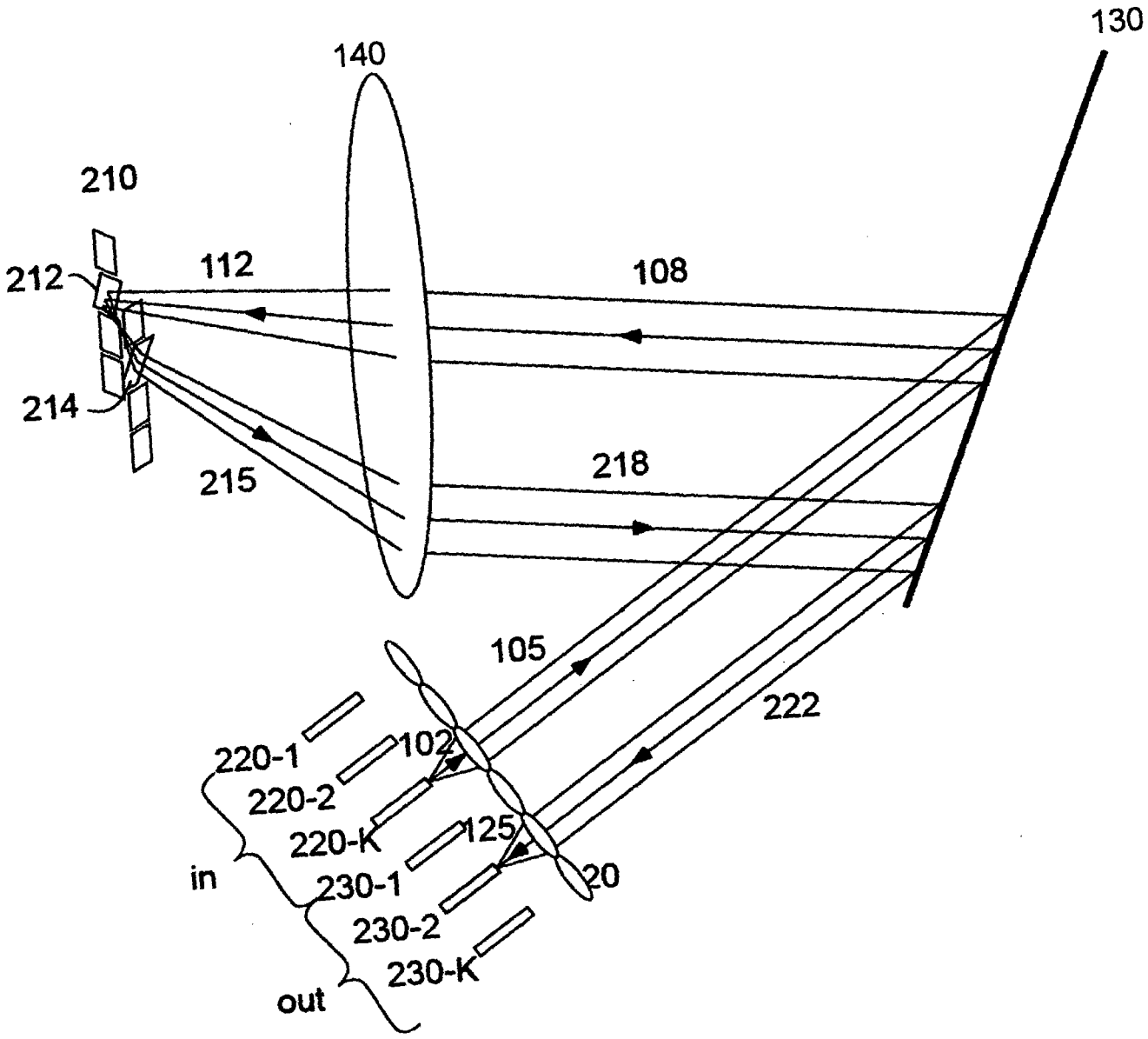


FIG. 2 (Prior Art)

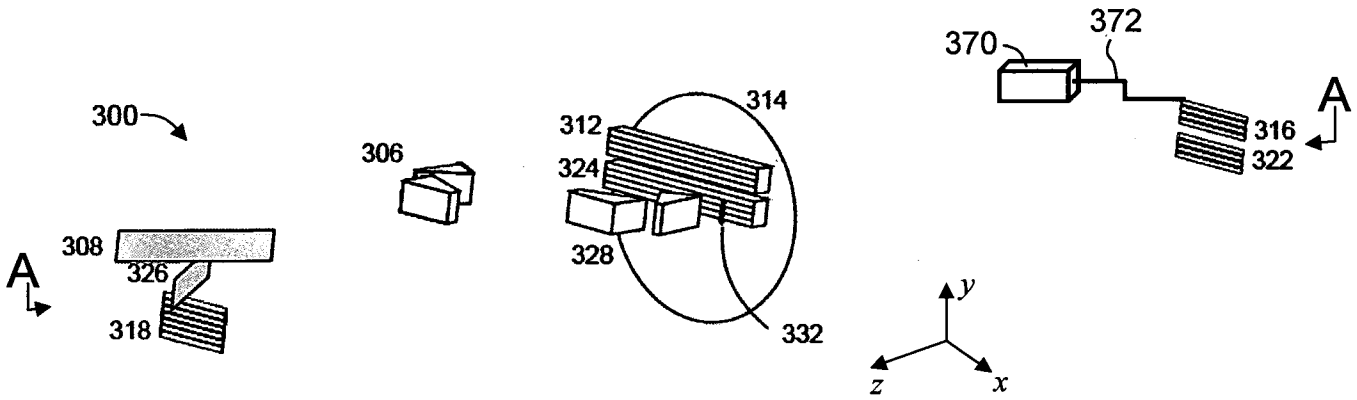

300
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332
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316
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308
326
318
y
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x

FIG. 3A

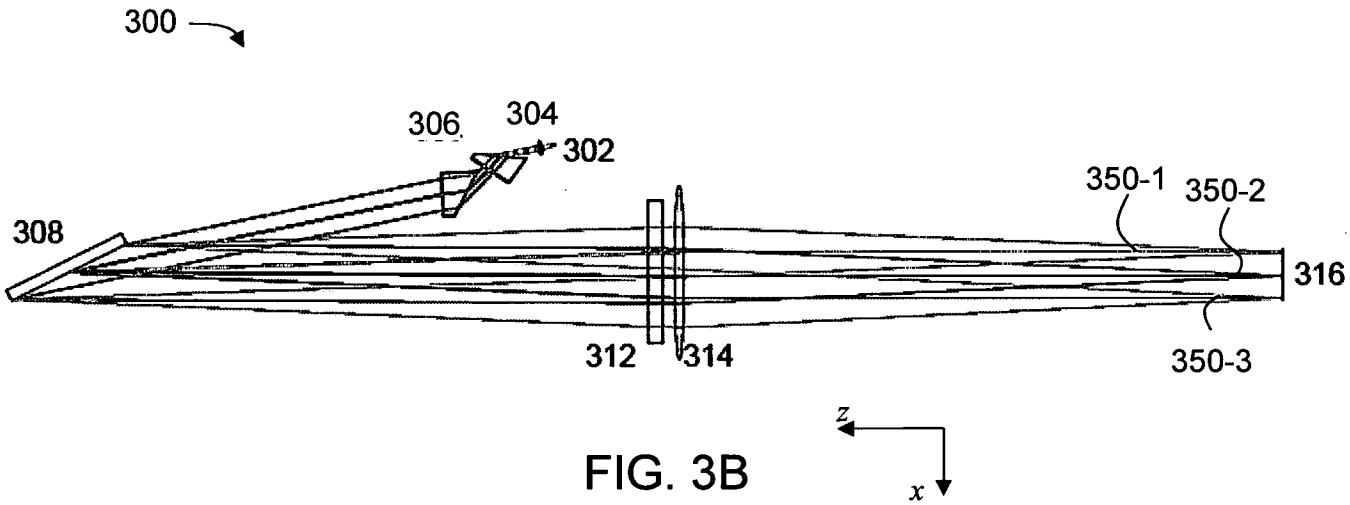

300
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350-1
350-2
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314
350-3
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FIG. 3B

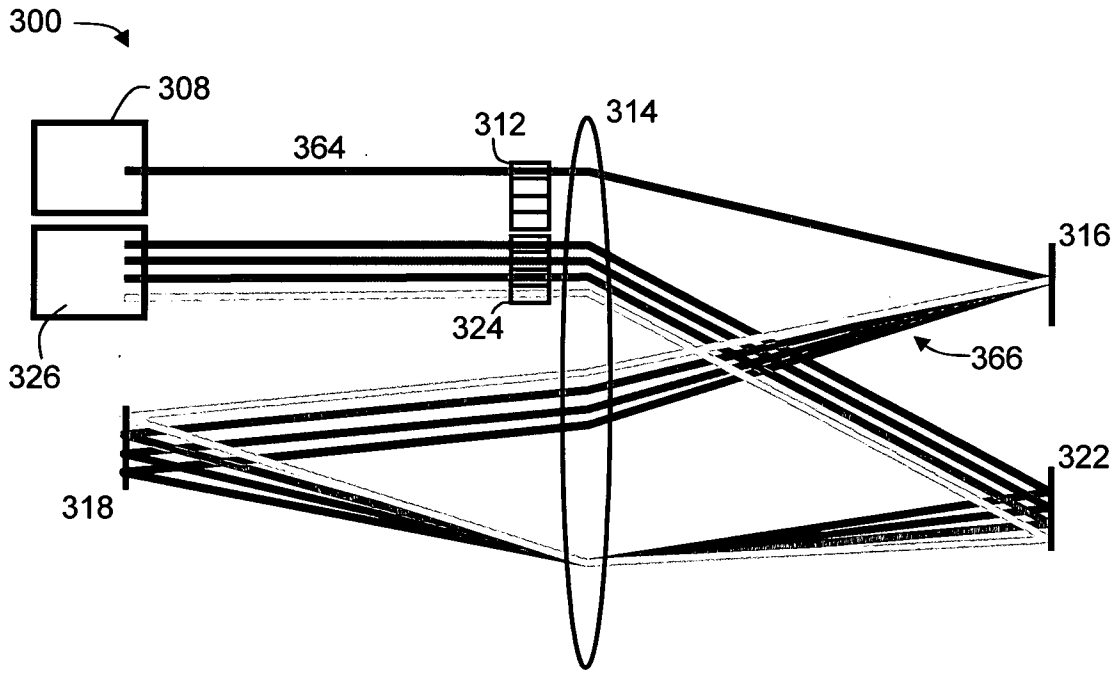
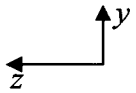

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318

FIG. 3C


y
z

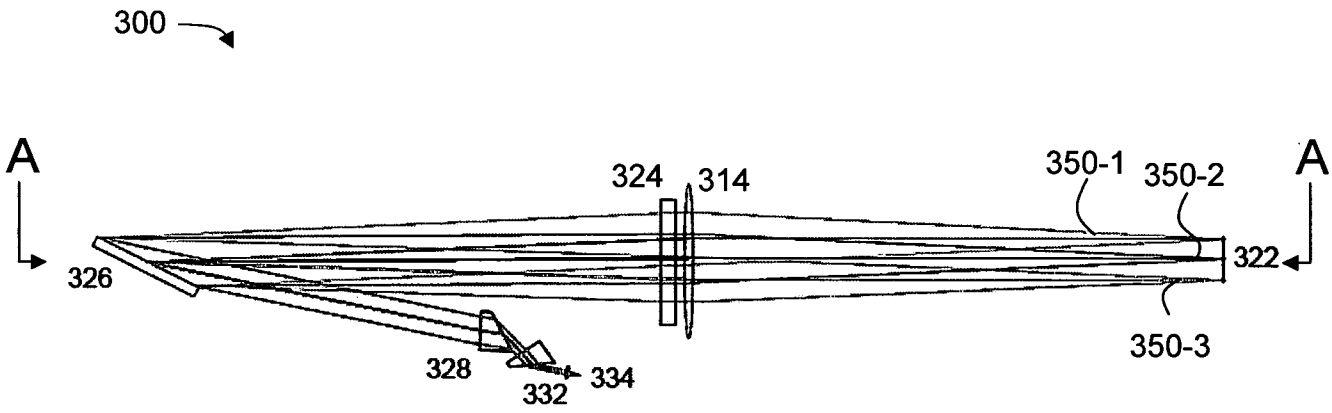
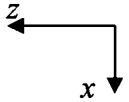

300
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A
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314
350-1
350-2
322
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328
334
332
350-3

FIG. 3D


z
x

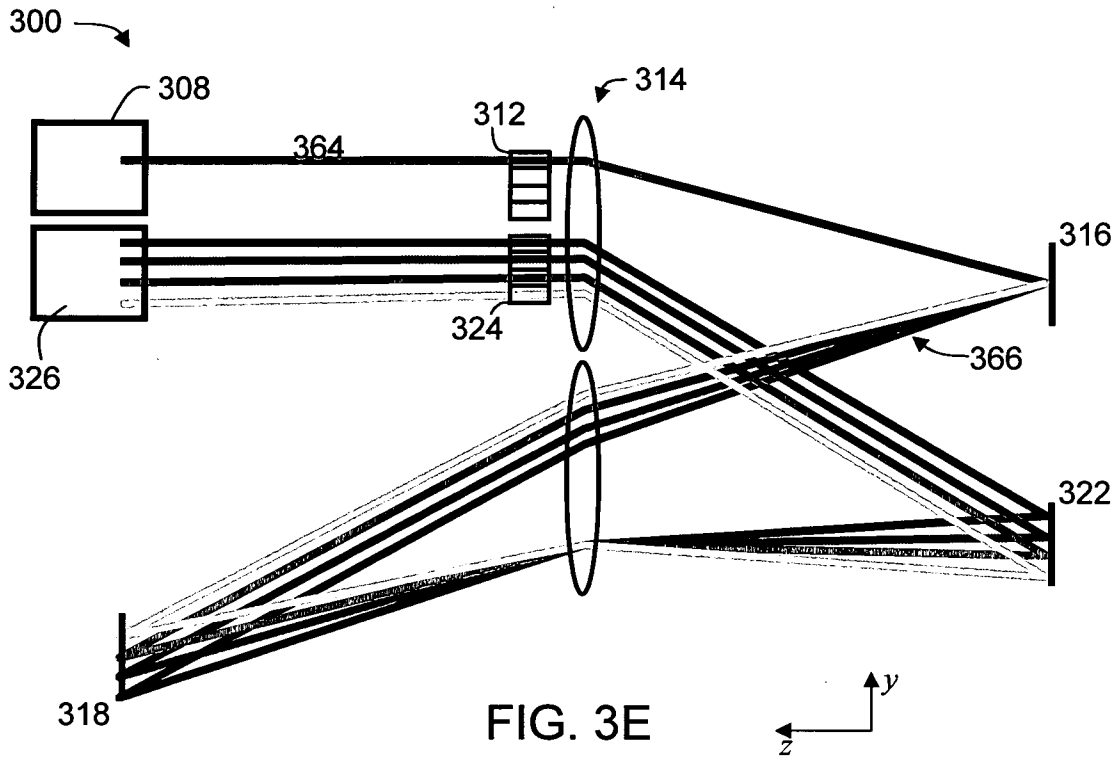

300
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y
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FIG. 3E

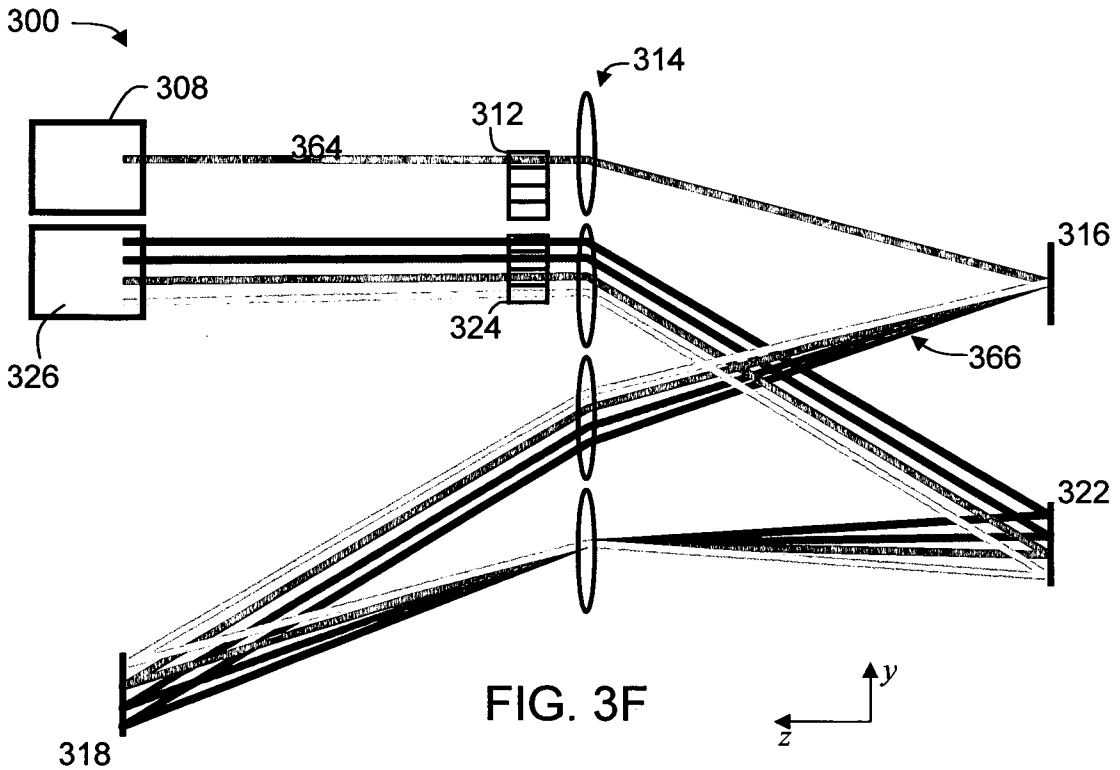

300
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326
366
322
318
y
z

FIG. 3F

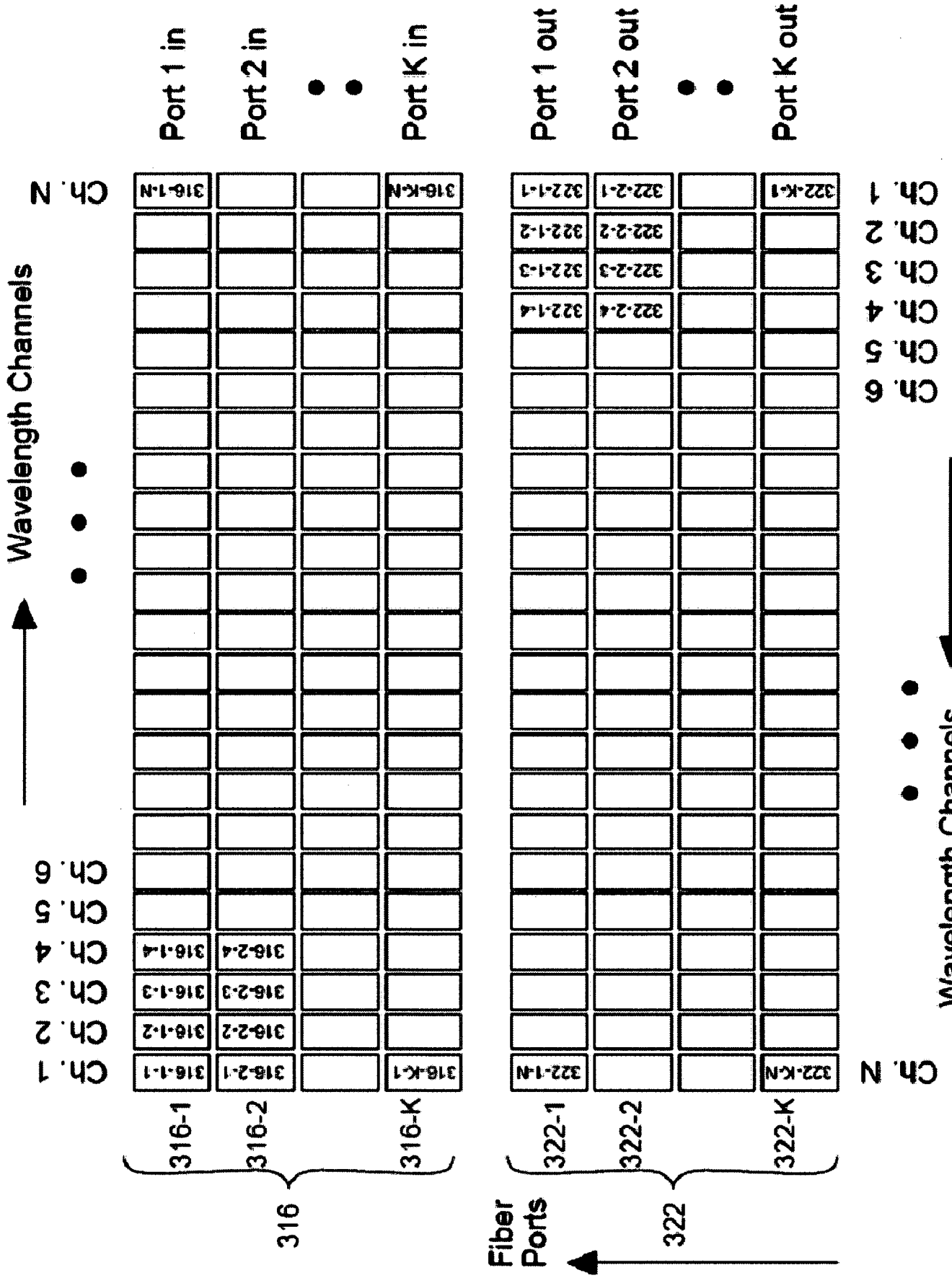

Port 1 in
Port 2 in
Port K in
Port 1 out
Port 2 out
Port K out
Wavelength Channels
Ch. 1
Ch. 2
Ch. 3
Ch. 4
Ch. 5
Ch. 6
Ch. N
316-1
316-2
316-K
322-1
322-2
322-K
316
322
Fiber Ports

Figure 4

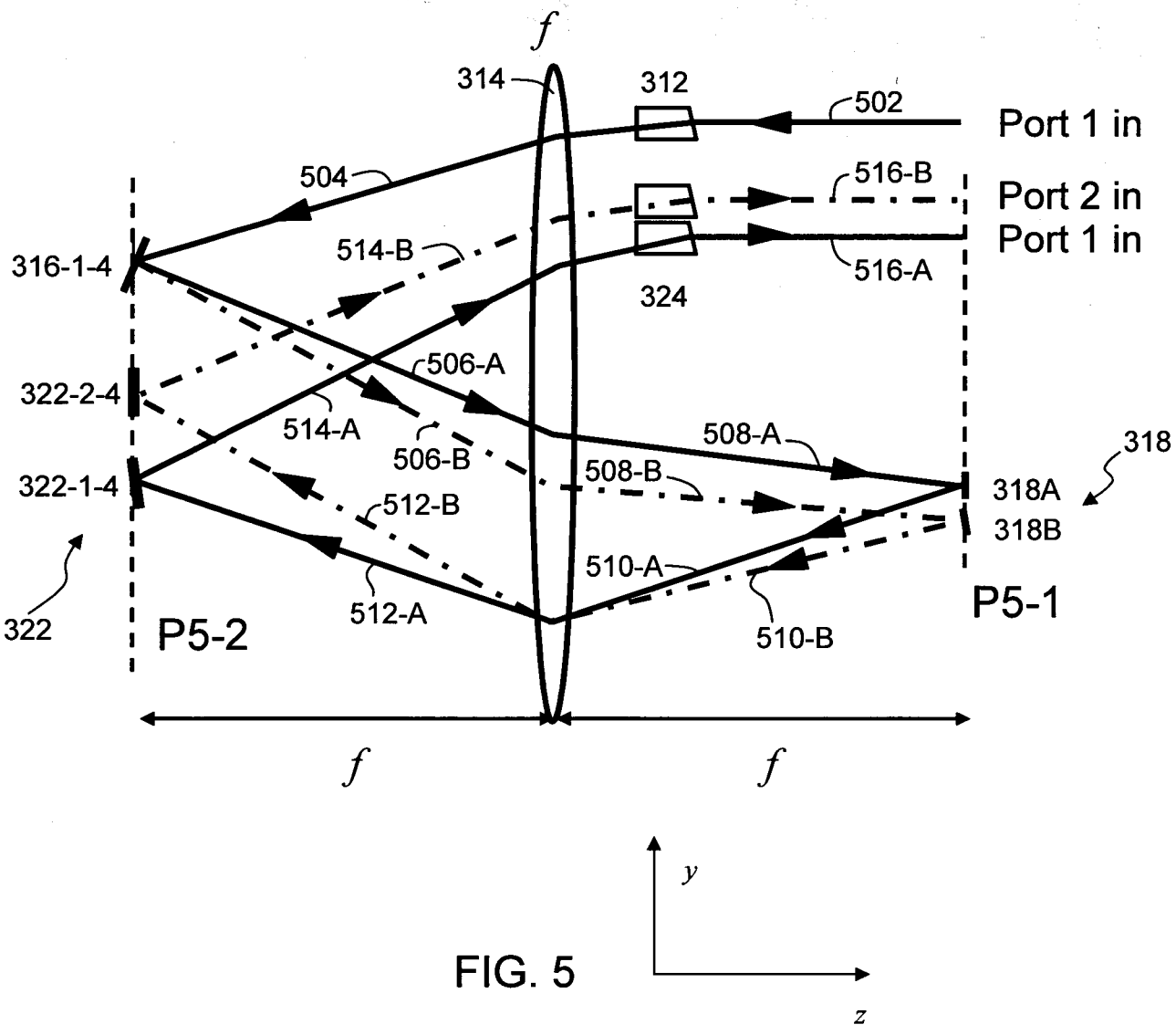
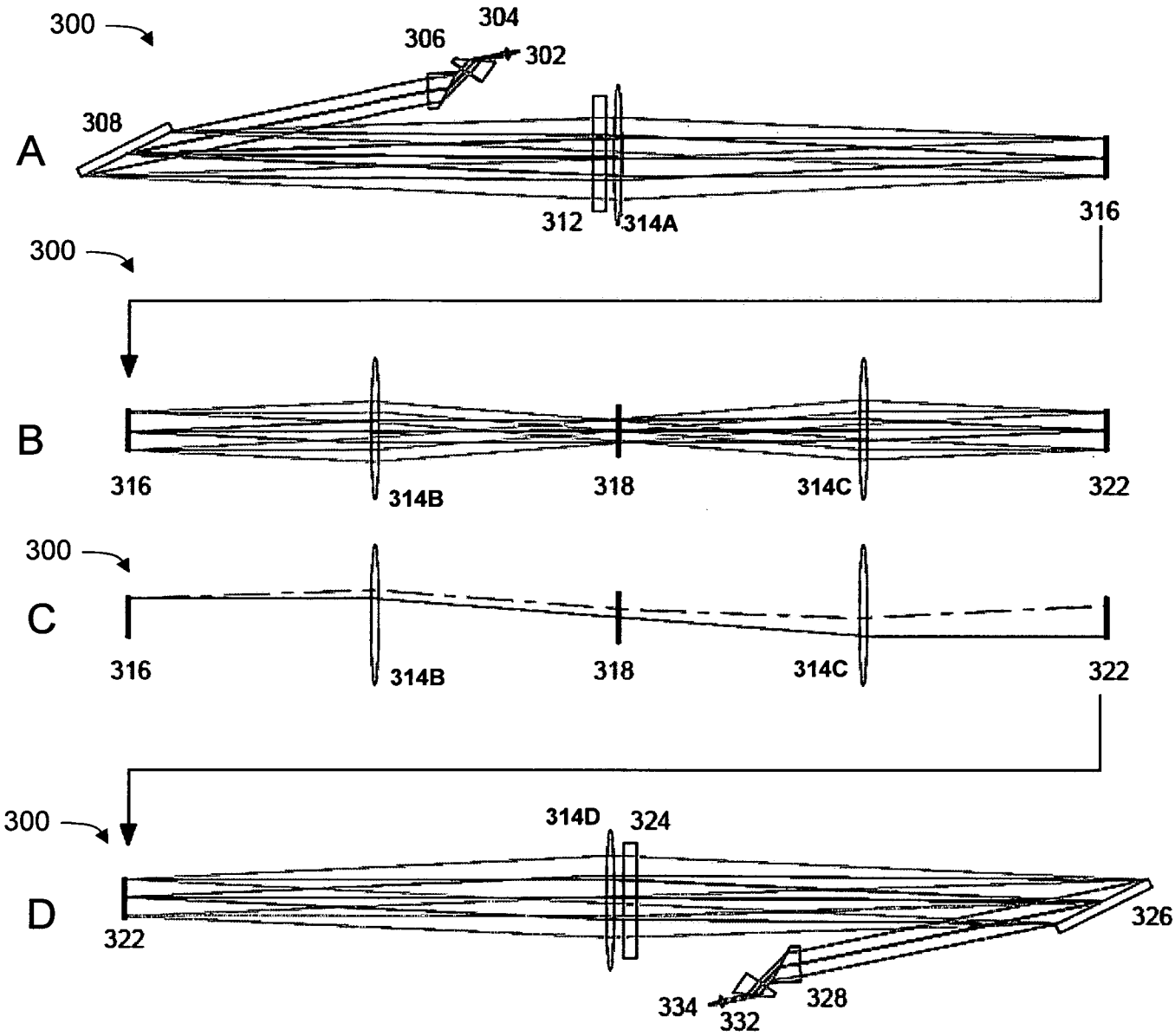

f
314
312
502
Port 1 in
504
516-B
Port 2 in
514-B
Port 1 in
316-1-4
516-A
324
506-A
322-2-4
514-A
506-B
508-A
318
322-1-4
508-B
318A
512-B
318B
510-A
322
P5-2
512-A
510-B
P5-1
f
f
y
z

FIG. 5


300
304
306
302
308
A
312
314A
316
300
B
316
314B
318
314C
322
300
C
316
314B
318
314C
322
300
314D
324
D
322
326
334
332
328

FIGs. 6A-D

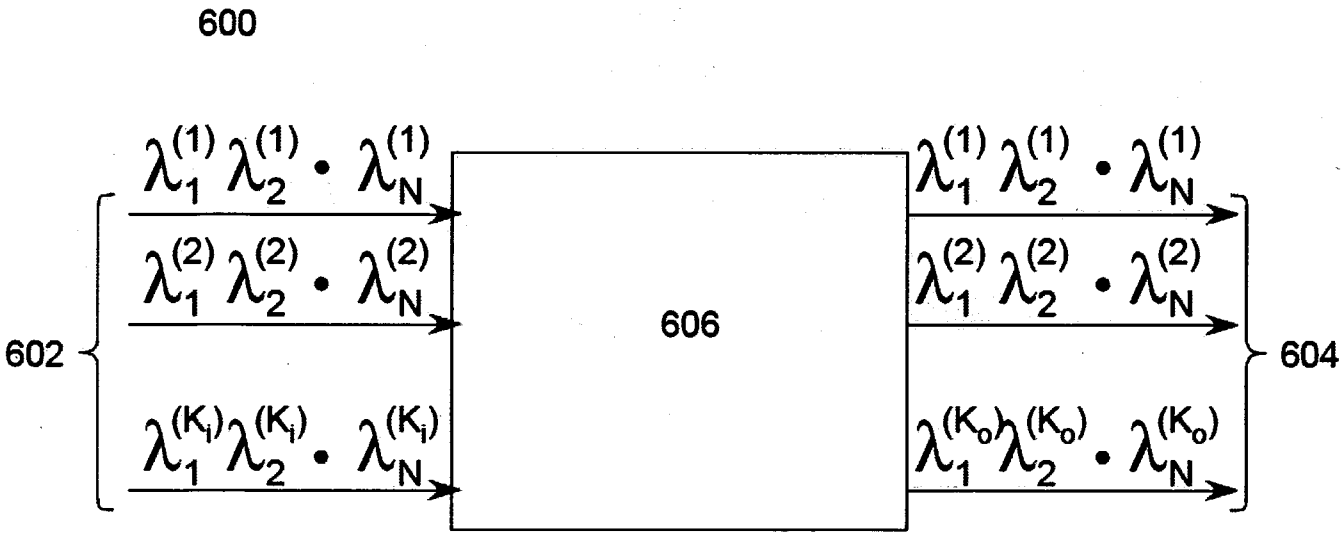

600
$\lambda_1^{(1)}\lambda_2^{(1)}\bullet\lambda_N^{(1)}$
$\lambda_1^{(2)}\lambda_2^{(2)}\bullet\lambda_N^{(2)}$
$\lambda_1^{(K_i)}\lambda_2^{(K_i)}\bullet\lambda_N^{(K_i)}$
602
606
$\lambda_1^{(1)}\lambda_2^{(1)}\bullet\lambda_N^{(1)}$
$\lambda_1^{(2)}\lambda_2^{(2)}\bullet\lambda_N^{(2)}$
$\lambda_1^{(K_o)}\lambda_2^{(K_o)}\bullet\lambda_N^{(K_o)}$
604

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2010/000873

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B6/35
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	JP 2006 284740 A (FUJITSU LTD) 19 October 2006 (2006-10-19) * abstract; figures 4.1-4.2 -----	1-23
X	WO 2008/118451 A1 (TREX ENTPR CORP [US]) 2 October 2008 (2008-10-02) figures 1-2b figure 12i -----	1-4, 10-23
X	WO 03/019974 A1 (MARCONI COMM SPA [IT]; CERATO UGO [IT]) 6 March 2003 (2003-03-06) page 6 - page 9 -----	1-23
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 February 2011	04/03/2011

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Bourhis, J

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2010/000873

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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