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TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME

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TECHNICAL FIELD

[0001] The present disclosure relates to optical transceiver modules, and more particularly, to direct optical coupling of photodetectors to optical demultiplexer outputs to reduce fiber use and insertion loss.

BACKGROUND INFORMATION

[0002] Optical transceivers are used to transmit and receive optical signals for various applications including, without limitation, internet data centers, cable TV broadband, and fiber to the home (FTTH) applications. Optical transceivers provide higher speeds and bandwidth over longer distances, for example, as compared to transmission over copper cables. The desire to provide higher speeds in smaller optical transceiver modules for a lower cost has presented challenges, for example, with respect to maintaining optical efficiency (power), thermal management, insertion loss, and manufacturing yield. Optical transceivers can include one or more transmitter optical subassemblies (TOSAs) and receiver optical subassemblies (ROSAs) for the purpose of transmitting and receiving optical signals. As channel density becomes an increasingly important aspect of optical transceivers, the ability scale-down while maintaining nominal transceiver performance raises numerous non-trivial challenges.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] These and other features and advantages will be better understood by reading the following detailed description, taken together with the drawings wherein:

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[0004] FIG. 1 is a schematic diagram of an example arrayed waveguide grating (AWG) device.

[0005] FIG. 2 is a perspective view of the AWG device of FIG. 1 with an output coupled to a fiber array.

[0006] FIG. 3 schematically illustrates an embodiment of an optical transceiver module including a multi-channel transmitter optical sub-assembly (TOSA) and multi-channel receiver optical sub-assembly (ROSA).

[0007] FIG. 4 is a perspective view of an example small form-factor (SFF) pluggable transceiver with a multi-channel TOSA configuration and a multi-channel ROSA having a direct-coupling arrayed waveguide grating (AWG) device, in accordance with an embodiment of the present disclosure.

[0008] FIG. 5A shows a side plan view of the AWG device of FIG. 4, in accordance with an embodiment of the present disclosure.

[0009] FIG. 5B shows a cross-sectional view of the AWG device of FIG. 5A taken along the line A-A, in accordance with an embodiment of the present disclosure.

[0010] FIG. 6 shows an top plan view of the AWG device of FIG. 4, in accordance with an embodiment of the present disclosure.

[0011] FIG. 7 shows an enlarged detail view of the AWG device of FIG. 6 taken along the line B-B, in accordance with an embodiment of the present disclosure.

[0012] FIG. 8 shows an enlarged view of a direct coupling end of the AWG device of FIG. 4, in accordance with an embodiment of the present disclosure.

[0013] FIG. 9 shows a perspective view of the direct coupling end of the AWG device of FIG. 4, in accordance with an embodiment of the present disclosure.

[0014] These and other features of the present embodiments will be understood better by reading the following detailed description, taken together with the figures herein described. The accompanying drawings are not intended to be drawn to scale. In the drawings, each identical or nearly identical component that is illustrated in various figures is represented by a like numeral. For purposes of clarity, not every component may be labeled in every drawing.

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DETAILED DESCRIPTION

[0015] As discussed above, optical transceivers can include receiver optical subassemblies (ROSAs) that are configured to receive multiple channel wavelengths via a common fiber and de-multiplex the same for detection, amplification and conversion purposes. Some approaches to ROSAs include the use of an arrayed waveguide grating (AWG), which operate based on some underlying principles of optics that recognize light waves of different wavelengths interfere linearly with each other. This fundamental principle manifests itself in WDM signaling, which allows a plurality of channel wavelengths to be carried by a single optical fiber with negligible crosstalk between channels. AWGs can both multiplex and de-multiplex a WDM signal.

[0016] A schematic of one example AWG device 100 configured to multiplex/de-multiplex WDM signals is shown in FIG. 1. The AWG device 100 may be a silica-based AWG device fabricated using planar lightwave circuit (PLC) techniques, which are similar to semiconductor processes used to produce ICs and can include depositing doped and un-doped layers of silica on a substrate, such as silicon. The AWG device 100 includes an input coupling region 102 to couple to the fiber 101, an AWG chip region 103 or circuit for de-multiplexing channel wavelengths, and an output coupling region 104 for coupling to a fiber array 106, with each fiber 106-1 to 106-4 being configured to receive different channel wavelengths. The AWG chip region 103 includes of an array of waveguides 107 (also called a phased array) and two couplers 109 and 111. An input waveguide, e.g., waveguide 105, carries an optical signal consisting of multiple wavelengths $\lambda_1 - \lambda_n$ into the first input coupler 109, which then distributes the light amongst an array of waveguides. The light subsequently propagates through the array of waveguides 107 to the second output coupler 111. The length of each of the waveguides 107 is chosen so that the optical path length difference between adjacent waveguides (dL) equals an integer multiple of the central wavelength λ_c of the demultiplexer. Linearly increasing length of the array waveguides 107 will cause interference and diffraction when light mixes in the output coupler 111. As a result, each wavelength is focused into only one of the N output waveguides 106-1 to 106-N, which may also be called output channels.

[0017] The particular configuration illustrated in FIG. 1 is a 1x4 PLC demultiplexer (or demux), but other channel configurations, e.g., 1x8, 1x16, 2x8, 2x16, etc., should be apparent in

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light of this disclosure. PLC-type demuxes can provide relatively low insertion loss, low polarization dependent loss (PDL) and function within a range of operating temperatures. FIG. 2 shows one example packaging of the AWG device 100. As shown, the AWG device 100 includes the output coupling region 104 coupled to the fiber array 106, with the fiber array 106 being coupled to detector devices such as photodiodes (not shown).

[0018] In use, a multiplexed optical signal (e.g., a WDM) may be received via the input fiber 101 and split into separate channel wavelengths via, for example, waveguides 107 of the AWG circuit 103. The AWG device 100 may then launch the separated channel wavelengths into respective fibers 106-1 to 106-N of the fiber array 106. The AWG device 100 can introduce an insertion loss of about 3 to 7db based on, for example, the optical coupling between the optical fiber 101 and the input coupling region 102, and by virtue of the AWG circuit 103 itself. At an output end, additional loss can be introduced based on the optical coupling between the output coupling region 104 and the fiber array 106. While the fiber array 106 can include a 45 degree cut to reduce back-reflection and insertion loss, the overall insertion loss introduced can be about 0.5 to 1.0db, if not greater. Likewise, the optical coupling between the fiber array 106 and detector devices (not shown) can further introduce insertion loss of about 0.5 to 1.0db. Thus the overall insertion loss introduced by use of the fiber array 106 can total about 1.0 to 2.0db, which can significantly reduce sensitivity of the ROSA device and consequently reduce overall transceiver performance.

[0019] Thus, in accordance with an embodiment, a direct-coupling AWG device is disclosed that provides direct coupling between output channels of the AWG device and detector devices without the necessity of an intermediate fiber or other physical device. The direct-coupling AWG device may be used in combination with detectors and associated circuitry and can comprise a receiver optical subassembly (ROSA) for use in an optical transceiver device, or other optical device that seeks to de-multiplex optical WDM signals.

[0020] In more detail, the direct-coupling AWG device may be formed using, for example, PLC techniques or other suitable formation processes. In an embodiment, the AWG device is formed on a substrate such as a silicon wafer or any other suitable substrate, and may include depositing sequential layers of cladding and core material thereon. In an embodiment, the

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cladding layer may comprise silicon (Si) and the core material may comprise silicon dioxide (SiO_2), also known as Silica. However, other cladding and core materials may be used and are also within the scope of this disclosure. The formed AWG device may then form essentially a monolithic structure and provide a PLC configured to de-multiplex a WDM signal into multiple different channel wavelengths for output to associated detectors. The formed AWG device can include a plurality of sidewalls that extend longitudinally from a first end to a second end, with the plurality of sidewalls being formed at least in part by the cladding material. The first end of the AWG device may be configured to optically couple with an input fiber, and a portion proximal to the second end of the AWG device may be configured to optically couple with a plurality of detector devices. Thus, and for the purpose of reference, the first end may be generally understood to be an input coupling end and the second end may be generally understood as providing an output coupling region.

[0021] The input coupling end of the AWG device may be coupled to, for example, an LC connector receptacle or other suitable connector receptacle. The connector receptacle may be coupled to the AWG device by, for example, an adhesive or other suitable approach. The input end may be configured with a surface that is angled at about 8 degrees for the purposes of reducing back reflection of an optical signal launched into the AWG device by an associated input fiber.

[0022] The output coupling region of the AWG device can include output waveguides or output channels comprising core materials that are configured to substantially confine light, e.g., at least 80 percent of incident light, along a first light path that extends longitudinally towards a substantially reflective surface. The substantially reflective surface may be provided by a portion of the output coupling end that includes a tapered region. As generally referred to herein, the term substantially reflective refers to a surface capable of reflecting at least 80 percent of incident light. The tapered region may be formed by cutting away and polishing a portion of the AWG chip such that an angled surface is formed, although other approaches to providing the tapered region will be apparent. The core material may have an index of refraction different from that of the medium adjacent to the AWG chip, such as air. Thus, and in accordance with Snell's law, light traveling via the longitudinal path provided by the output waveguides can

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encounter the angled surface and substantially reflect along a second light path, with the second light path being generally orthogonal to the first light path. The particular amount of light reflected by the angled surface can be about 80% or more. Light along the second light path can encounter a sidewall of the AWG chip and be emitted therefrom towards detector devices. The surface of the sidewall region that emits the light away from the AWG device may be accurately described as an output interface or a direct coupling interface.

[0023] Detector devices such as a photodiode may be disposed in a manner that aligns light-sensitive regions of the same with the direct coupling interface of the AWG device. A detector device may be provided for each channel output such that each channel wavelength is received and detected by an associated detector. Each detector device may be configured to detect channel wavelengths and provide the same to associated circuitry for amplification and conversion to electrical signaling. The detector devices may be disposed a distance D from the direct coupling interface of the AWG device in order to reduce the potential of damage to the detector devices and/or the AWG device when, for example, shifting/moving the ROSA components during active alignment procedures. Active alignment procedures can be conducted during manufacturing by providing a test WDM signal into the AWG device and monitoring the optical power of the signals received by the detectors, moving components (e.g., the AWG device and/or the detectors) and retesting. Thus the potential for damage may be reduced by providing a small gap between the AWG device and detector devices. In some cases, a material such as a gel may be inserted between the AWG device and detector devices. The index of refraction for the material may be about 1.0 or other suitable index that allows light to pass into the detector devices. In other cases, the detector devices may be disposed directly on the surface of the AWG chip forming the direct coupling interface.

[0024] Thus, numerous advantages to the direct-coupling AWG device will be apparent in light of this disclosure. For example, the insertion losses associated with coupling a fiber array to an output end of the AWG device can be eliminated. Consequently, the insertion loss associated with coupling the fiber array to associated detectors devices may also be eliminated. Thus, overall insertion loss may be reduced by at least 1db to 2db. To this end, the overall performance of the ROSA improves as the sensitivity of the ROSA is increased by the same

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amount, e.g., 1db to 2db. In addition, the overall length of the AWG device can be reduced as the direct coupling interface of the AWG allows detector devices to be positioned beside the AWG device versus a fiber array such as a pigtail that extends from an end of the AWG device. This reduction in length is particularly important when designing AWG devices for highly-constrained housings, e.g., small form-factor configurations.

[0025] As used herein, "channel wavelengths" refer to the wavelengths associated with optical channels and may include a specified wavelength band around a center wavelength. In one example, the channel wavelengths may be defined by an International Telecommunication (ITU) standard such as the ITU-T dense wavelength division multiplexing (DWDM) grid or course wavelength division multiplexing (CWDM).

[0026] The term "coupled" as used herein refers to any connection, coupling, link or the like and "optically coupled" refers to coupling such that light from one element is imparted to another element. Such "coupled" devices are not necessarily directly connected to one another and may be separated by intermediate components or devices that may manipulate or modify such signals. Likewise, the term "directly coupled" or "directly optically coupled" as used herein refers any optical connection that allows light to be imparted from one element to another without the use of an intermediate device such as a fiber.

Example Optical Transceiver System

[0027] Now turning to FIG. 3, there is an optical transceiver 300 consistent with embodiments of the present disclosure. In more detail, the optical transceiver 300 transmits and receives four (4) channels using four different channel wavelengths (λ_1, λ_2, λ_3, λ_4) and may be capable of transmission rates of at least about 25 gigabits (Gbs) per channel or more. In one example, the channel wavelengths λ_1, λ_2, λ_3, λ_4 may be 1270 nm, 1290 nm, 1310 nm, and 1330 nm, respectively. The optical transceiver 300 may also be capable of both short transmission distances of tens of meters, for example, to distances of 2 kilometers or more. The optical transceiver 300 may be used, for example, in internet data center applications or fiber to the home (FTTH) applications. In an embodiment, the optical transceiver 300 implements a Quad Small Form-Factor Plugging (QSFP) transceiver. For example, the optical transceiver 300 may

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be implemented within a QSFP receiver that comports with the "SFF Committee Specification SFF-8665 for QSFP+ 28 Gb/s 4X Pluggable Transceiver Solution (QSFP28)" published on May 10, 2013. The aspects and embodiments disclosed herein may be used within other transceiver types and is not necessarily limited to QSFP or QFSP+ transceivers. The optical transceiver 300 may be configured for dense wavelength division multiplexing (DWDM) or course wavelength division multiplexing (CWDM), depending on a desired configuration. Although aspects and scenarios disclosed herein discuss a four (4) channel configuration, other channel configurations, e.g., 2, 4, 16, 32, and so on, are within the scope of this disclosure.

[0028] As shown, the optical transceiver 300 includes a housing 302 that includes a multi-channel TOSA arrangement 310 for transmitting optical signals on different channel wavelengths, and a multi-channel ROSA 312 for receiving optical signals on different channel wavelengths. A transmit connecting circuit 304 and a receive connecting circuit 308 provide electrical connections to the multi-channel TOSA 310 and the multi-channel ROSA 312, respectively, within the transceiver housing 302. The transmit connecting circuit 304 and the receive connecting circuit 308 may communicate with external systems via data bus 303. In some cases, data bus 303 is a 38-pin connector that comports with physical connector QSFP standards and data communication protocols.

[0029] In any event, the transmit connecting circuit 304 electrically couples to the electronic components in the multi-channel TOSA arrangement 310, e.g., laser assemblies, and the receive connecting circuit 308 electrically couples to the electronic components in the multi-channel ROSA 312, e.g., an array waveguide grating (AWG), detectors, amplification circuitry and so on. The transmit connecting circuit 304 and the receive connecting circuit 308 include at least conductive paths to provide electrical connections, and may also include additional circuitry. The multi-channel TOSA 310 transmits and multiplexes multiple different channel wavelengths, and is coupled to an optical interface port 314. The optical interface port 314 may include an LC connector port, although other connector types are also within the scope of this disclosure.

[0030] In cases where the optical interface port 314 comprises a duplex, or bi-directional, LC receptacle, the LC connector receptacle provides optical connections to the multi-channel TOSA 310, and provides optical connections to the multi-channel ROSA 312. The LC connector

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receptacle may be configured to receive and be coupled to a mating LC connector 316 such that transmit optical fiber 322 of the external fibers 324 optically couples to the multi-channel TOSA 310 arrangement, and the receive optical fiber 317 of the external fibers 324 optically couples to the multi-channel ROSA 312.

[0031] The multi-channel TOSA arrangement 310 can include multiple laser packages 311-1 to 311-N (FIG. 4) and optics for producing associated channel wavelengths, and can couple the same into the transmit optical fiber 322. In particular, the lasers 311-1 to 311-N in the multi-channel TOSA arrangement 310 can convert electrical data signals (TX_D1 to TX_D4) received via the transmit connecting circuit 304 into modulated optical signals transmitted over transmit optical fiber 322. The lasers may include, for example, distributed feedback (DFB) lasers with diffraction gratings. In other cases, the lasers may comprise electro-absorption modulated laser (EML) laser diode packages. The multi-channel TOSA 310 may also include monitor photodiodes for monitoring the light emitted by the lasers. The multi-channel TOSA 310 may further include one or more temperature control devices, such as a resistive heater and/or a thermoelectric cooler (TEC), for controlling a temperature of the lasers, for example, to control or stabilize the laser wavelengths.

[0032] The multi-channel ROSA 312 can include demultiplexing optics such as an AWG device 402, as discussed further below, and a plurality of detectors such as photodiode packages configured to receive de-multiplexed channel wavelengths. The ROSA 312 can use the detectors and associated circuitry (e.g., a TIA) to detect, amplify and convert de-multiplexed channel wavelengths and can provide the same as electrical data signals, e.g., RX_D1 to RX_D4.

[0033] Referring to FIG. 4, an example small form-factor (SFF) pluggable optical transceiver 400 with a multi-channel TOSA arrangement and multi-channel ROSA is shown in greater detail. The embodiment shown in FIG. 4 is one example of the optical transceiver 300 of FIG. 3 implemented in a small-form factor. In some cases, the optical transceiver 400 may implement the QSFP+ specification, or other applicable pluggable small-form factor specification. To this end, and in an embodiment, the optical transceiver 400 may be compliant with the QSFP28 MSA standard, and may include physical dimensions that conform to the SFF-8661 specification. In other cases, the optical transceiver 400 may implement the C form-factor pluggable (CFP)

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standard. In any such cases, the optical transceiver 400 may be configured to transmit and receive at a line rate of at least 100 Gb/s, respectively. This may be particularly advantageous when using the optical transceiver in, for example, a 100GBASE-LR4 application, per the IEEE 802.3ba standard. As shown, the optical transceiver 400 includes a transceiver housing 302, a multi-channel TOSA arrangement 310 including a plurality of laser assemblies to generate associated channel wavelengths and associated circuitry. The multi-channel TOSA arrangement 310 electrically couples to transmit flexible printed circuits (FPCs) 304 and couples to the optical interface port 314 at an end of the housing 302. The multi-channel ROSA arrangement 312 electrically couples to a receive FPC 308, and couples to the optical interface port 315 at an end of the housing 302. In an embodiment, the transceiver 400 can be configured to operate in a WDM passive optical network (PON), and to this end, the AWG 402 may be configured as a passive optical device. However, in some cases the AWG 402 can include active components and is not necessarily limited in this regard.

[0034] The multi-channel TOSA arrangement 310 can include a plurality of laser packages 311-1 to 311-N with each comprising, for example, an EML laser diode package. Each EML laser may include an integrated electro-absorption modulator (EAM) on a single chip, for example. Other laser types are also within the scope of this disclosure such as, for example, directly modulated laser (DML) diodes and TO can-type laser diodes. The particular laser type chosen may be based on a desired application. For instance, applications that require long-distance, e.g., about 10km or greater, may favor EML lasers. Conversely, applications requiring shorter distances may use DMLs. In any event, and in accordance with an embodiment, each laser diode device of the multi-channel TOSA arrangement can be configured to transmit at about 25Gb/s, or greater. Each laser package of the multi-channel TOSA arrangement 310 may provide a relatively narrow spectrum of channel wavelengths such as a single channel wavelength, or may be configured to provide a broad spectrum of channel wavelengths based on associated optics. In an embodiment, the lasers can provide center wavelengths 375 nm to 1650 nm, for example.

[0035] The multi-channel ROSA arrangement 312 can include a demux device, such as the direct-coupling arrayed waveguide grating (AWG) device 402. The direct-coupling AWG 402

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may be configured to demultiplex a signal, e.g., a WDM signal, received via the optical interface port 315 into individual channel wavelengths. A fiber or other waveguide (not shown) can extend from the optical interface port 315 to an input of the AWG device 402. An output of the AWG 402 device can be coupled to, for example, an array of quad p-intrinsic-n (PIN) diodes and associated TIAs 403 for the purposes of detecting, amplifying and converting each of the channel wavelengths into an electrical signal. The AWG device 402 can be compatible with channel spacing configurations that comport with, for example, 25nm IEEE LX-4 grids, 20-nm ITU G.694.2 CWDM grids, and a range of ITU G.694.1 DWDM grids in the range of 400 Ghz to 800 Ghz (e.g., 2nm to 4nm). The AWG device 402 may be directly coupled to detector devices, e.g., the array of photodetectors 801 (FIG. 8), as discussed in greater detail below.

[0036] Referring to FIG. 5A, one example of the direct-coupling AWG device 402 is shown in further detail, in accordance with an embodiment of the present disclosure. As shown, the AWG device 402 includes an AWG chip 503 having a first end 505 coupled to an input coupling region 504 and having a second end 506, with the second end 506 being proximal to a direct coupling interface 517 or region. The input coupling region 504 can include an optical coupling port 507, with the optical coupling port 507 being configured to receive and optically couple to a fiber of the optical coupling receptacle 215. In general, AWG devices can support both multiplexing and de-multiplexing of optical signals, and thus, the first end 505 is not necessarily an "input" in all applications. However, for the purposes of the aspects and scenarios disclosed herein, the first end 505 is configured to receive an optical signal via fiber 508 and generally launch the same along a longitudinal path indicated by arrows appearing along fiber 508 to launch a WDM optical signal into the AWG chip 503. In some cases, the optical coupling port 507 is an LC receptacle. The input coupling region 504 may not necessarily contain a length of fiber and instead comprise, for instance, a cavity or other waveguide structure. Moreover, the length of fiber 508 depicted in FIG. 5A can be provided by an optical cable mated with optical coupling port 507 and is not necessarily a separate length of fiber.

[0037] The input coupling region 504 may be coupled to the AWG chip 503 using, for example, an adhesive, although other methods of fixation should be apparent in light of this disclosure. The input coupling region 504 can include an end with a mounting surface 510

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having an angle 509, with angle 509 being about 8 degrees. The angle 509 can reduce back reflection when launching light into the AWG chip 503. To this end, the first end 505 of the AWG chip may also include a mounting surface with an angle of about 8 degrees, thus allowing for proper alignment between a core of the fiber 508 and an input of the AWG chip 503.

[0038] The AWG chip 503 can comprise, for example, a planar lightwave circuit (PLC) such as a silica-based planar lightwave PLC device. PLC devices can be fabricated using a wafer process similar to those used for integration of silicon microchips and ICs. Processes for AWG chips can include, for example, forming a circuit pattern using photolithography, etching and deposition and/or epitaxial growth on a substrate, e.g., a silicon or silicon-based substrate. The formed AWG chip 503 can include a cladding material of, for example, silica (SiO_2), and a core material of doped silica, or other suitable composition that can provide a contrasting index of refraction for light confinement purposes. The contours of the AWG chip 503 may be defined by the shaping/etching of the silica during formation processes, or by post-processes such as cutting and polishing. Thus the AWG chip 503 can comprise a plurality of sidewalls that are formed from a cladding material layer. However, the AWG chip 503 can include additional protective layers/coatings, such as a metal housing, and is not necessarily limited to the embodiment shown.

[0039] Turning to FIG. 5B, an enlarged cross-section taken along the line A-A of FIG. 5A shows additional aspects of the AWG chip 503 in greater detail. As shown, the AWG chip 503 can include a plurality of optical paths 511 or output waveguides formed via deposited/grown core layers, with the output waveguides 511 extending longitudinally along the AWG chip 503. The output waveguides 511 may be formed using, for example, sequentially deposited/grown layers of doped silica or suitable core material. The output waveguides 511 form at least a portion of the waveguide circuit of the AWG chip 503 and operate similar to that of conductive leads/traces on a printed circuit board. Each of the output waveguides 511 may have a width W2 of about 6 microns and a height H3 of about 3 microns, although other core configurations are also within the scope of this disclosure. Channel spacing, e.g., width W3, between each waveguide is discussed below with regard to FIG. 7.. Likewise, the cladding layer 513 can be formed from sequentially deposited/grown layers of silica or other suitable cladding material.

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[0040] In an embodiment, the output waveguides 511 of the AWG chip 503 can enable confinement of light within the waveguides defined by the circuit patterned on the AWG chip 503. This functionality is based at least in part on the relative index of refraction between the compositions of the core versus the cladding. For example, a silica-based cladding material can include an index of refraction N_1 of about 1.45. In contrast, the output waveguides 511 can be formed from a core material having an index of refraction N_2, with index of refraction N_2 being within about 0.7% of N_1. The particular material composition of the core and cladding may be selected to reduce insertion loss with the fiber 508, which is also known as index-matching. In any event, aspects and embodiments disclosed herein are not necessarily limited to silicon or silicon-based compositions and are equally applicable to other materials used to form an AWG device.

[0041] Turning back to FIG. 5A, the AWG chip 503 can include an output interface 517 (also called a direct coupling interface), which is discussed in greater detail below. As shown, the second end 506 of the AWG chip 503 includes an angled surface 520 that extends from a first sidewall 519 to a second sidewall 523, with the angled surface 520 defining a tapered region of the AWG chip 503. The angled surface 520 can include an angle 514 relative to longitudinal axis 521, with angle 514 being selected to cause incident light to reflect downwardly at about a 90-degree angle towards the region indicated at 515, which is shown and discussed in further detail with reference to FIG. 8. Depending on the particular materials used to form the AWG chip 503, and more particularly, their respective index of refraction, the angle 514 can vary. Likewise, the angle 514 may vary within nominal manufacturing tolerances of, for instance, ± 2%. In an embodiment, the angle 514 is a range between about 40 degrees to 45 degrees. In some cases, the angled surface 520 is provided by cutting, buffing, etching, or otherwise removing a portion of the AWG chip 503. This removed region is generally indicated at 516 for purposes of illustration. The surface of the second end 506 may be polished to ensure surface-level defects caused by the removal process are removed or otherwise reduced such that a substantial portion, e.g., at least 80%, of light is reflected downwards towards to the region indicated at 515. Formation of the AWG chip 503 can include removing a portion of the

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substrate generally indicated at 515 to expose the output interface region 517. The exposed output interface region 517 may be polished to ensure a suitable optical coupling.

[0042] In an embodiment, the AWG device 402 can include an overall length L1 of about 13mm. The overall length L1 can be less than a similarly configured AWG chip that uses a fiber array coupling scheme, such as the one discussed above with regard to FIGs. 1 and 2. The AWG chip 503 can include a length L2 of about 10mm, and a height H2 of about 1.30mm including the substrate 502, and about 1mm without. To this end, the substrate can include a height H1 of about 0.3mm. The region generally indicated at 515, and more particularly the output interface region 517, can include a length L3 of about 0.60mm.

[0043] Turning to FIG. 6, a top plan view of the AWG 402 is shown, in accordance with an embodiment. As shown, the AWG 402 can include a width W of about 1.5mm. Other configurations are within the scope of this disclosure and the specific examples provided herein should not be construed as limiting. FIG. 7 shows a detail view of a portion of the AWG 402 taken along the line B-B, in accordance with an embodiment of the present disclosure. As shown, the output waveguides 511 include a channel spacing W3 of about 0.25mm, although other channel spacing arrangements will be apparent in light of this disclosure.

[0044] Turning to FIG. 8, an enlarged perspective view of the second end 506 of the AWG chip 503 is shown, in accordance with an embodiment of the present disclosure. The embodiment of FIG. 8 is illustrated in a highly simplified and exaggerated manner for the purposes of clarity and practicality. As shown, the output waveguides 511 can each provide a first light path generally indicated at 806, with the first light path 806 extending longitudinally towards the direct coupling end 506. A detector array 801 such as a photodiode (PD) array or bar can be positioned at a distance D1 from the direct coupling interface 517, with D1 being about 50 microns. As previously discussed, the second end 506 can include the surface 520 which has an angle 514 of about 40 degrees to 45 degrees relative to the light path 806, depending on the composition of the AWG chip. For example, the angle 514 may be about 41 degrees in instances where the output waveguides 511 and the cladding layer 513 are silicon-based or otherwise have an index of refraction of about 1.45 to 1.5. Each of the output waveguides 511 form at least a portion of the angled surface 520, and thus also include a tapered

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region having the angle 514. Note that the tapered regions of the output waveguides 511 may be introduced when, for instance, a portion of the AWG chip 503 is cut or otherwise removed.

[0045] In any event, the angle 514 can provide an angle of incidence that can allow a substantial amount of light, e.g., at least 80 percent, to reflect towards the detectors 801. For example, as shown, light incident to the angled surface 520 or tapered region can reflect downwards along a second light path 530 and pass through the direct coupling interface 517, with the second light path 530 being generally orthogonal to the first light path 806. As previously discussed, the difference in the index of refraction between the cladding layer 513 (denoted as n_1) and the output waveguides 511 allow light signals to be substantially confined within the output waveguides 511. Furthermore, the external regions 809 adjacent to the AWG 402, and more particularly the angled surface 520, can include an index of refraction of n_3, with the index of refraction N_3 being less than that of n_1 and n_2. For example, the external regions 809 may comprise air which has an index of refraction of about 1.00. Thus the separated channel wavelengths that launch along associated ones of the output waveguides 511 along light path 806 can be reflected towards the detectors 804 as a result of the contrast between index of refraction n2 and n3. The resulting angle of reflection may be calculated based on Snell's Law:

$$n1 \sin \theta_1 = n2 \sin \theta_2 \qquad \text{Equation (1)}$$

Where n1 is the refractive index of a first medium, n2 is a refractive index of a second medium, $\sin\theta_1$ is the angle of incidence and $\sin\theta_2$ is the angle of reflection, thus:

$$\sin \theta_2 = \frac{n1 \sin \theta_1}{n2} \qquad \text{Equation (2)}$$

[0046] In use, each of the output waveguides 511 can provide associated channel wavelengths along a first light path generally indicated at 806. The light along light path 806 may then encounter the angled surface 520 and reflect therefrom along the second light path 530, with the second light path 530 being generally orthogonal to the first light path 806. Then, light traveling along the second light path 530 can encounter the photo-sensitive regions of the detectors 804. FIG. 9 shows the orientation of the detectors 804 relative to each of the waveguides 511 in greater detail.

[0047] Turning to FIG. 9, and with additional reference to FIG. 8, another perspective view shows the second end 506 of the AWG chip 503 adjacent to the array of detectors 801, in

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accordance with an embodiment of the present disclosure. The second end 506 is illustrated in a fully-transparent and simplified manner for practicality and clarity. As shown, each of the output waveguides 511 extends longitudinally to the second end 506 such that each of the output waveguides 511 provides a first respective light path, e.g., the first light path 806. As previously discussed with reference to FIG. 7, the output waveguides 511 can be spaced at a nominal distance W3, with the nominal distance W3 being about 0.25mm or a different distance depending on a desired channel spacing configuration. As further shown, each of the detector devices 804 are aligned beneath the output interface region 517, and more particularly, beneath respective ones of the output waveguides 511. Thus the AWG 402 may be understood to directly couple to the detectors 804, without the necessity of an additional waveguide or fiber device there between. The detectors 804 may be electrically coupled to associated circuitry of the receive connecting circuit 108 such as a TIA via, for example, wire bonding 901 or other suitable electrical interconnection.

Further Example Embodiments

[0048] In one aspect an arrayed waveguide grating (AWG) chip is disclosed. The AWG chip comprising a first end for coupling to an optical coupling receptacle to receive an optical signal comprising a plurality of channel wavelengths, a planar lightwave circuit (PLC) coupled to the first end configured to de-multiplex each channel wavelength of the plurality of channel wavelengths, a plurality of output waveguides coupled to the PLC, each of the output waveguides configured to receive light corresponding to an associated de-multiplexed channel wavelength launched from the PLC and provide the light along a light path that extends towards a second end of the AWG chip, and a tapered region disposed at the second end of the AWG chip configured to receive light via the plurality of output waveguides and reflect the same towards an output interface region of the AWG chip.

[0049] In another aspect, an optical transceiver module is disclosed. The optical transceiver module comprising a transceiver housing, a multi-channel receiver optical sub-assembly (ROSA) located in the transceiver housing and including an arrayed waveguide grating (AWG) chip, the AWG chip comprising a first end for coupling to an optical coupling receptacle to receive an

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optical signal comprising a plurality of channel wavelengths, a planar lightwave circuit (PLC) coupled to the first end configured to de-multiplex each channel wavelength of the plurality of channel wavelengths, a plurality of output waveguides coupled to the PLC, each of the output waveguides configured to receive light corresponding to an associated de-multiplexed channel wavelength launched from the PLC and provide the light along a light path that extends towards a second end of the AWG chip, and a tapered region disposed at the second end of the AWG chip configured to receive light via the plurality of output waveguides and reflect the same towards an output interface region of the AWG chip, an array of detector devices disposed adjacent to the output interface region of the AWG chip, and a multi-channel transmitter optical assembly (TOSA) including at least one laser package located in the transceiver housing for transmitting optical signals at different channel wavelengths.

[0050] In yet another aspect, a method of forming an arrayed waveguide grating (AWG) is disclosed. The method comprising depositing sequential layers of cladding and core material onto a substrate to form a planar lightwave circuit (PLC), removing a portion of the substrate to expose an output interface region of the PLC, and removing a portion of the PLC to provide a tapered region proximal to the output interface region of the PLC.

[0051] While the principles of the disclosure have been described herein, it is to be understood by those skilled in the art that this description is made only by way of example and not as a limitation as to the scope of the disclosure. Other embodiments are contemplated within the scope of the present disclosure in addition to the exemplary embodiments shown and described herein. Modifications and substitutions by one of ordinary skill in the art are considered to be within the scope of the present disclosure, which is not to be limited except by the following claims.

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CLAIMS

What is claimed is:

1. An arrayed waveguide grating (AWG) chip comprising:

a first end for coupling to an optical coupling receptacle to receive an optical signal comprising a plurality of channel wavelengths;

a planar lightwave circuit (PLC) coupled to the first end configured to de-multiplex each channel wavelength of the plurality of channel wavelengths;

a plurality of output waveguides coupled to the PLC, each of the output waveguides configured to receive light corresponding to an associated de-multiplexed channel wavelength launched from the PLC and provide the light along a first light path that extends towards a second end of the AWG chip; and

a tapered region disposed at the second end of the AWG chip configured to receive light via the plurality of output waveguides and reflect the same towards an output interface region of the AWG chip.

2. The AWG chip of claim 1, wherein the output interface region is configured to pass the reflected light received via the plurality of output waveguides out of the AWG chip along a second light path that is substantially orthogonal to the first light path.

3. The AWG chip of claim 1, wherein the AWG chip defines a plurality of sidewalls extending longitudinally from the first end to the second end, and wherein the tapered region of the second end defines an angled surface that extends from a first sidewall of the plurality of sidewalls to a second sidewall of the plurality of sidewalls.

4. The AWG chip of claim 3, wherein the angled surface has an interior angle of about 41 to 45 degrees relative to the output interface region.

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5. The AWG chip of claim 3, wherein each of the output waveguides comprise a core material, and wherein a cladding material is disposed on the core material, the core material defining at least a portion of the plurality of sidewalls of the AWG chip.

6. The AWG chip of claim 5, wherein the core material of each of the plurality of output waveguides has a first index of refraction, and a medium external to and adjacent the tapered region has a second index of refraction, the first index of refraction being greater than the second index of refraction.

7. The AWG chip of claim 5, wherein the core material of each of the plurality of output waveguides provide a portion of the angled surface, and wherein the angled surface is configured to reflect incident light based on at least an interior angle of the angled surface.

8. The AWG chip of claim 5, wherein the core material comprises doped silica (SiO_2) having an index of refraction of about 1.45 to 1.50.

9. The AWG chip of claim 6, wherein the external medium comprises a material having an index of refraction of about 1.0.

10. The AWG chip of claim 1, wherein the AWG chip is configured as a 1xN demultiplexer device whereby a single optical input signal is de-multiplexed into N different channel wavelengths.

11. The AWG chip of claim 1, wherein the AWG chip is implemented in an AWG device package.

12. An optical transceiver module comprising:

a transceiver housing;

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a multi-channel receiver optical sub-assembly (ROSA) located in the transceiver housing and including an arrayed waveguide grating (AWG) chip, the AWG chip comprising:

a first end for coupling to an optical coupling receptacle to receive an optical signal comprising a plurality of channel wavelengths;

a planar lightwave circuit (PLC) coupled to the first end configured to de-multiplex each channel wavelength of the plurality of channel wavelengths;

a plurality of output waveguides coupled to the PLC, each of the output waveguides configured to receive light corresponding to an associated de-multiplexed channel wavelength launched from the PLC and provide the light along a first light path that extends towards a second end of the AWG chip; and

a tapered region disposed at the second end of the AWG chip configured to receive light via the plurality of output waveguides and reflect the same towards an output interface region of the AWG chip;

an array of detector devices disposed adjacent to the output interface region of the AWG chip; and

a multi-channel transmitter optical assembly (TOSA) including at least one laser package located in the transceiver housing for transmitting optical signals at different channel wavelengths.

13. The optical transceiver module of claim 12, wherein an air gap separates the output interface region of the AWG chip and the array of detector devices.

14. The optical transceiver module of claim 12, wherein the output interface region of the AWG chip is separated from the array of detector devices by about 50 microns.

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15. The optical transceiver module of claim 12, wherein the AWG chip defines a plurality of sidewalls extending longitudinally from the first end to the second end, and wherein the tapered region of the second end defines an angled surface that extends from a first sidewall of the plurality of sidewalls to a second sidewall of the plurality of sidewalls.

16. The optical transceiver module of claim 15, wherein the angled surface has an interior angle of about 41 to 45 degrees relative to the output interface region.

17. The optical transceiver module of claim 15, wherein each of the output waveguides comprise a core material, and wherein a cladding material is disposed on the core material, the core material defining at least a portion of the plurality of sidewalls of the AWG chip.

18. The optical transceiver module of claim 17, wherein the core material of each of the plurality of output waveguides provide a portion of the angled surface, and wherein the angled surface is configured to reflect incident light based on at least an interior angle of the angled surface relative to the output interface of the AWG chip.

19. The optical transceiver of claim 12, wherein the transceiver is a Small Form-factor Pluggable (SFP) transceiver module and the ROSA is configured to receive at least four different channel wavelengths at transmission rates of at least about 25 Gbps per channel.

20. A method of forming an arrayed waveguide grating (AWG) comprising:

depositing sequential layers of cladding and core material onto a substrate to form a planar lightwave circuit (PLC);

removing a portion of the substrate to expose an output interface region of the PLC; and

removing a portion of the PLC to provide a tapered region proximal to the output interface region of the PLC.

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TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME

ABSTRACT OF THE DISCLOSURE

An arrayed waveguide grating (AWG) device for use in an optical transceiver is disclosed, and can de-multiplex an optical signal into N number of channel wavelengths. The AWG device can include an AWG chip, with the AWG chip providing a planar lightwave (PLC) circuit configured to de-multiplex channel wavelengths and launch the same into output waveguides. A region of the AWG chip may be tapered such that light traveling via the output waveguides encounters an angled surface of the tapered region and reflects towards an output interface region of the AWG chip. Thus detector devices may optically couple to the output interface region of the AWG chip directly, and can avoid losses introduced by other approaches which couple an output of an AWG to detectors by way of a fiber array or other intermediate device.

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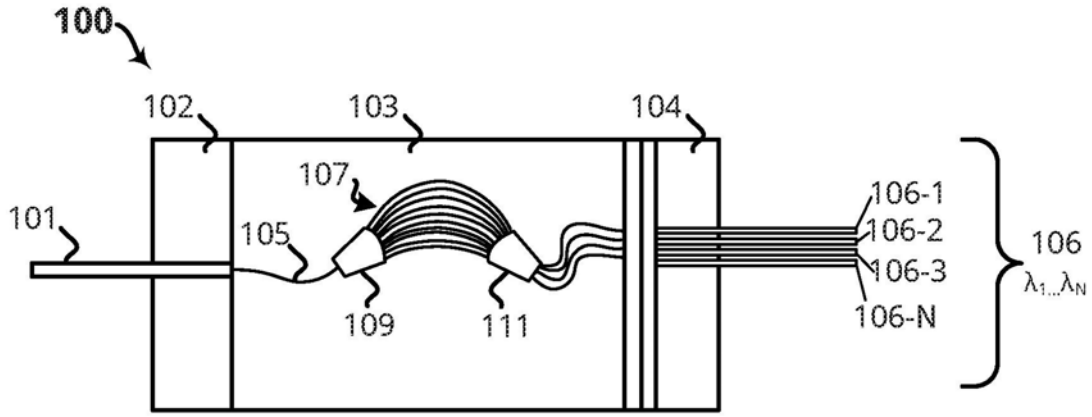


FIG. 1

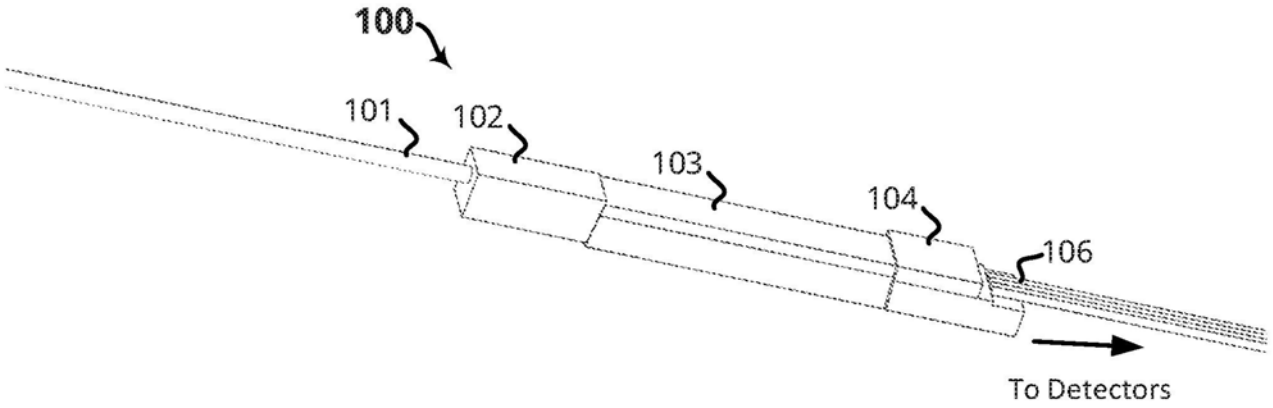


FIG. 2

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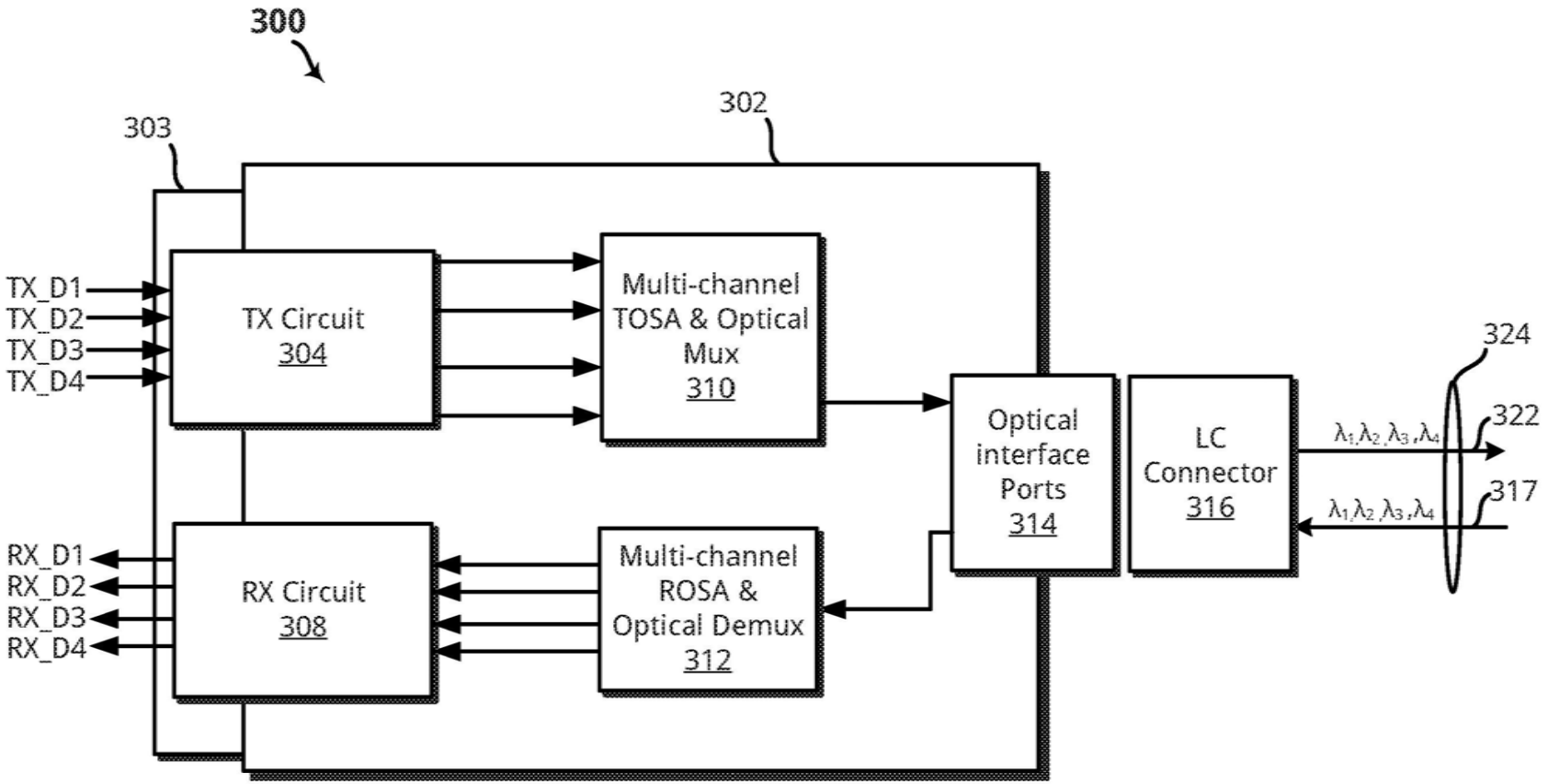


FIG. 3

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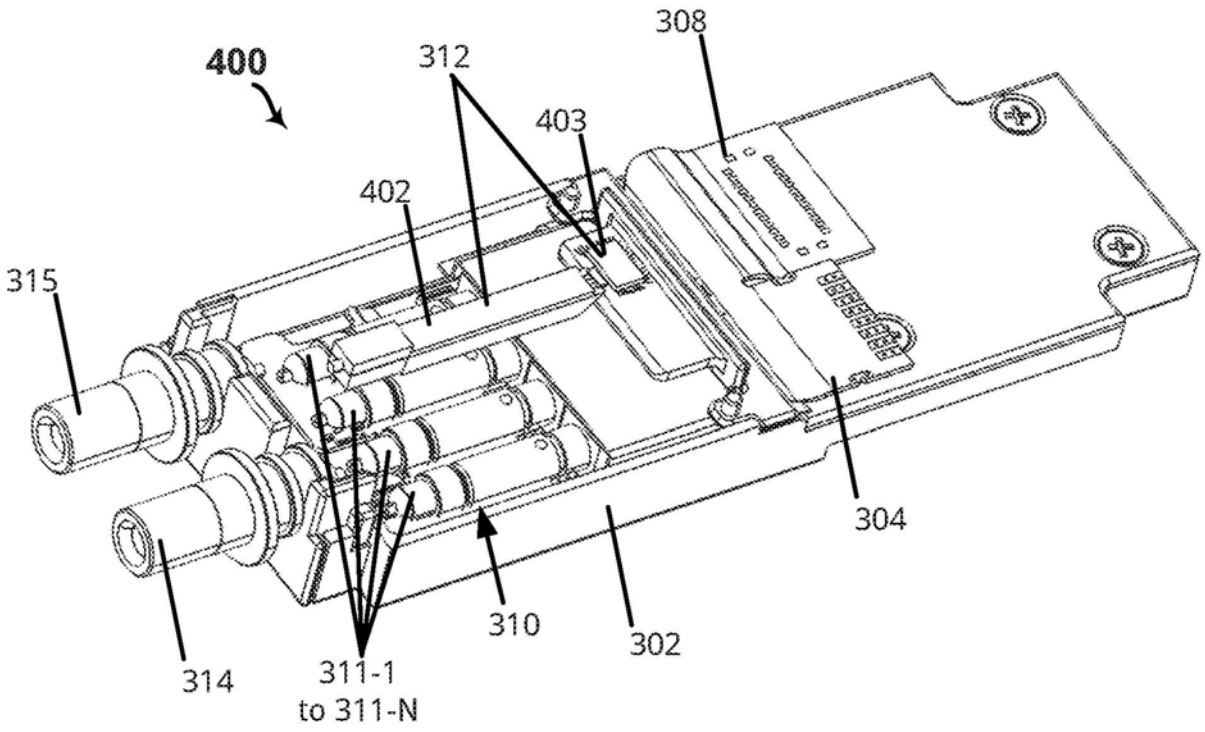


FIG. 4

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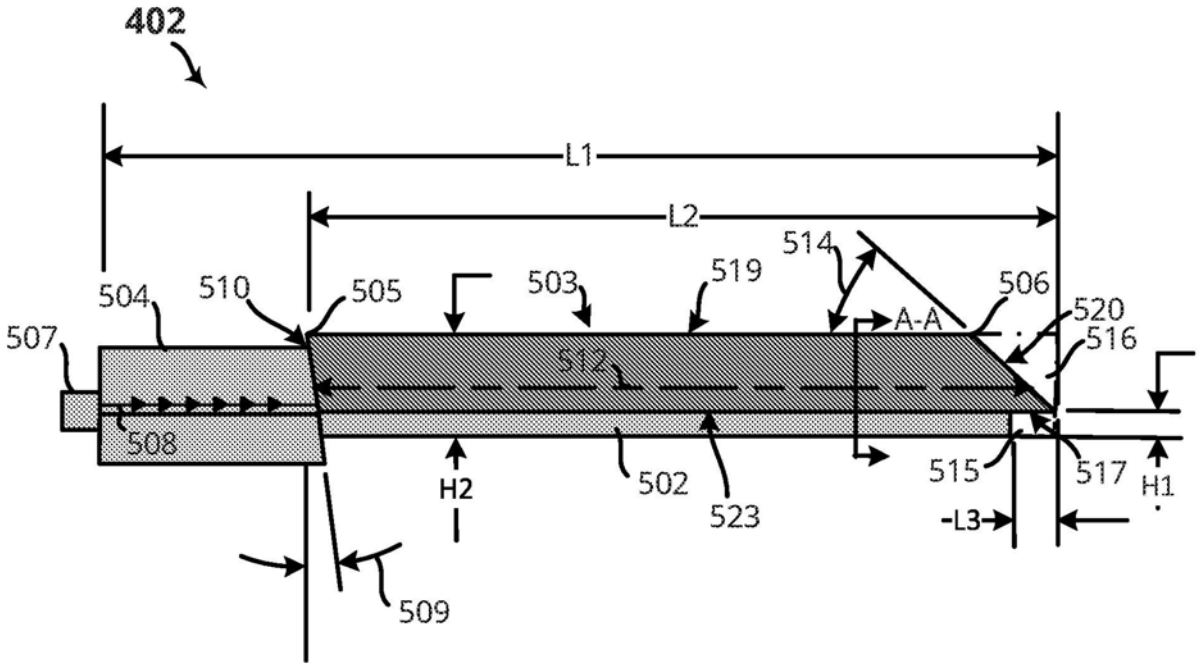


FIG. 5A

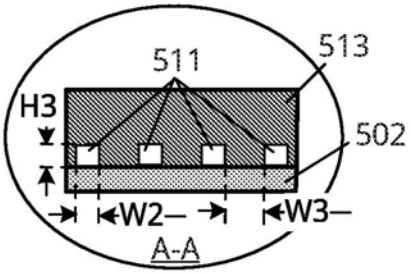


FIG. 5B

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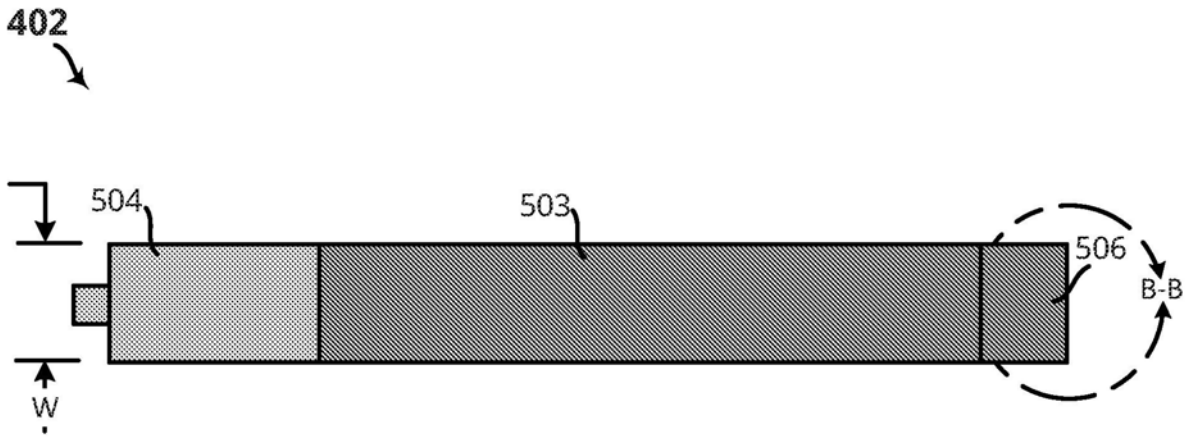


FIG. 6

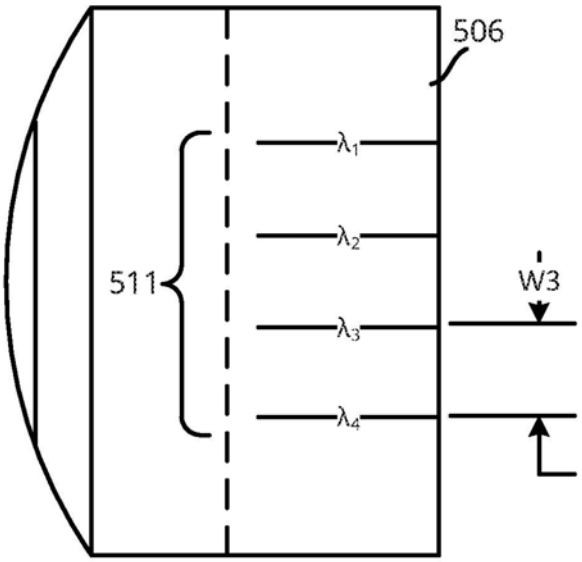


FIG. 7

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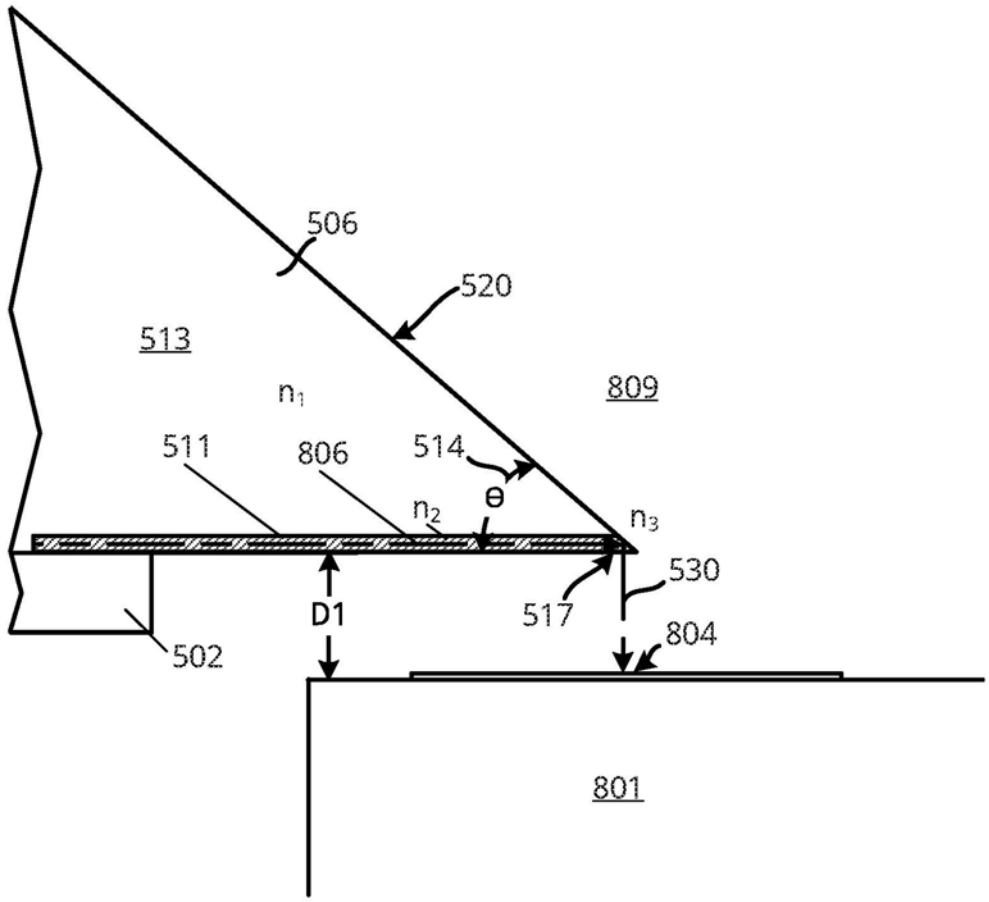


FIG. 8

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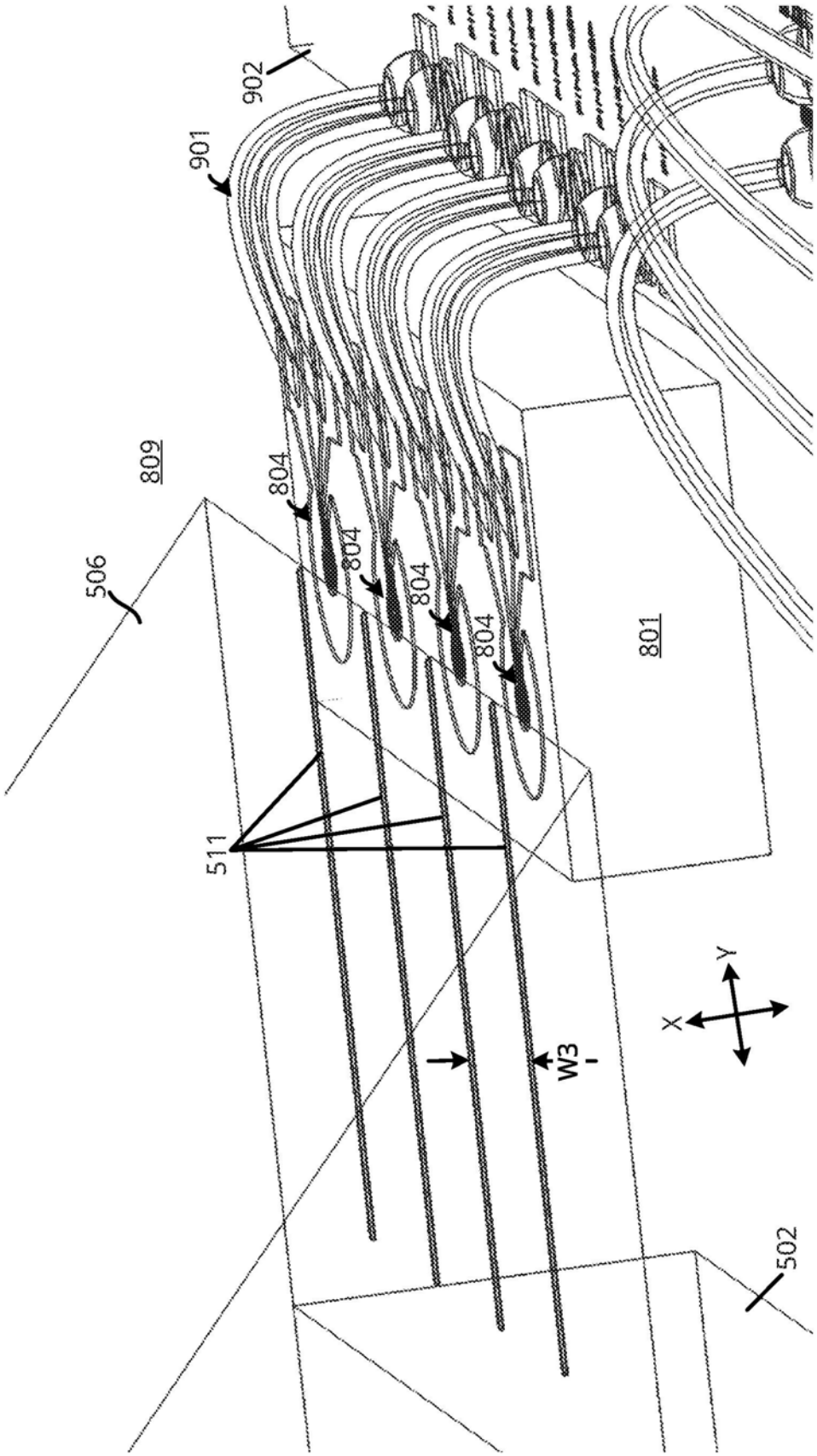


FIG. 9

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Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME
First Named Inventor/Applicant Name:	I-Lung HO
Filer:	Kevin J. Carroll/April Davis
Attorney Docket Number:	PAT260-018US

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility application filing	1011	1	280	280
Utility Search Fee	1111	1	600	600
Utility Examination Fee	1311	1	720	720
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Post-Allowance-and-Post-Issuance:				
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Miscellaneous:				
		Total in USD ($)		**1600**

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Electronic Acknowledgement Receipt

EFS ID:	25590514
Application Number:	15137823
International Application Number:	
Confirmation Number:	2275
Title of Invention:	TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME
First Named Inventor/Applicant Name:	I-Lung HO
Customer Number:	27543
Filer:	Kevin J. Carroll/April Davis
Filer Authorized By:	Kevin J. Carroll
Attorney Docket Number:	PAT260-018US
Receipt Date:	25-APR-2016
Filing Date:	
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Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$1600
RAM confirmation Number	6535
Deposit Account	501705
Authorized User	CARROLL, KEVIN J.
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	PAT260_018US_ADS.pdf	1823244 3412b54622e98f64fc71c40cdf40b7ba30ed5594	no	9
Warnings:					
Information:					
2	Oath or Declaration filed	PAT260_018US_Declaration_executed.pdf	137018 247686560e0f25be26ba7423a476f9f0f8be4a11	no	2
Warnings:					
Information:					
3	Power of Attorney	AOI_GENERAL_POA.pdf	41669 901025a5b736d47b5484029f2f40ce7f02c5b368	no	1
Warnings:					
Information:					
4		PAT260_018US_Application_as filed_042516.pdf	144824 014951ef42a79717dc2ab44eaed4231adfd129cd	yes	22

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	17
Claims	18	21
Abstract	22	22

Warnings:					
Information:					
5	Drawings-only black and white line drawings	PAT260_018US_Drawings_asfiled_042516.pdf	460839 942c139ef3afcd1367dc3054aaef88637c7432db	no	7
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Information:					
6	Fee Worksheet (SB06)	fee-info.pdf	35313 e691f171fb8f7454d3c6deff9b72c6d1835d4acc	no	2

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

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

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	PAT260-018US
	Application Number	
Title of Invention	TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
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☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

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Inventor 3 Remove

Legal Name

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	PAT260-018US
	Application Number	
Title of Invention	TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME	

City	Houston	State/Province	TX	Country of Residence	US

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Address 2			
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Postal Code	77096	Country	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	27543		
Email Address	kcarroll@gtpp.com	Add Email	Remove Email

Application Information:

Title of the Invention	TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME		
Attorney Docket Number	PAT260-018US	Small Entity Status Claimed	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	7	Suggested Figure for Publication (if any)	

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Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	PAT260-018US
	Application Number	
Title of Invention	TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME	

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	● Customer Number	US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	27543		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status			Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Remove

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	PAT260-018US
	Application Number	
Title of Invention	TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME	

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	PAT260-018US
	Application Number	
Title of Invention	TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

PTO/AIA/14 (11-15)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	PAT260-018US
	Application Number	
Title of Invention	TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1 — Remove

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

● Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.	Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☒

Organization Name	Applied Optoelectronics, Inc.		
Mailing Address Information For Applicant:			
Address 1	13115 Jess Pirtle Blvd.		
Address 2			
City	Sugar Land	**State/Province**	TX
Country	US	Postal Code	77478
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button. Add

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	PAT260-018US
	Application Number	
Title of Invention	TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME	

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

Remove

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		**State/Province**	
Country i		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button. Add

Signature:

Remove

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Kevin J. Carroll/			Date (YYYY-MM-DD)	2016-04-25
First Name	Kevin J.	Last Name	Carroll	Registration Number	36384

Additional Signature may be generated within this form by selecting the Add button. Add

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	PAT260-018US
	Application Number	
Title of Invention	TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME	

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1 The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3 A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent CooperationTreaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Declaration for United States Patent Application

TITLE OF APPLICATION: TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME

As a below named inventor, I hereby declare that:

This declaration is directed to:
[X] the attached application, or
[ ] United States Application No. or PCT Application No. _____ filed on _____

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I have reviewed and understand the contents of the application, including the claims, and I am aware of the duty to disclose to the Office all information known to the person to be material to patentability as defined in 37 C.F.R. § 1.56 (attached hereto).

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

I-Lung HO Full name of sole or first inventor
Sole or first inventor's signature Date 4/22/16

Zhengyu MIAO Full name of additional inventor, if any
Additional inventor's signature Date 4/22/16

Qin LI Full name of additional inventor, if any
Additional inventor's signature Date 4/22/16

AOI_NDCal 4-24cv09041_ 00001774

§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application:

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.

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SCORE Placeholder Sheet for IFW Content

Application Number: 15137823 Document Date: 04/25/2016

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

- Drawings – Other than Black and White Line Drawings

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

To access the documents in the SCORE database, refer to instructions below.

At the time of document entry (noted above):

- Examiners may access SCORE content via the eDAN interface.
- Other USPTO employees can bookmark the current SCORE URL (http://Score.uspto.gov/ScoreAccessWeb/).
- External customers may access SCORE content via the Public and Private PAIR interfaces.

Form Revision Date: September 30, 2013

AOI_NDCal 4-24cv09041_ 00001776

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 15/137,823

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	280
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	600
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720
TOTAL CLAIMS (37 CFR 1.16(i))	20 minus 20 =	*			OR	x 80 =	0.00
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*				x 420 =	0.00
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	1600

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)	OR	RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

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

AOI_NDCal 4-24cv09041_ 00001777

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
15/137,823	04/25/2016	2883	1600	PAT260-018US	20	3

CONFIRMATION NO. 2275

27543
APPLIED OPTOELECTRONICS, INC.
13115 JESS PIRTLE BLVD.
SUGAR LAND, TX 77478

FILING RECEIPT

OC000000082784423

Date Mailed: 05/11/2016

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

Inventor(s)

I-Lung HO, Sugar Land, TX;
Zhengyu MIAO, Sugar Land, TX;
Qin LI, Houston, TX;

Applicant(s)

Applied Optoelectronics, Inc., Sugar Land, TX;

Power of Attorney: The patent practitioners associated with Customer Number 27543

Domestic Applications for which benefit is claimed - None.
A proper domestic benefit claim must be provided in an Application Data Sheet in order to constitute a claim for domestic benefit. See 37 CFR 1.76 and 1.78.

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 05/09/2016

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 15/137,823**

Projected Publication Date: 10/26/2017

Non-Publication Request: No

Early Publication Request: No

Title

TECHNIQUES FOR DIRECT OPTICAL COUPLING OF PHOTODETECTORS TO OPTICAL DEMULTIPLEXER OUTPUTS AND AN OPTICAL TRANSCEIVER USING THE SAME

Preliminary Class

385

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

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

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

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

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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Application	Document	Mailroom Date	Attorney Docket No.
15137823	APP.FILE.REC	05/11/2016	PAT260-018US

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/137,823	04/25/2016	I-Lung HO	PAT260-018US	2275

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APPLIED OPTOELECTRONICS, INC.
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ART UNIT	PAPER NUMBER
2636	

NOTIFICATION DATE	DELIVERY MODE
06/07/2017	ELECTRONIC

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