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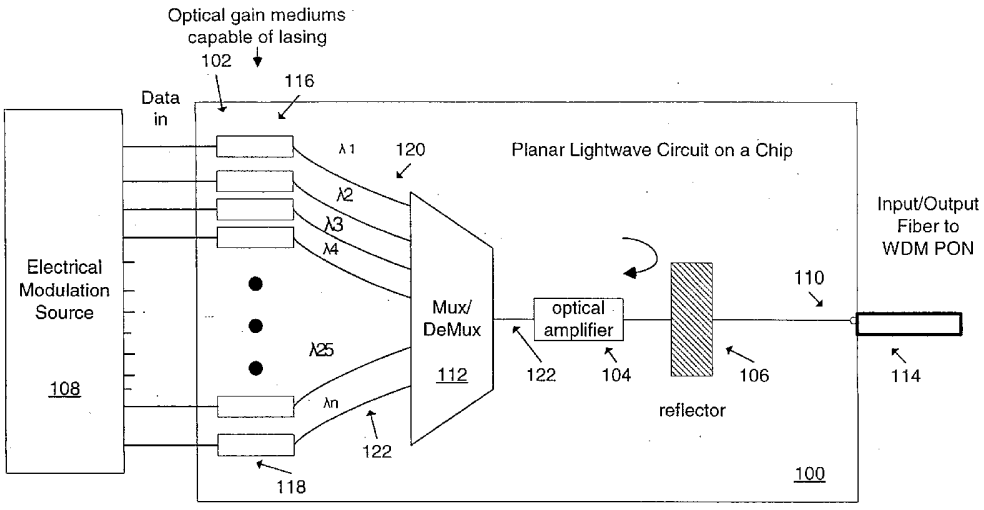
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(54) Title: INTEGRATION OF LASER SOURCES AND DETECTORS FOR A PASSIVE OPTICAL NETWORK



(57) Abstract: Various methods and apparatuses are described in which an array of optical gain mediums capable of lasing are contained in a single integral unit. The array may contain four or more optical gain mediums capable of lasing. Each optical gain medium capable of lasing supplies a separate optical signal containing a band of wavelengths different than the other optical gain mediums capable of lasing in the array to a first multiplexer/demultiplexer. A connection for an output fiber exists to route an optical signal to and from a passive optical network.

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INTEGRATION OF LASER SOURCES AND DETECTORS FOR A PASSIVE OPTICAL NETWORK

FIELD

[001] Embodiments of the invention generally relate to optical networks. More particularly, an aspect of an embodiment of the invention relates to array of optical gain mediums capable of lasing contained in a single integral unit.

BACKGROUND

[002] Fiber optic systems typically transmit optical signals back and forth between a central office to a multitude of residential and business locations. Each residential or business location may be assigned a narrow bandwidth of wavelengths or channel within an overall optical signal to communicate with and from the central office. As the number of subscribers using that fiber optical system increases, the amount of components in the central office may increase to transmit and receive optical signals from those subscribers.

SUMMARY

[003] Various methods and apparatuses are described in which an array of optical gain mediums capable of lasing contained in a single integral unit. The array may contain four or more optical gain mediums capable of lasing. Each optical gain medium capable of lasing supplies a separate optical signal containing a band of wavelengths different than the other optical gain mediums capable of lasing in the array to a first multiplexer/demultiplexer. A connection for an output fiber exists to route an optical signal to and from a passive optical network.

[004] Other features and advantages of the present invention will be apparent from the accompanying drawings and from the detailed description that follows below.

BRIEF DESCRIPTION OF THE DRAWINGS

[005] The present invention is illustrated by example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

Figure 1 illustrates a block diagram of an embodiment of an array of multiple wavelength optical gain mediums capable of lasing.

Figure 2 illustrates a block diagram of an embodiment of an array of four or more distributed feedback lasers in an integral unit. The array of four or more distributed feedback lasers 202 each coupled to a power splitter 212.

Figure 3 illustrates a block diagram of an embodiment of an array of lasers and a broadband light source to supply an optical signal to each of the lasers all contained in an integral unit.

Figure 4 illustrates a block diagram of an embodiment of an array of four or more optical receivers and a multiplexer/demultiplexer integrated in to a single integral unit.

Figure 5 illustrates a block diagram of an embodiment of an array of optical gain mediums capable of lasing and an array of optical receivers contained within an integral unit.

Figure 6 illustrates a block diagram of an embodiment of an array of lasers and an array of optical receivers in an integral unit..

DETAILED DISCUSSION

[006] In general, various methods and apparatuses are described in which an array of optical gain mediums capable of lasing and an array of optical receivers are contained in a single integral unit. The array may contain four or more optical gain mediums capable of lasing. Each optical gain medium capable of lasing supplies a separate optical signal containing a band of wavelengths different than the other optical gain mediums capable of lasing in the array to a first multiplexer/demultiplexer. Similarly, a second multiplexer/demultiplexer may route optical signals to the array of optical receivers. A connection for an output fiber exists to route an optical signal to and from a passive optical network.

[007] Figure 1 illustrates a block diagram of an embodiment of an array of multiple wavelength optical gain mediums capable of lasing. The planar lightwave circuit 100 may contain an array of four more optical gain mediums capable of lasing 102, such as lasers, a multiplexer/demultiplexer 112, an optical amplifier 104, a broadband wavelength reflector 106, an electrical modulation source 108, a connection 110 to an output fiber, and an output fiber 114 going to a wavelength-division-multiplexed passive optical network.

[008] Multiple optical gain mediums capable of lasing 102, such as a first gain medium 116 through an Nth gain medium 118, may exist in the planar light circuit 100. Each gain medium 102 supplies an optical signal having a narrow band of wavelengths (λ) different than the other gain mediums. Each of the gain mediums 102 couples to it's own port on the multiplexer/demultiplexer 112. The broadband wavelength reflector 106 couples to the output of the

multiplexer/demultiplexer 112. The wavelength reflector 106 routes a portion of each optical signal as regenerative feedback through the multiplexer/demultiplexer 112 to the gain medium 102 that supplied the optical signal.

[009] The modulation source 108 may supply a data signal to the gain medium array 102 to directly modulate the gain mediums in that array. The electrical modulation source 108, by directly supplying the data to a particular gain medium, directly modulates that gain mediums capable of lasing. For example, the modulation source 108 may directly modulate the first gain medium capable of lasing 116. The data signal is amplified by the first gain medium capable of lasing 116 at a band of wavelengths around approximately one or more of its cavity modes. The first gain medium capable of lasing 116 routes the modulated signal to a first input 120 of the multiplexer/demultiplexer 112.

[0010] The multiplexer/demultiplexer 112 routes the modulated signal to the wavelength reflector 106. The wavelength reflector 106 routes a portion of the modulated signal as regenerative feedback back through the multiplexer/demultiplexer 112 to the first gain medium capable of lasing 116 that supplied that modulated signal. The modulated signal and the reflected portion of the modulated signal reinforce each other, in phase, at a resonant frequency of the first gain medium capable of lasing 116. The modulated signal and the reflected portion of the modulated signal are also amplified by the first gain medium capable of lasing 116.

[0011] The first gain medium capable of lasing 116 then transmits the reinforced modulated signal through the multiplexer/demultiplexer 112 and a portion of that reinforced modulated signal passes through the wavelength reflector 106 to the connection 110 to the output fiber. Also, as described above, the wavelength reflector 106 reflects a portion of that reinforced modulated signal back through the multiplexer/demultiplexer 112 to the first gain medium. This regenerative amplification of a narrow band occurs for each of the gain mediums capable of lasing 102. Each of the gain mediums capable of lasing 102 amplifying its own distinct narrow band of wavelengths.

[0012] The multiplexer/demultiplexer 112 acts as a narrow band filter to define the band of wavelength developed by the first gain medium capable of lasing 116. A natural characteristic of the multiplexer/demultiplexer 112 is to pass a different band of wavelengths on each of its outputs. For example, the first output may pass the band of wavelengths from 1530 to 1531 nanometers (nm). The second output may pass the band of wavelengths from 1531 to 1532 nm. Therefore, the multiplexer/demultiplexer 112 creates a narrow band of wavelengths supplied back to each gain medium capable of lasing 102. Accordingly, each gain medium capable of lasing 102 develops and amplifies a resonant wavelength within that band of wavelengths corresponding to a cavity mode of the gain medium. When the amplified band of wavelengths is reinforced with the reflected modulated signal, then the gain medium generates an optical signal of sufficient power to transmit over the passive optical network

to a subscriber's home. The reflected modulated signal provides resonant feedback to the gain medium capable of lasing.

[0013] The array of gain mediums capable of lasing 102, the multiplexer/demultiplexer 112, the optical amplifier 104, and the broadband wavelength reflector 106 can all be integrated into a single integrated unit. The integral unit may be a single substrate where all the components are grown on that single substrate. Alternatively, the integral unit may be two or more substrates made out of different materials and physically joined together.

[0014] The integral unit may use optical couplings other than optical fibers 122 in the optical path of the integral unit, such as air, lens arrays, or other such waveguides. Optical fibers typically require minimum bend radiuses and have other disadvantages that do not allow them to be used in a small compact space. However, optical couplings other than optical fibers 122 such as air or lens arrays may be used in a very small physical space to allow the communication of optical signals from one optical component to the next optical component. Further, in an integral unit where all of the gain mediums capable of lasing 102 are grown on the same substrate, the physical spacing between the gain mediums may be much shorter and smaller in physical size than if each of the gain mediums capable of lasing 102 was a fabricated as a discrete component and placed onto a common platform.

[0015] The substrate may be composed of Indium-Phosphide, where both active devices, such as the gain mediums capable of lasing, optical amplifiers, and modulators, can be integrated along with passive devices, such as the wave-

guides and multiplexer/demultiplexer. The substrate may also be composed from other materials, such as erbium-doped silica.

[0016] The array of gain mediums capable of lasing 102 may contain a large number of lasers, such as thirty-two or sixty-four lasers, acting as gain mediums, however the gain medium array may be as small as four or so laser sources acting as gain mediums capable of lasing. The optical gain medium capable of lasing may be a distributed feed back laser having its center wavelength set by a Bragg grating, a Fabry Perot laser diode, reflective semiconductor optical amplifiers, or similar laser grown on a single substrate. Each of the gain mediums capable of lasing has its own resonant wavelength and may be biased to operate above or below a lasing threshold.

[0017] The reflective semiconductor optical amplifiers may be gain mediums capable of lasing that have a highly reflective back facet, such as 90 %, with a front facet surface that is at a non-normal angle/non-perpendicular angle to the optical waveguide of the reflective semiconductor optical amplifier. The highly reflective back facet causes a greater amount of the injected wavelengths to be amplified and reflected back out of the reflective semiconductor optical amplifier. The front facet waveguide at a non-normal angle reduces the front facet reflectivity and allows a greater amount of gain to be provided by the reflective semiconductor optical amplifier before lasing action occurs in the reflective semiconductor optical amplifier on the injected wavelengths.

[0018] The optical amplifier 104 coupled to the multiplexer/demultiplexer 112 may amplify the optical signal coming from the multiplexer/demultiplexer 112 to

increase the overall gain and compensate for any insertion losses. A connection 110 to an output fiber exists in the output optical path of the multiplexer/demultiplexer 112 to a passive optical network. The passive optical network may have an optical splitting component such as a wave division multiplexer.

[0019] The gain mediums capable of lasing may be also continuous wave sources modulated by a separate array of modulators rather than directly modulated. Each continuous wave modulator connects to its own gain medium. The continuous wave modulator data modulates the continuous wave coming from the gain medium capable of lasing. The multiplexer/demultiplexer 112 may be an array wave-guide, an eschelle grating, or other similar technique to combine multiple unique wavelengths into a single wave-guide with a low signal power loss.

[0020] The wavelength reflector 106 may also be located at the output of the planar lightwave circuit 100 to provide regenerative optical feedback to each gain medium capable of lasing 102 in order to develop the resonant wavelength of that gain medium. The wavelength reflector 106 may be created by etching a vertical facet in the wave guide to create a change in the index of refraction, or be a Bragg grating, or maybe a coating at the edge of the substrate of the integral unit/interface with the output optical fiber with a reflective material to reflect a portion of the optical signal back to the multiplexer/demultiplexer 112, or may be a grating at the entrance of the optical fiber 114 pigtailed to the planar lightwave circuit 100.

[0021] The construction of the planar lightwave circuit 100 having an array of gain mediums capable of lasing resembles a distributed laser having an external cavity which can operate above or below the lasing threshold in order to develop or reinforce a multiple bands of wavelengths each having different wavelength bands. Thus, the construction of the distributed laser may be defined as from the gain mediums capable of lasing section through the multiplexer/demultiplexer 112 to the wavelength reflector 106 and back through the multiplexer/demultiplexer 112 to each gain medium section. Each laser in the gain medium section may or may not have a reflective front facet.

[0022] Figure 2 illustrates a block diagram of an embodiment of an array of four or more distributed feedback lasers in an integral unit. The array of four or more distributed feedback lasers 202 each coupled to a power splitter 212. Each distributed feedback laser in the array 202 supplies a separate optical signal containing a band of wavelengths different than the other distributed feedback lasers in that array to the power splitter. Each distributed feedback laser in the array 202 has it's center wavelength of that band of wavelengths set by a Bragg grating at the output of the distributed feedback laser. For example, the first distributed feedback laser 216 has the center wavelength of the band of wavelengths supplied from the laser set by the first Bragg grating 224 intermixed with the gain medium of the first distributed feedback laser 216. A semiconductor optical amplifier 204 may exist in an output optical path of the power splitter 212 to make up for the insertion losses caused by the power splitter 212. A connection 210 exists for an output fiber to route the optical signal

from the power splitter 212 or at least in the output optical path of the power splitter 212 to a wave-division-multiplexed passive optical network. The array of distributed feedback lasers 202 may be integrated onto a first substrate 226. The semiconductor optical amplifier 204, the power splitter 212, and the connection 210 may be integrated into a second substrate 228 that is joined to the first substrate 226 and that communicates optical signals in the optical path between the first substrate and the second substrate using optical couplings 222 such as air or lens arrays but not using optical fibers.

[0023] Thus, the active components may be fabricated on a first substrate 226 and the passive components may be fabricated on a second substrate 228 that are merged and physically joined together into an integral unit. The first substrate 226 as discussed may be silicon dioxide, indium phosphide, or similar substrate. Note, Distributed Bragg Reflector lasers, for example, can also be used to generate the optical signal containing the band of wavelengths instead of the distributed feedback lasers. The Distributed Bragg Reflector lasers may have Bragg grating at the output of the laser to set the center wavelength of that laser.

[0024] Figure 3 illustrates a block diagram of an embodiment of an array of lasers and a broadband light source to supply an optical signal to each of the lasers all contained in an integral unit. The integral unit may contain an array of four or more lasers such as Fabry-Perot laser diodes 302 on a first substrate 326. The integral unit may contain a second substrate 328 containing a

multiplexer/demultiplexer 312, a broadband light source 330, and a connection 310.

[0025] The broadband light source 330 supplies an optical signal containing a broad band of wavelengths, such as the C-band (1530 nm ~ 1560 nm), through an optical coupler 331 to the multiplexer/demultiplexer 312. Each of the Fabry-Perot laser diodes in the array 302 couples to it's own port on the multiplexer/demultiplexer 312. Each of the Fabry-Perot laser diodes in the array 302 receives a spectral slice of the optical signal from the broadband light source 330 in order to wavelength lock an output wavelength of that Fabry-Perot laser diode to within the bandwidth of the injected spectral slice. For example, the first Fabry-Perot laser diode 316 may receive a spectral slice of 1530 to 1531 nm. The first Fabry-Perot laser diode 316 then may reflect and amplify the spectral slice back out through the multiplexer/demultiplexer 312 to the connection 310. The connection 310 couples to an output fiber 314 in order to route an optical signal to the wavelength division multiplexing passive optical network.

[0026] All of the Fabry-Perot laser diodes in the array 302, the multiplexer/demultiplexer 312, the connection 310, and the broadband light source 330 are integrated into a compact integral unit. The broadband light source 330 may also be discrete from the integral unit. The broadband light source 330 may consist of two or more super luminescent diodes connected to supply orthogonal polarized signals, an erbium fiber that acts as a broadband light source, an erbium doped waveguide, a single super luminescent diodes connected to the integral unit with polarization persevering fiber, a single on chip

super luminescent diode, or other similar light emitting source. All of the components may be located in a single planar lightwave circuit.

[0027] Figure 4 illustrates a block diagram of an embodiment of an array of four or more optical receivers and a multiplexer/demultiplexer integrated in to a single integral unit. The integral unit may contain an array of four or more optical receivers 432, such as a first optical receiver 434 through an Nth optical receiver 436, an electrical processing chip 438 to process the received data signals $\lambda 1$ through λn, a multiplexer/demultiplexer 430, and a connection 410 to receive an input fiber from a wave-division-multiplexed passive optical network having a component to combine multiple optical signals coming from subscribers of that passive optical network. Each of the optical receivers in the array 432 may contain one or more photo detectors.

[0028] The integral unit containing the receivers 440 may be located at the central office where returning signals need to be locally processed. Note, the integral unit of the optical gain mediums capable of lasing may also be located at the central office where minimizing the space occupied by components is at a premium and all of the components may be compactly, centrally located. The first substrate 426 having the optical receivers array 432 may be composed of indium phosphide, gallium arsenide, silicon, or other similar semiconductor substrates. The first substrate 426 may be coupled in a planar lightwave circuit to the multiplexer/demultiplexer 430 on the second substrate 428. The electrical processing chip 438 containing the electrical processing components that process the signal from the optical receivers in the array 432 can also be on

another third substrate 442 made of silicon. The third substrate 442 may be coupled and physically joined to the first substrate 426. The substrates 426, 428 in the integral unit may communicate optical signals via wave-guides without optical fibers, such as the first non-optical fiber waveguide 422, the second non-optical fiber waveguide 423, and the third non-optical fiber waveguide 425. All of the substrates 426, 428, 442 may be fabricated as a single integral unit 440.

[0029] Figure 5 illustrates a block diagram of an embodiment of an array of optical gain mediums capable of lasing and an array of optical receivers contained within an integral unit. The array of optical gain mediums capable of lasing 550 may generate N number of individual bands of wavelengths. Each optical gain medium capable of lasing communicates an optical signal across the passive optical network to a corresponding subscriber, such as the first subscriber location 552. The array of optical receivers 554 may receive N number of individual bands of wavelengths from those subscribers. For example, a first receiver may receive an optical signal generated from the first subscriber location 552. The array of optical receivers 554 may include the same number of receivers as gain mediums capable of lasing in the array of gain mediums capable of lasing. For example, a first array of optical receivers 554 may contain thirty-two receivers and a first array of gain mediums capable of lasing may contain thirty-two gain mediums capable of lasing. The array of optical gain mediums capable of lasing 550 and the array of optical receivers 554 may be on a single substrate or may be on separate substrates joined to each other in the integral unit 556.

[0030] Each of the arrays 550, 554 may contain a multiplexer/demultiplexer or a power splitter to distribute the signals coming from and going to the passive optical network 558. On each of the arrays 550, 554, the components may be grown on that substrate to make the spacing between individual components as small as possible. The integral unit 556 may also contain a band splitting filter 560 and a broadband light source. The broadband light source 562 may also be exterior to the integral unit 556.

[0031] The broadband light source supplies an optical signal containing a broadband of wavelengths, such as the L-band, to the multiplexer/demultiplexer in the optical gain medium array 550. As discussed above, the multiplexer/demultiplexer routes a narrow band optical signals to each of the optical gain medium in the array 550 to wavelength lock the output wavelength of the optical gain medium capable of lasing within the bandwidth of the injected spectral slice.

[0032] The array of optical gain mediums capable of lasing 550 through its multiplexer/demultiplexer may send a single optical signal consisting of, for example, thirty-two individual bands of wavelengths contained within the C-band across the passive optical network 558 to a remote multiplexer/demultiplexer 564. The remote multiplexer/demultiplexer 564 may distribute the individual band of wavelengths from each optical gain mediums capable of lasing in the array 550 to a corresponding subscriber location. For example, the remote multiplexer/demultiplexer 564 may distribute the band of wavelengths from the second optical gain medium capable of lasing to the location of a second

subscriber 566. The remote multiplexer/demultiplexer 564 may distribute all of the N number of individual band of wavelengths from the array of optical gain mediums capable of lasing 550 in this manner to corresponding subscriber locations.

[0033] The group of users/subscribers may also transmit optical signals back to the array of receivers 554 in central office in the L-band (1570 nm ~ 1600 nm). The band-splitting filter 560 separates the L-band wavelengths from the C-band wavelengths. The band-splitting filter 560 routes the L-band signals to the array of optical receivers 554 and the C-band wavelengths from the broad light source to the array of optical gain mediums capable of lasing 550.

[0034] The transmitters in the central officer may use a first band such as the L-band to communicate information to subscribers and the transmitters at the subscribers use another band such as the C-band to communicate information to the central office. Accordingly, the optical gain mediums capable of lasing may generate individual optical signals in different band of wavelengths such as the O-band (around 1300 nm), S-band (around 1480 nm), etc.

[0035] A second multiplexer/demultiplexer in the optical receiver array 554 routes individual signals in the C-band to each of the corresponding optical receivers. Each of the optical receivers receives a separate signal containing a band of wavelengths different than the other optical receivers in the array 554. The array of optical gain mediums capable of lasing 550 and the array of optical receivers 554 may be positioned at set angles such as approximately 90 degrees and approximately 180 degrees with respect to the band splitting filter 560 to

route optical signals with waveguides, lenses or in air and without using optical fibers.

[0036] Figure 6 illustrates a block diagram of an embodiment of an array of lasers and an array of optical receivers in an integral unit. The array of lasers 650 and the array of receivers 664 may each couple to a lens array 670, 672. The integral unit 676 may contain the array of lasers 650, a band splitting filter 660, a multiplexer/demultiplexer 674, the array of optical receivers 664, a first lens array 670, a second lens array 672, and a connection 610 to a passive optical network. The multiplexer/demultiplexer 674 routes signals to and from the array of receivers 664 and the array of lasers 650. The multiplexer/demultiplexer 674 routes signals back and forth from the passive optical network. The array of optical receivers 664 is put close to the multiplexer/demultiplexer 674 so that the angle of the reflected C-band wavelengths from the band splitting filter 660 remains at a small angle. The array of optical receivers 664 may be positioned at set angles such as 45 degrees or less to route optical signals with air and the second lens array 672. The band splitting filter 660 coated with a standard dielectric coating may split different wavelength, bands such as the C-band wavelengths and the L-band wavelengths.

[0037] The fabrication of the array of optical receivers and lasers in a single integral unit may be accomplished in a more simple fashion by using a band-splitting filter reflecting optical signals to the arrays at a small angle. If the laser array is operated in the O-band, around 1300 nanometers, rather than the L-

band, then the reflected angle may be about 90° which can make the packaging easier by using a beam splitting prism. All of the configurations described above may be integrated into a passive optical network. The passive optical network may or may not wavelength lock gain mediums capable of lasing by injecting a narrow band Amplified Spontaneous Emission light into laser diodes acting as gain mediums capable of lasing.

[0038] In the forgoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention as set fourth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustration rather then a restrictive sense.

CLAIMS

We claim:

1. An apparatus, comprising:

an array of four or more optical gain mediums capable of lasing, each optical gain medium capable of lasing to supply a separate optical signal containing a band of wavelengths different from the other optical gain mediums capable of lasing in the array to a multiplexer/demultiplexer; and

a connection for an output optical fiber to route a first optical signal in an output optical path of the multiplexer/demultiplexer to a passive optical network, wherein the four or more optical gain mediums capable of lasing, the multiplexer/demultiplexer, and the connection are integrated into one planar lightwave circuit in an integral unit.

2. The apparatus of claim 1, wherein the integral unit comprises a single substrate.

3. The apparatus of claim 2, wherein the single substrate is comprised of Indium-Phosphide.

4. The apparatus of claim 1, wherein the integral unit comprises two or more substrates physically joined together that use optical couplings other than optical fibers in the optical paths of the integral unit.

5. The apparatus of claim 1, further comprising:

an optical amplifier coupled to the multiplexer/demultiplexer to amplify the first optical signal coming from the multiplexer/demultiplexer.

6. The apparatus of claim 1, further comprising:

a wavelength reflector coupled in an output optical path of the multiplexer/demultiplexer to supply feedback on the band of wavelengths supplied by each optical gain medium capable of lasing.

7. The apparatus of claim 6, wherein the wavelength reflector is provided by an interface between the integral unit and the output optical fiber.

8. The apparatus of claim 1, wherein a first optical gain medium capable of lasing operates at below a lasing threshold to amplify a first band of wavelengths.

9. The apparatus of claim 1, wherein a first optical gain medium capable of lasing operates at above and below a lasing threshold to amplify a first band of wavelengths.

10. The apparatus of claim 1, wherein a first optical gain medium capable of lasing is a distributed feed back laser having its center wavelength set by a Bragg grating.

11. The apparatus of claim 1, wherein a first optical gain medium capable of lasing is a Fabry Perot laser diode.

12. An apparatus, comprising:

an array of four or more distributed feed back lasers, each distributed feed back laser to supply a separate optical signal containing a band of wavelengths different than the other distributed feedback lasers in the array to a power splitter; and

a connection for an output fiber to route a first optical signal in an output optical path of an optical power splitter to a wavelength-division-multiplexing passive optical network, wherein the four or more distributed feed back lasers, the optical power splitter, and the connection are integrated into a first substrate.

13. The apparatus of claim 12, wherein a first distributed feed back laser has its center wavelength set by a Bragg grating.

14. The apparatus of claim 12, further comprising:

a semiconductor optical amplifier in an output optical path of the power splitter.

15. A method, comprising:

fabricating an array of four or more optical gain medium capable of lasing and a multiplexer/demultiplexer in an integral unit, wherein each optical gain medium capable of lasing is configured to supply a separate optical signal containing a band wavelengths different than the other optical gain medium capable of lasing to a wavelength-division-multiplexing passive optical network.

16. The method of claim 15, further comprising:

fabricating an array optical receivers, wherein each optical receiver to receive a separate optical signal containing a band wavelengths different than the other optical receivers in the array into that integral unit.

17. The method of claim 15, further comprising:

fabricating optical couplings other than optical fibers to communicate all of the optical signals within the integral unit.

18. An apparatus, comprising:

an array of four or more reflective semiconductor optical amplifiers;

a multiplexer/demultiplexer;

a broadband light source to supply an optical signal containing a first broad band of wavelengths to the multiplexer/demultiplexer, wherein each of the reflective semiconductor optical amplifiers to couple to its own port of the

multiplexer/demultiplexer to receive a spectral slice of the optical signal from the broadband light source in order to wavelength lock an output wavelength of that reflective semiconductor optical amplifiers within a bandwidth of the injected spectral slice; and

a connection for an output fiber to route a first optical signal in an output optical path of the multiplexer/demultiplexer to a wavelength-division-multiplexing passive optical network, wherein the four or more reflective semiconductor optical amplifiers, the multiplexer/demultiplexer, and the connection are integrated on a single substrate.

19. The apparatus of claim 18, further comprising:

a modulator to directly modulate the four or more reflective semiconductor optical amplifiers.

20. The apparatus of claim 18, wherein the multiplexer/demultiplexer is an arrayed waveguide.

21. An apparatus, comprising:

an array of four or more optical receivers, each optical receiver to receive a separate optical signal containing a band of wavelengths different than the other optical receivers in the array;

a multiplexer/demultiplexer to supply a signal to each of the optical receivers; and

a connection for an input fiber to route a first optical signal in an inbound optical path of the multiplexer/demultiplexer from a wavelength-division-multiplexing passive optical network, wherein the four or more optical receivers, and the multiplexer/demultiplexer are integrated into a single substrate and the four or more optical receivers, the multiplexer/demultiplexer, and the connection are integrated into an integral unit.

22. The apparatus of claim 21 further comprising:

a band splitting filter to route optical signals to the multiplexer/demultiplexer.

23. The apparatus of claim 21 further comprising:

an array of optical gain mediums capable of lasing to supply a band of wavelengths different than supplied by the other optical gain mediums capable of lasing, wherein the array of optical gain mediums capable of lasing are also contained in the integral unit.

24. A multiple wavelength optical light source, comprising:

an array of four or more gain mediums, wherein each gain medium supplies a band of wavelengths different than the other gain mediums;

a multiplexer/demultiplexer, wherein each of the four or more gain mediums couple to its own port of the multiplexer/demultiplexer; and

a wavelength reflector to route a portion of an optical signal as regenerative feed back through the multiplexer/demultiplexer to a first gain medium, wherein the multiplexer/demultiplexer filters to define the band of wavelengths developed by the first gain medium.

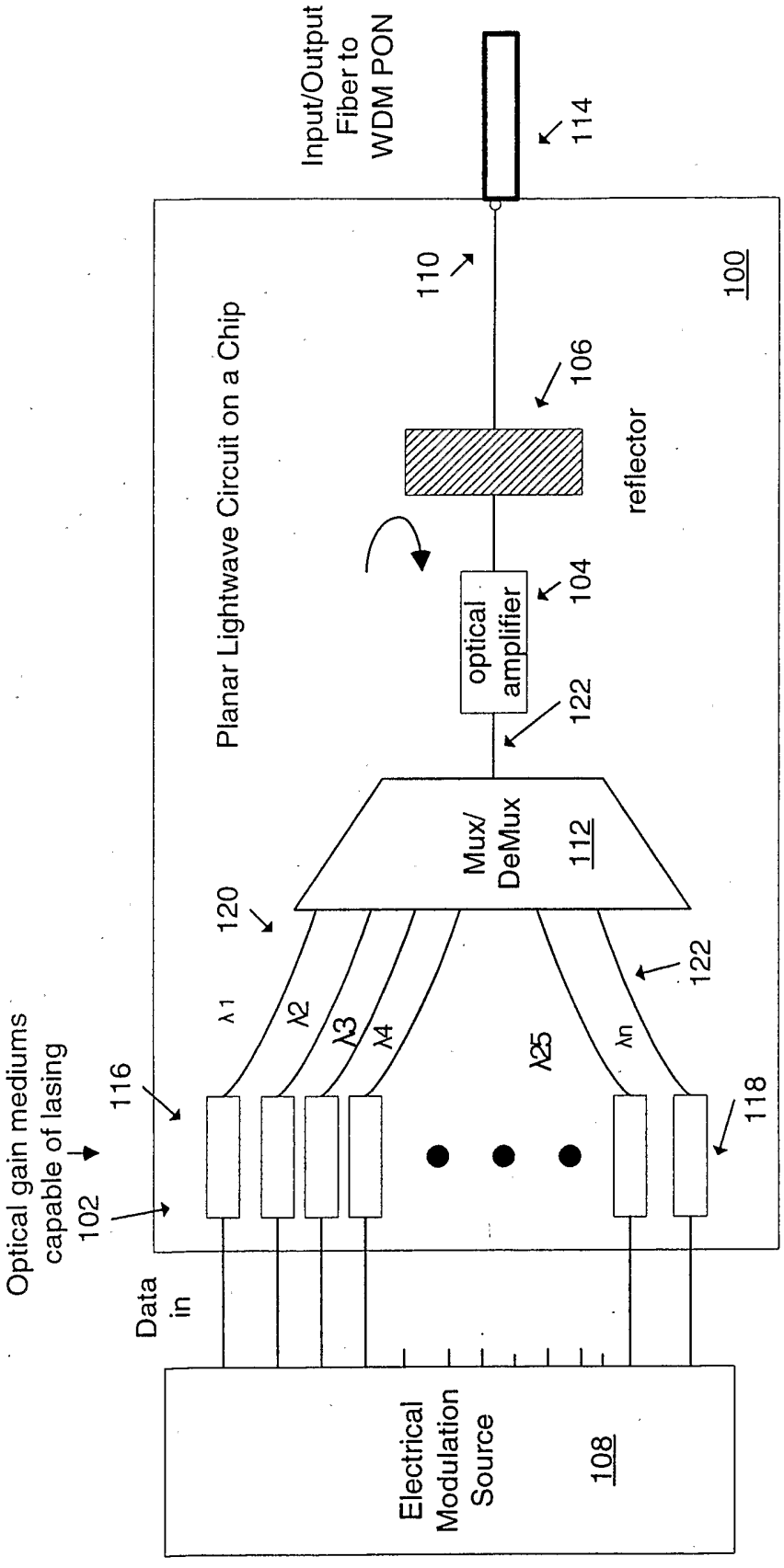

Input/Output Fiber to WDM PON
114
110
100
Planar Lightwave Circuit on a Chip
106
reflector
optical amplifier
104
122
Mux/ DeMux
112
120
λ1
λ2
λ3
λ4
λ5
λn
122
Optical gain mediums capable of lasing
102
116
118
Data in
Electrical Modulation Source
108

Figure 1

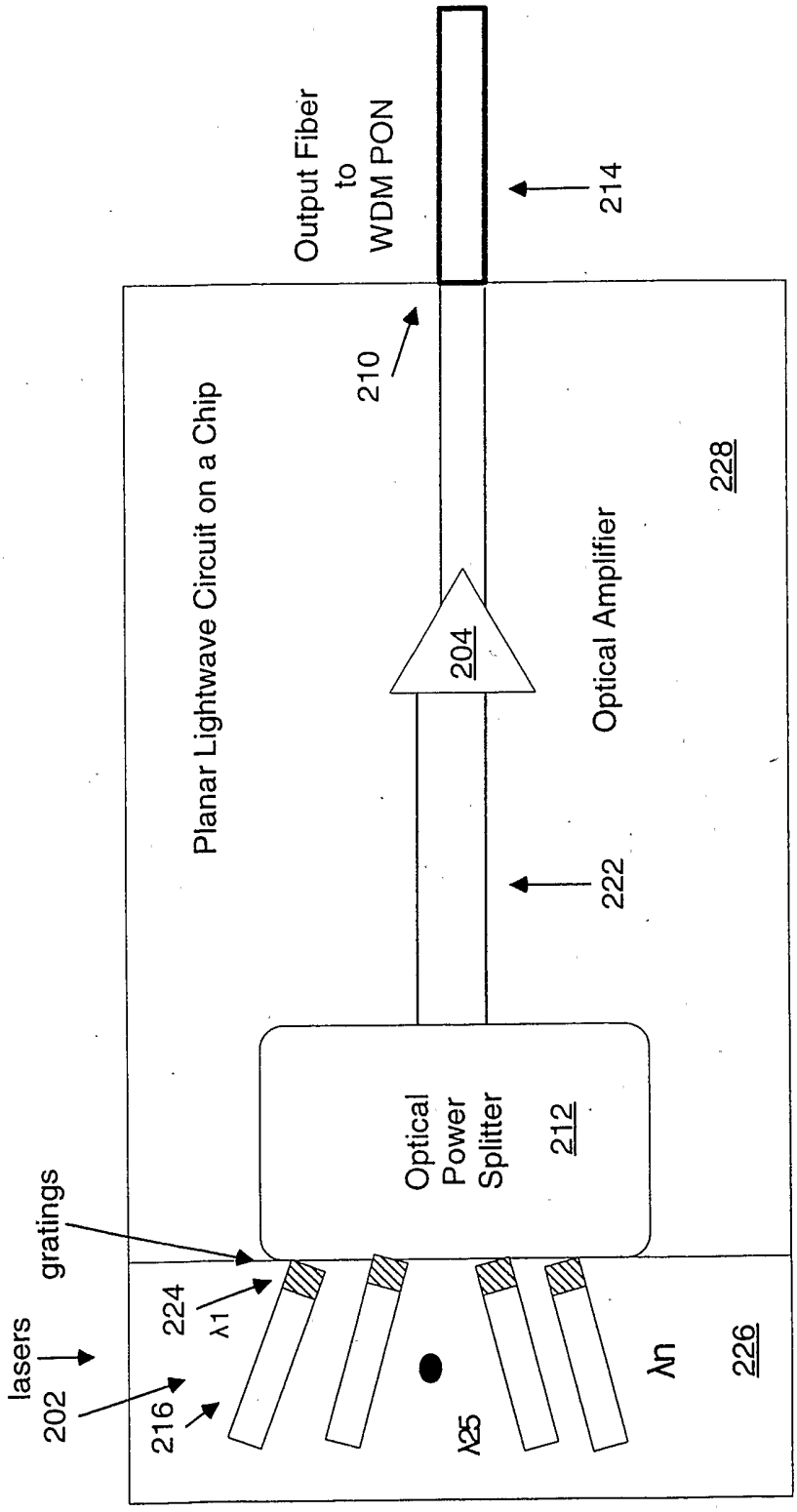

Output Fiber
to
WDM PON
214
210
Planar Lightwave Circuit on a Chip
228
Optical Amplifier
204
222
Optical
Power
Splitter
212
gratings
224
λ1
lasers
202
216
λ25
λn
226

Figure 2

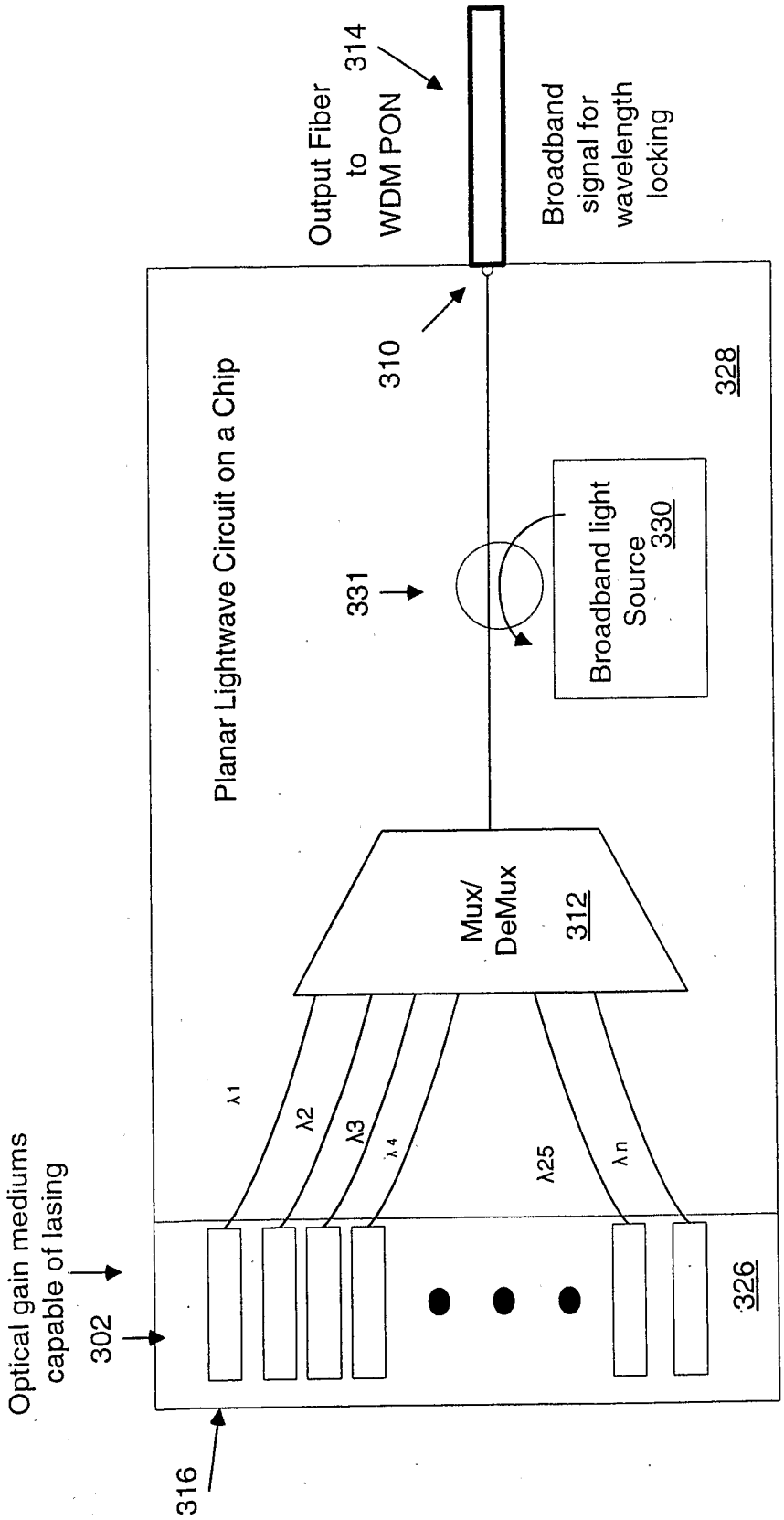

Output Fiber to WDM PON
314
Broadband signal for wavelength locking
310
328
Planar Lightwave Circuit on a Chip
331
Broadband light Source 330
Mux/ DeMux 312
λ1
λ2
λ3
λ4
λ25
λn
326
Optical gain mediums capable of lasing
302
316

Figure 3

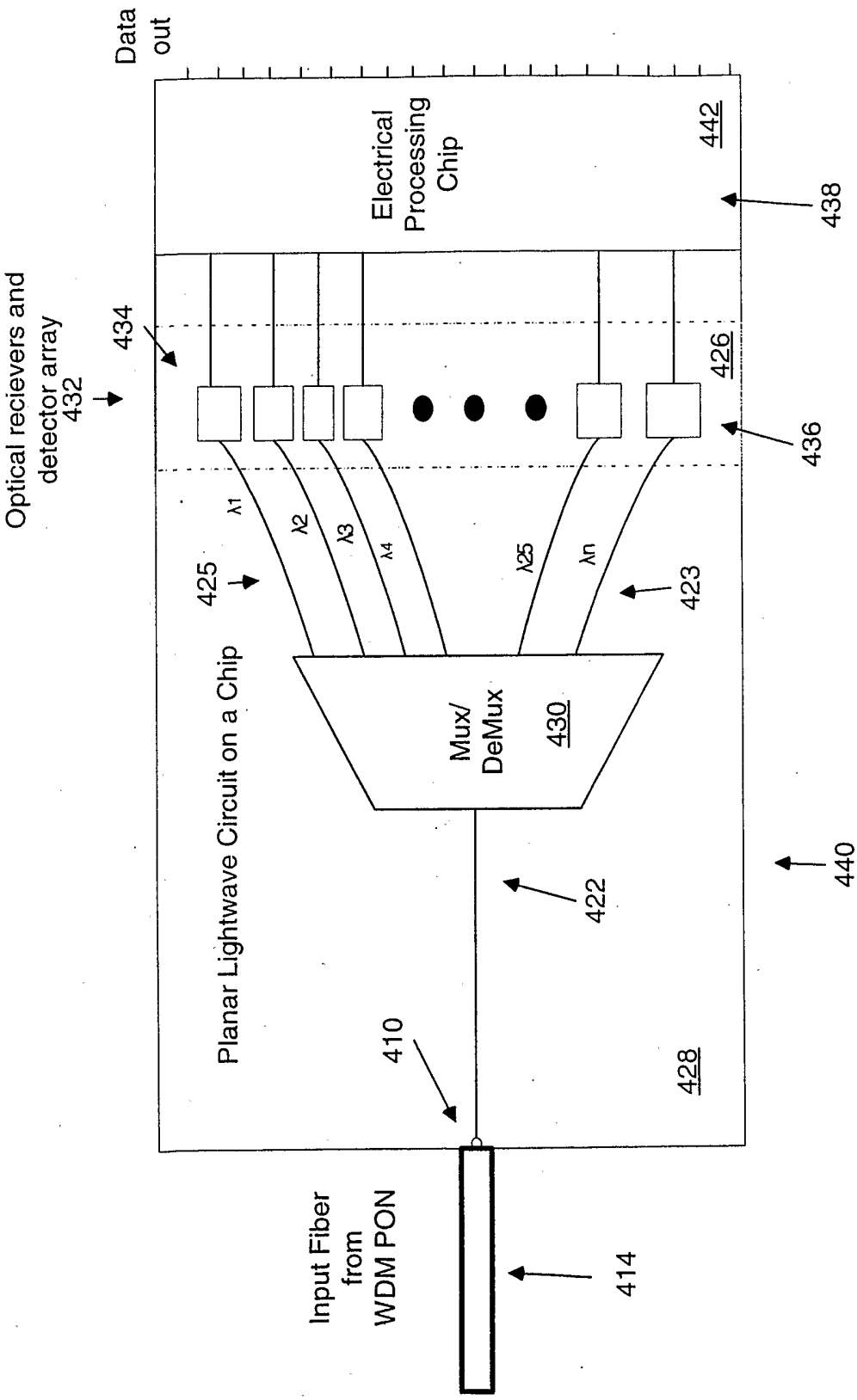

Data out
Electrical Processing Chip
442
438
Optical recievers and detector array
432
434
426
436
λ1
λ2
λ3
λ4
λ5
λn
425
423
Mux/ DeMux
430
Planar Lightwave Circuit on a Chip
422
440
410
428
Input Fiber from WDM PON
414

Figure 4

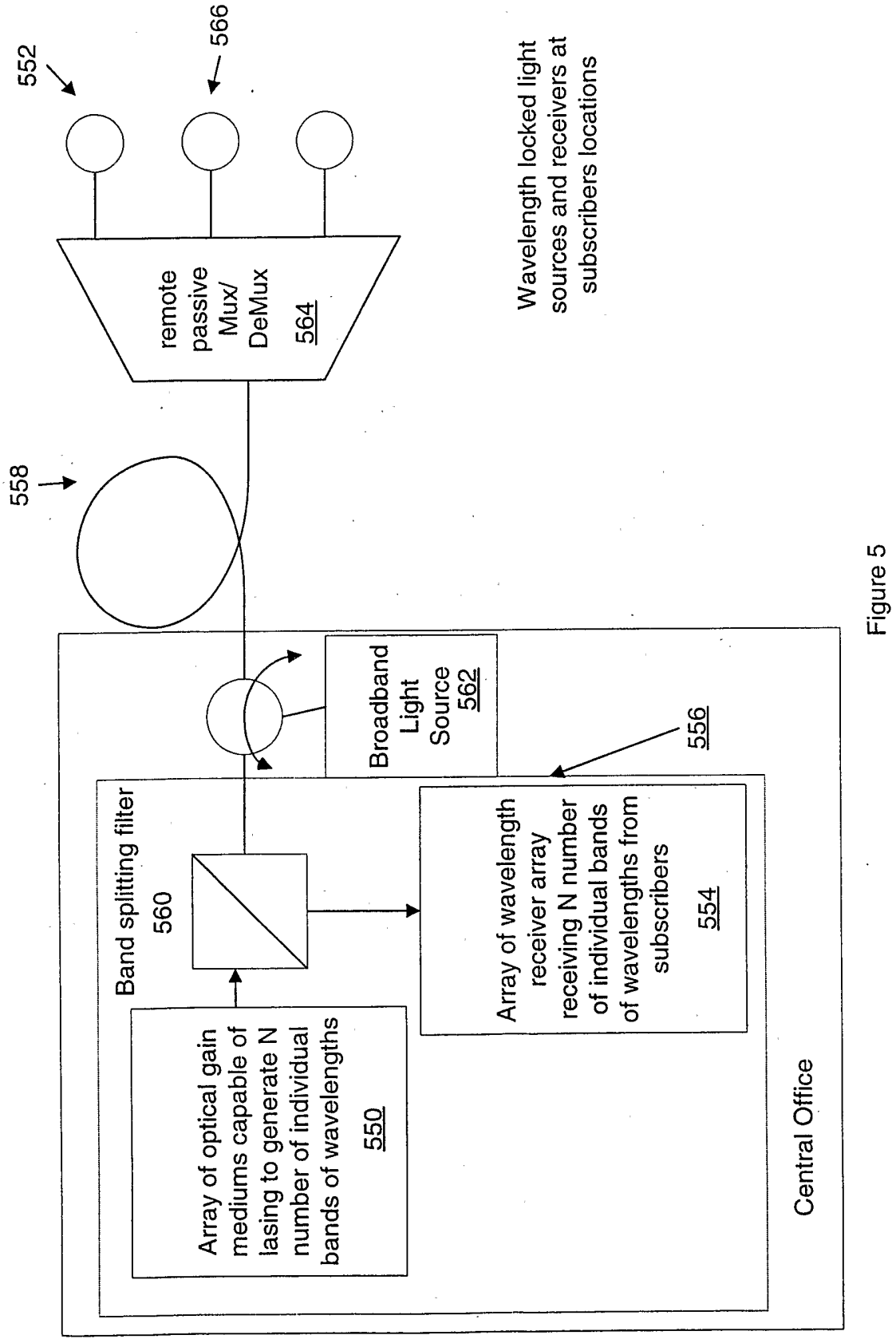

552
566
remote passive Mux/ DeMux 564
Wavelength locked light sources and receivers at subscribers locations
558
Broadband Light Source 562
556
Band splitting filter 560
Array of wavelength receiver array receiving N number of individual bands of wavelengths from subscribers 554
Array of optical gain mediums capable of lasing to generate N number of individual bands of wavelengths 550
Central Office

Figure 5

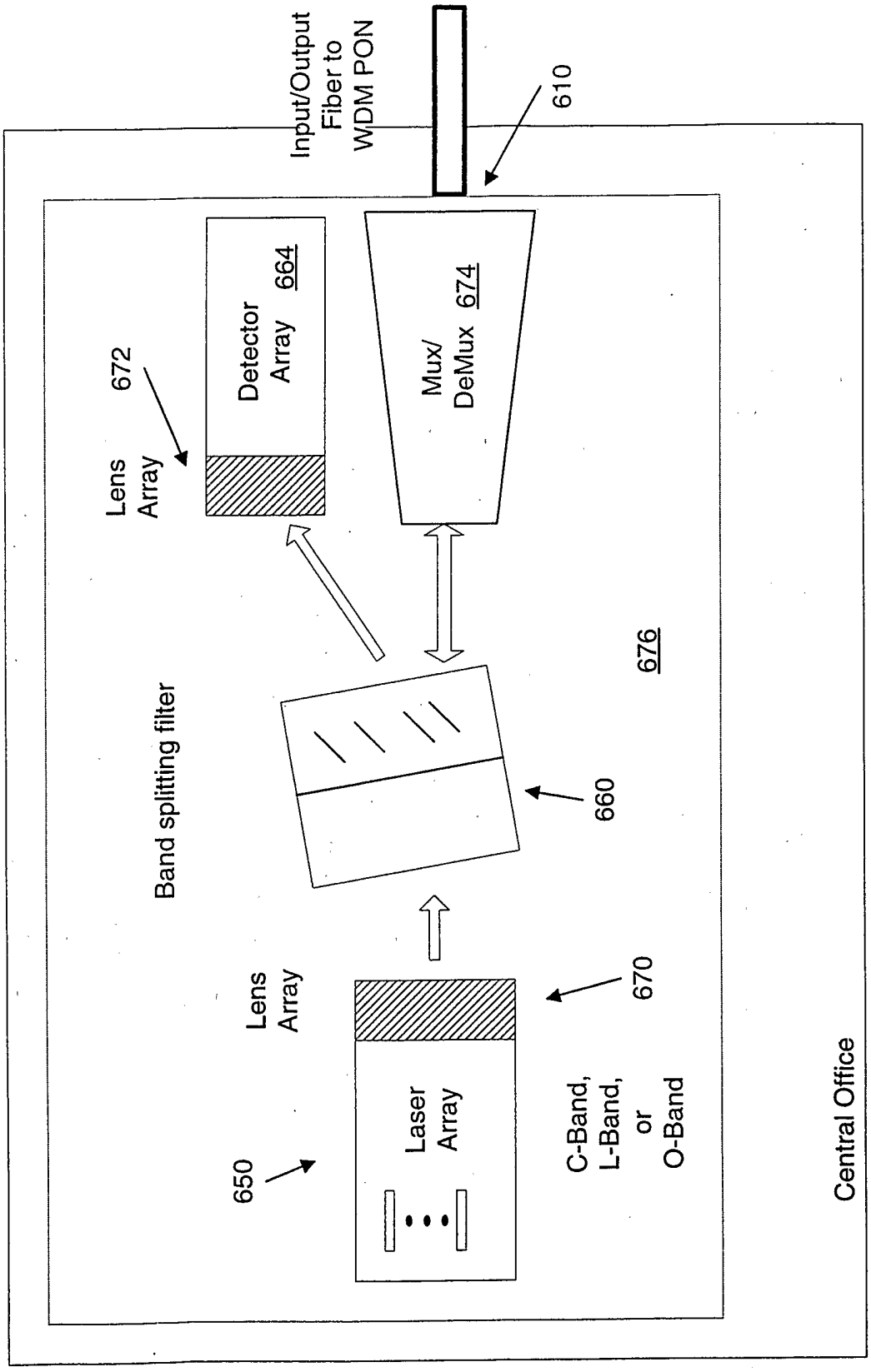

Input/Output
Fiber to
WDM PON
610
Detector
Array 664
Mux/
DeMux 674
672
Lens
Array
Band splitting filter
676
660
Lens
Array
670
Laser
Array
650
C-Band,
L-Band,
or
O-Band
Central Office

Figure 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2004/031407

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B10/155 H01S5/10 H01S5/40 H01S5/50 H04B10/158

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)
IPC 7 H04B H01S

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, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 195 867 A1 (LUCENT TECHNOLOGIES INC) 10 April 2002 (2002-04-10) the whole document	1-11,15, 17,24
X	US 6 034 799 A (HANSEN ET AL) 7 March 2000 (2000-03-07) abstract column 1, line 10 - line 53 column 2, line 36 - column 3, line 29 figures 2,3	1-11,15, 17,24
X	WO 99/37002 A1 (NORTHERN TELECOM LIMITED; EPWORTH, RICHARD, EDWARD; KING, JONATHAN, PA) 22 July 1999 (1999-07-22) page 1, line 23 - page 2, line 7 page 3, line 29 - page 4, line 23 claims 1,2 figure 1	1-11,15, 17,24

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

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
28 January 2005	09/02/2005

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, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Rolan Cisneros, E

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A		18

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Information on patent family members

International Application No
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