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(54) **THERMALLY ISOLATED MULTI-CHANNEL TRANSMITTER OPTICAL SUBASSEMBLY AND OPTICAL TRANSCEIVER MODULE INCLUDING SAME**

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CPC ***H04B 10/40*** (2013.01); ***H04B 10/506*** (2013.01); ***H04J 14/025*** (2013.01);
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USPC 385/31, 37, 88–92; 398/70, 139, 141, 398/158, 79, 82, 67, 68, 71, 72
See application file for complete search history.

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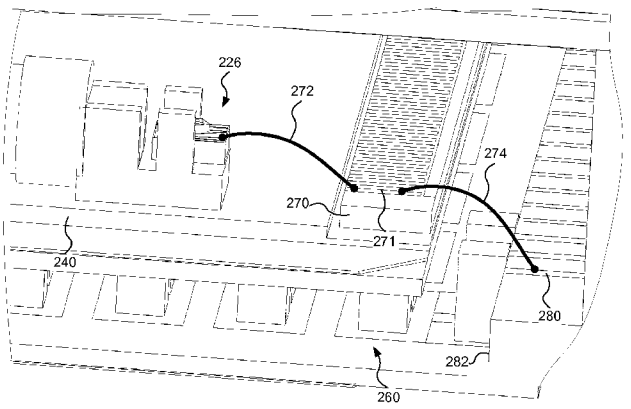
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(57) **ABSTRACT**

A thermally isolated multi-channel transmitter optical subassembly (TOSA) may be used in a multi-channel optical transceiver. The multi-channel TOSA generally includes an array of lasers optically coupled to an arrayed waveguide grating (AWG) to combine multiple optical signals at different channel wavelengths. The lasers, and possibly other components, are wire bonded to a thermal isolation bar. The thermal isolation bar provides an electrical connection to external circuitry and is thermally coupled to a temperature control device, such as a thermoelectric cooler (TEC). Thus, the thermal isolation bar electrically connects the lasers to the circuitry while preventing external heat from being conducted to the lasers from outside the TOSA. The optical transceiver may be used in a wavelength division multiplexed (WDM) optical system, for example, in an optical line terminal (OLT) in a WDM passive optical network (PON).

20 Claims, 4 Drawing Sheets



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IPR2026-00122

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G02B 6/42	(2006.01)
G02B 6/293	(2006.01)

(52) **U.S. Cl.**

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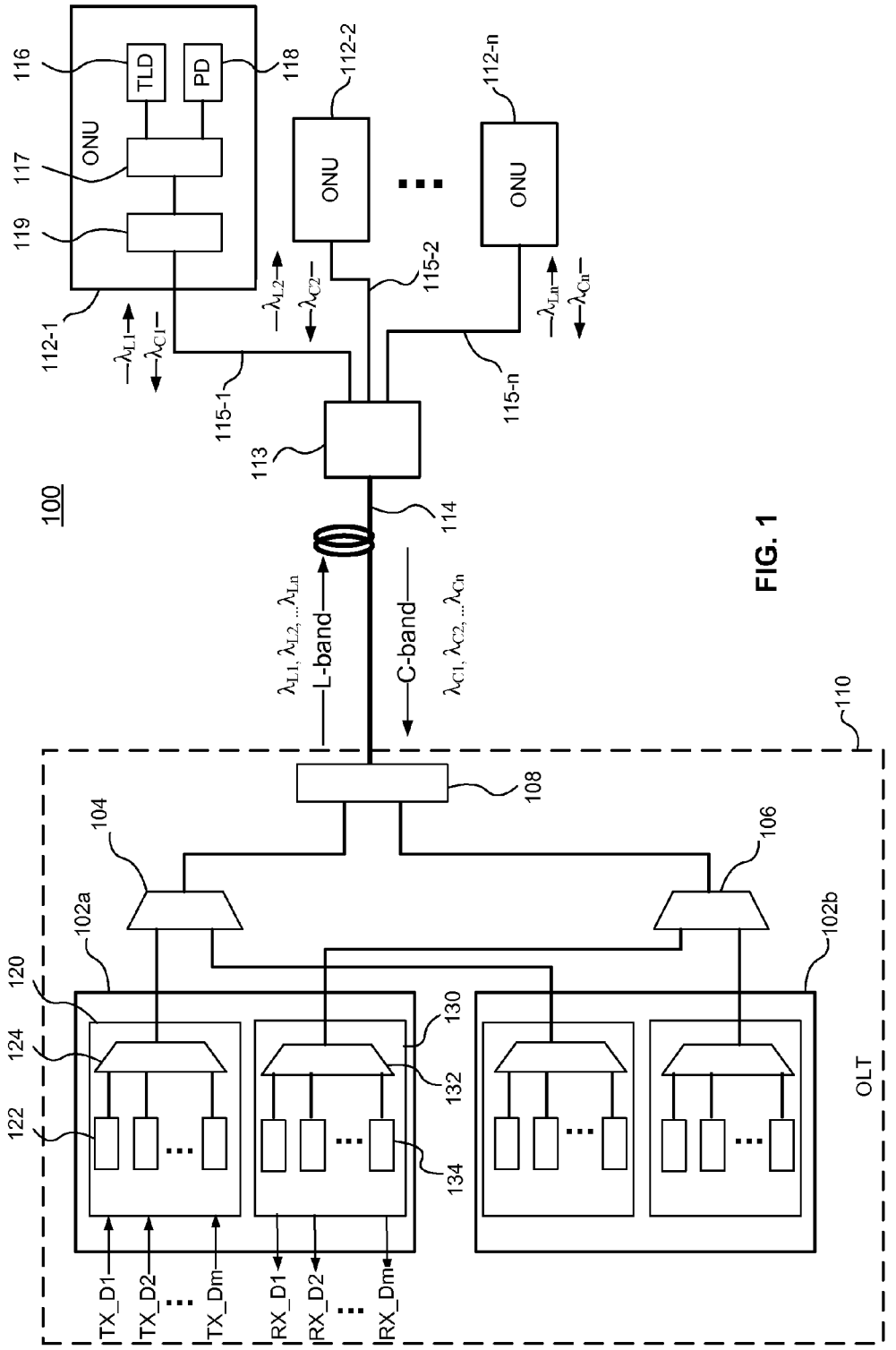

100
ONU
TLD
PD
116
117
118
119
112-1
112-2
112-n
115-1
115-2
115-n
113
114
L-band
C-band
108
110
104
106
102a
102b
120
122
124
130
132
134
OLT
TX_D1
TX_D2
TX_Dm
RX_D1
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RX_Dm

FIG. 1

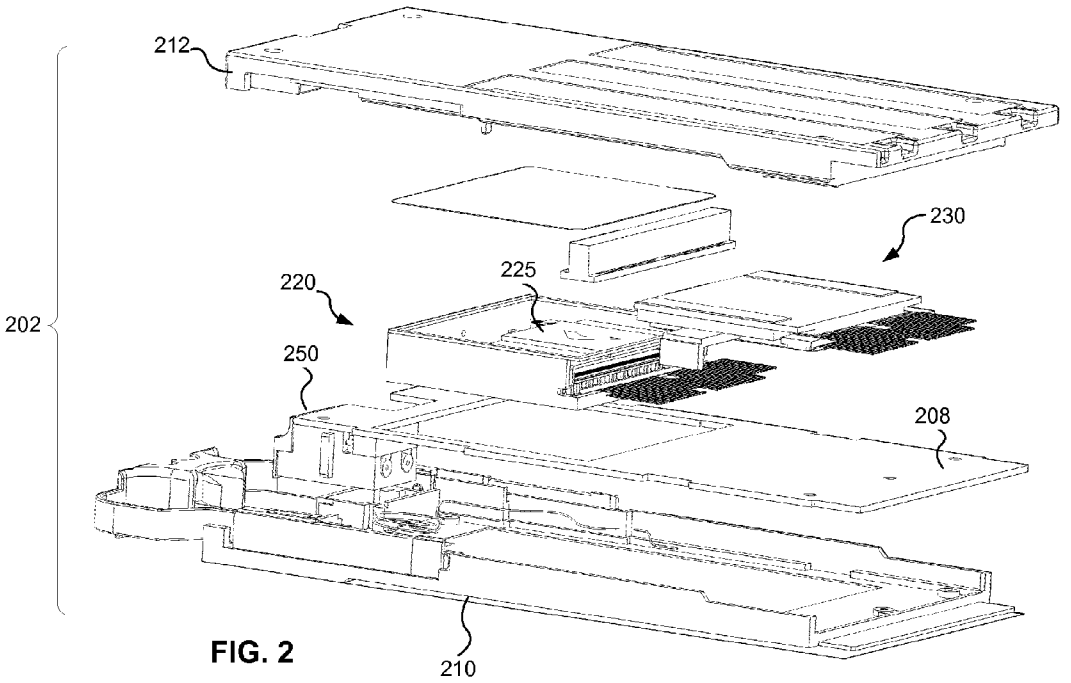

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FIG. 2

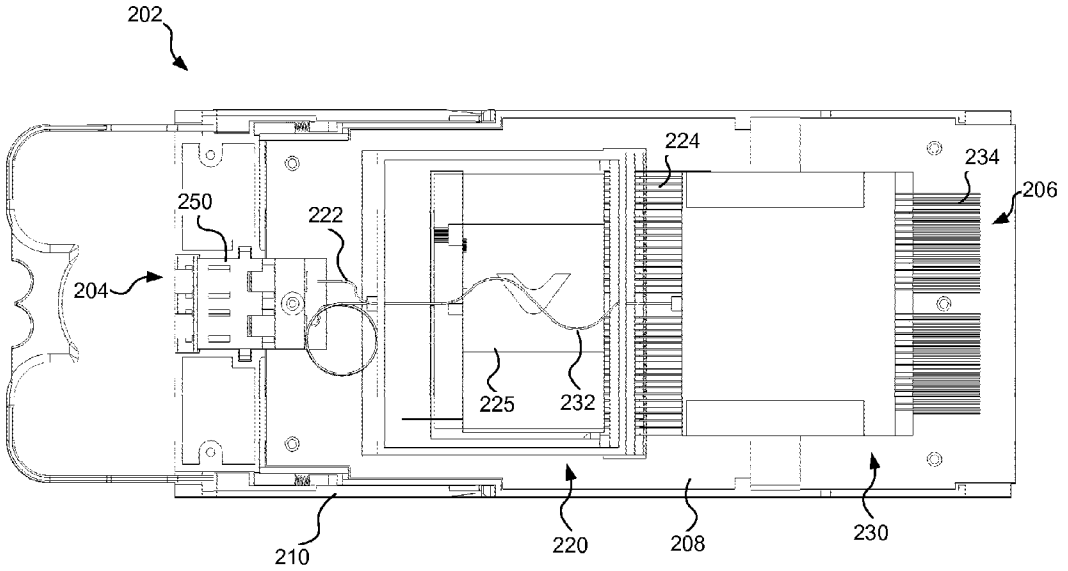

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FIG. 3

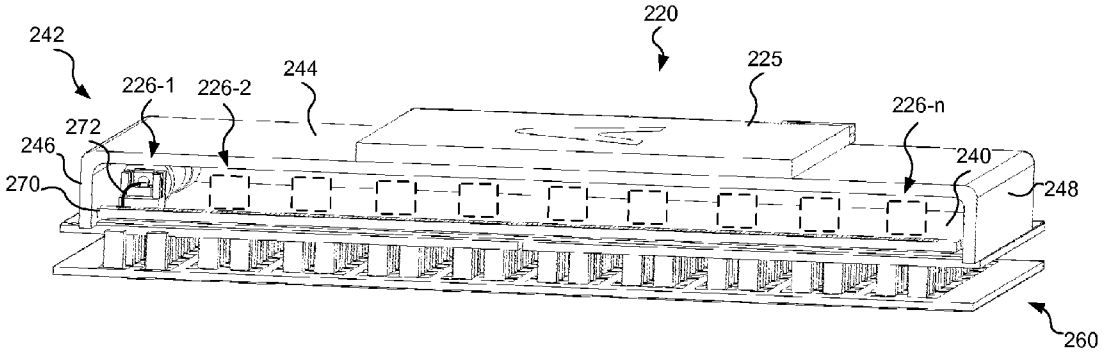

242
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244
226-1
226-2
226-n
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FIG. 4

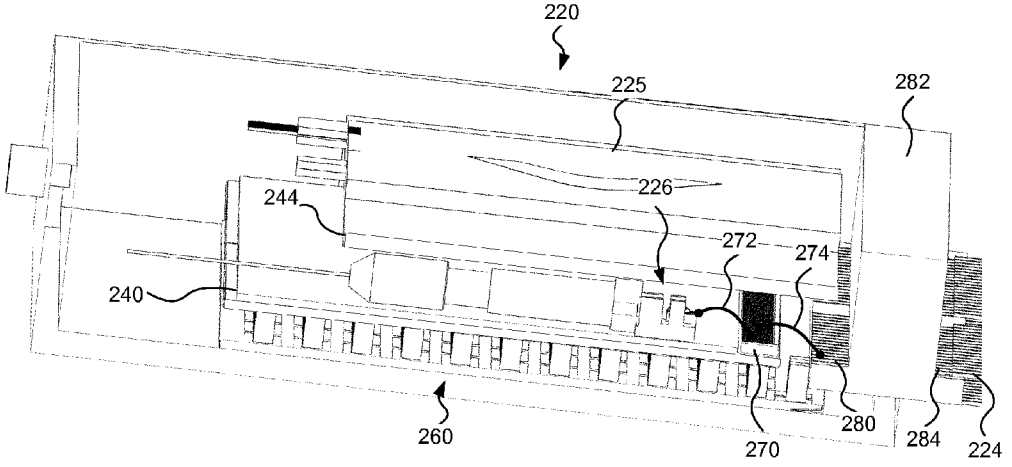

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FIG. 5

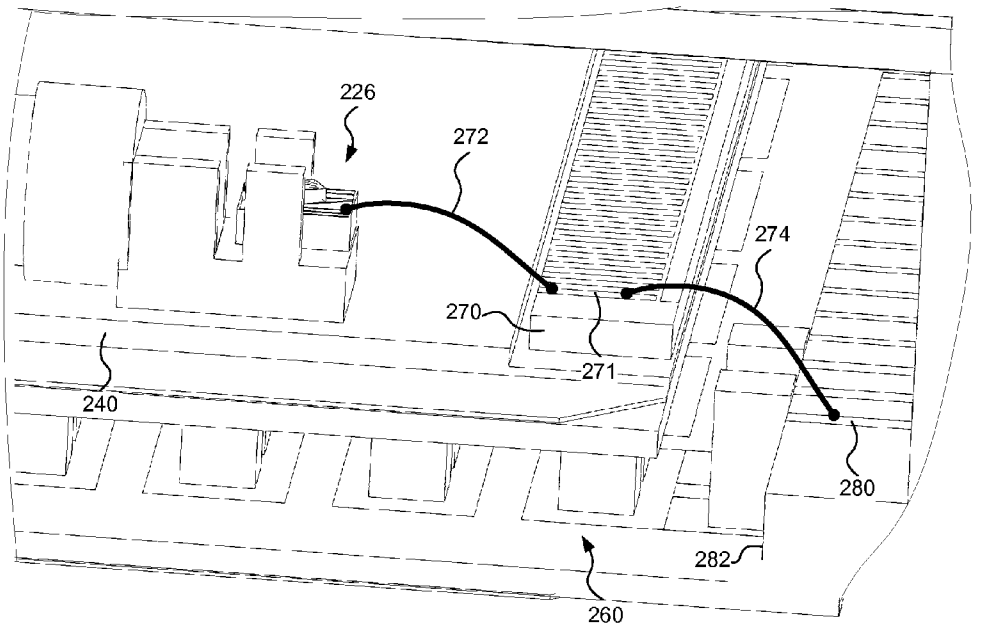

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FIG. 6

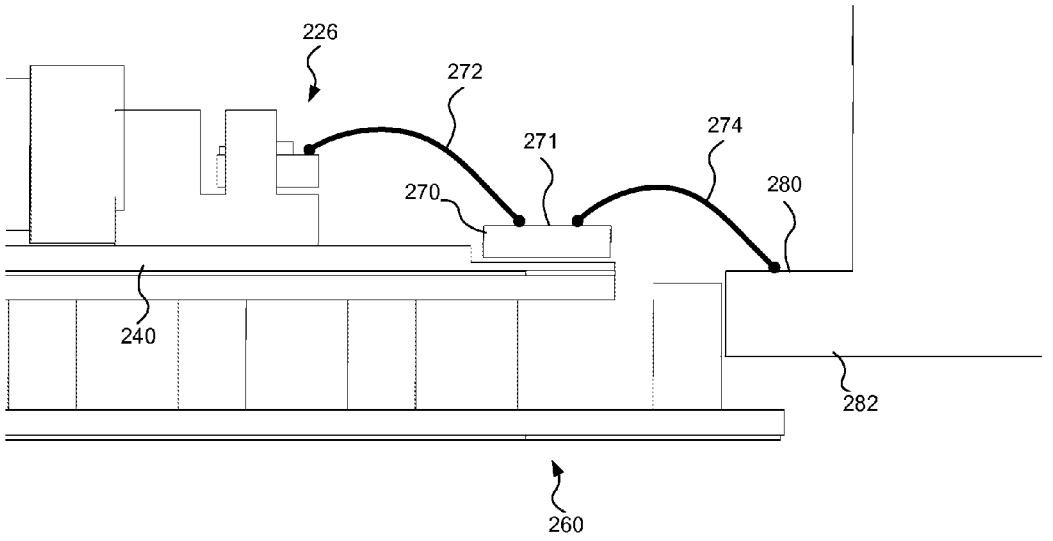

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FIG. 7

THERMALLY ISOLATED MULTI-CHANNEL TRANSMITTER OPTICAL SUBASSEMBLY AND OPTICAL TRANSCEIVER MODULE INCLUDING SAME

TECHNICAL FIELD

The present disclosure relates to multi-channel optical transmitters or transceivers and more particularly, to a thermally isolated multi-channel transmitter optical subassembly (TOSA).

BACKGROUND INFORMATION

Optical communications networks, at one time, were generally "point to point" type networks including a transmitter and a receiver connected by an optical fiber. Such networks are relatively easy to construct but deploy many fibers to connect multiple users. As the number of subscribers connected to the network increases and the fiber count increases rapidly, deploying and managing many fibers becomes complex and expensive.

A passive optical network (PON) addresses this problem by using a single "trunk" fiber from a transmitting end of the network, such as an optical line terminal (OLT), to a remote branching point, which may be up to 20 km or more. One challenge in developing such a PON is utilizing the capacity in the trunk fiber efficiently in order to transmit the maximum possible amount of information on the trunk fiber. Fiber optic communications networks may increase the amount of information carried on a single optical fiber by multiplexing different optical signals on different wavelengths using wavelength division multiplexing (WDM). In a WDM-PON, for example, the single trunk fiber carries optical signals at multiple channel wavelengths to and from the optical branching point and the branching point provides a simple routing function by directing signals of different wavelengths to and from individual subscribers. In this case, each subscriber may be assigned one or more of the channel wavelengths on which to send and/or receive data.

To transmit and receive optical signals over multiple channel wavelengths, the OLT in a WDM-PON may include a multi-channel transmitter optical subassembly (TOSA) and a multi-channel receiver optical subassembly (ROSA). One example of a TOSA includes an array of lasers optically coupled to an arrayed waveguide grating (AWG) to combine multiple optical signals at multiple channel wavelengths. The desired accuracy or precision of the wavelengths in a WDM-PON often depends on the number and spacing of the channel wavelengths and may be controlled in the TOSA by controlling temperature. OLT transceiver modules often are designed to fit a relatively small form factor. One challenge with such OLT transceiver modules is providing temperature control of the laser array and AWG in a relatively small space and with relatively low power consumption.

Another challenge is preventing external heat from adversely affecting the laser wavelengths. The lasers and other optoelectronic components in a multi-channel TOSA are often connected to circuitry by wire bonding. With multiple lasers in a multi-channel TOSA, hundreds of wire bonding connections may be used and linked to the environment external to the TOSA. External heat may thus be conducted to the lasers via the wire bonding and may affect the wavelengths of the lasers.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. **1** is a functional block diagram of a wavelength division multiplexed (WDM) passive optical network (PON) including at least one multi-channel optical transceiver, consistent with embodiments of the present disclosure.

FIG. **2** is an exploded view of a multi-channel optical transceiver including a thermally isolated multi-channel TOSA, consistent with an embodiment of the present disclosure.

FIG. **3** is a top view inside the multi-channel optical transceiver shown in FIG. **2**.

FIG. **4** is an end perspective view of one embodiment of a thermally isolated multi-channel TOSA.

FIG. **5** is a side perspective view of the thermally isolated multi-channel TOSA shown in FIG. **4** with a laser diode wire bonded to a thermal isolation bar.

FIG. **6** is an enlarged perspective view of a laser diode wire bonded to a thermal isolation bar in an embodiment of a thermally isolated multi-channel TOSA.

FIG. **7** is a side view of the laser diode wire bonded to the thermal isolation bar in an embodiment of a thermally isolated multi-channel TOSA.

DETAILED DESCRIPTION

A thermally isolated multi-channel transmitter optical subassembly (TOSA), consistent with embodiments described herein, may be used in a multi-channel optical transceiver. The multi-channel TOSA generally includes an array of lasers optically coupled to an arrayed waveguide grating (AWG) to combine multiple optical signals at different channel wavelengths. The lasers, and possibly other components, are wire bonded to a thermal isolation bar. The thermal isolation bar provides an electrical connection to external circuitry and is thermally coupled to a temperature control device, such as a thermoelectric cooler (TEC). Thus, the thermal isolation bar electrically connects the lasers to the circuitry while preventing external heat from being conducted to the lasers from outside the TOSA. The optical transceiver may be used in a wavelength division multiplexed (WDM) optical system, for example, in an optical line terminal (OLT) in a WDM passive optical network (PON).

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. 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. As used herein, "thermally coupled" refers to a direct or indirect connection or contact between two components resulting in heat being conducted from one component to the other component and "thermally isolated" refers to an arrangement where heat is prevented from being conducted to the isolated component from an external environment. In a thermally isolated multi-channel TOSA, for example, heat external to the TOSA is prevented from being conducted to one or more components in the TOSA.

Referring to FIG. **1**, a WDM-PON **100** including one or more multi-channel optical transceivers **102***a*, **102***b*, consistent with embodiments of the present disclosure, is shown and described. The WDM-PON **100** provides a point-to-multipoint optical network architecture using a WDM system.

According to one embodiment of the WDM-PON **100**, at least one optical line terminal (OLT) **110** may be coupled to a plurality of optical networking terminals (ONTs) or optical networking units (ONUs) **112-1** to **112-*n*** via optical fibers, waveguides, and/or paths **114**, **115-1** to **115-*n***. Although the OLT **110** includes two multi-channel optical transceivers **102*a***, **102*b*** in the illustrated embodiment, the OLT **110** may include one or more multi-channel optical transceivers.

The OLT **110** may be located at a central office of the WDM-PON **100**, and the ONUs **112-1** to **112-*n*** may be located in homes, businesses or other types of subscriber location or premises. A branching point **113** (e.g., a remote node) couples a trunk optical path **114** to the separate optical paths **115-1** to **115-*n*** to the ONUs **112-1** to **112-*n*** at the respective subscriber locations. The branching point **113** may include one or more passive coupling devices such as a splitter or optical multiplexer/demultiplexer. In one example, the ONUs **112-1** to **112-*n*** may be located about 20 km or less from the OLT **110**.

The WDM-PON **100** may also include additional nodes or network devices, such as Ethernet PON (EPON) or Gigabit PON (GPON) nodes or devices, coupled between the branching point **113** and ONUs **112-1** to **112-*n*** at different locations or premises. One application of the WDM-PON **100** is to provide fiber-to-the-home (FTTH) or fiber-to-the-premises (FTTP) capable of delivering voice, data, and/or video services across a common platform. In this application, the central office may be coupled to one or more sources or networks providing the voice, data and/or video.

In the WDM-PON **100**, different ONUs **112-1** to **112-*n*** may be assigned different channel wavelengths for transmitting and receiving optical signals. In one embodiment, the WDM-PON **100** may use different wavelength bands for transmission of downstream and upstream optical signals relative to the OLT **110** to avoid interference between the received signal and back reflected transmission signal on the same fiber. For example, the L-band (e.g., about 1565 to 1625 nm) may be used for downstream transmissions from the OLT **110** and the C-band (e.g., about 1530 to 1565 nm) may be used for upstream transmissions to the OLT **110**. The upstream and/or downstream channel wavelengths may generally correspond to the ITU grid. In one example, the upstream wavelengths may be aligned with the 100 GHz ITU grid and the downstream wavelengths may be slightly offset from the 100 GHz ITU grid.

The ONUs **112-1** to **112-*n*** may thus be assigned different channel wavelengths within the L-band and within the C-band. Transceivers or receivers located within the ONUs **112-1** to **112-*n*** may be configured to receive an optical signal on at least one channel wavelength in the L-band (e.g., λ_{L1}, λ_{L2}, . . . λ_{Ln}). Transceivers or transmitters located within the ONUs **112-1** to **112-*n*** may be configured to transmit an optical signal on at least one channel wavelength in the C-band (e.g., λ_{C1}, λ_{C2}, . . . λ_{Cn}). Other wavelengths and wavelength bands are also within the scope of the system and method described herein.

The branching point **113** may demultiplex a downstream WDM optical signal (e.g., λ_{L1}, λ_{L2}, . . . λ_n) from the OLT **110** for transmission of the separate channel wavelengths to the respective ONUs **112-1** to **112-*n***. Alternatively, the branching point **113** may provide the downstream WDM optical signal to each of the ONUs **112-1** to **112-*n*** and each of the ONUs **112-1** to **112-*n*** separates and processes the assigned optical channel wavelength. The individual optical signals may be encrypted to prevent eavesdropping on optical channels not assigned to a particular ONU. The branching point **113** also combines or multiplexes the upstream optical signals from the respective ONUs **112-1** to **112-*n*** for transmission as an upstream WDM optical signal (e.g., λ_{C1}, λ_{C2}, . . . λ_{Cn}) over the trunk optical path **114** to the OLT **110**.

One embodiment of the ONU **112-1** includes a laser **116**, such as a laser diode, for transmitting an optical signal at the assigned upstream channel wavelength (λ_{C1}) and a photodetector **118**, such as a photodiode, for receiving an optical signal at the assigned downstream channel wavelength (λ_{L1}). The laser **116** may include a tunable laser configured to be tuned to the assigned channel wavelength. This embodiment of the ONU **112-1** may also include a diplexer **117** coupled to the laser **116** and the photodetector **118** and a C+L band filter **119** coupled to the diplexer **117**, which allow the L-band channel wavelength (λ_{L1}) to be received by the ONU **112-1** and the C-band channel wavelength (λ_{C1}) to be transmitted by the ONU **112-1**.

The OLT **110** may be configured to generate multiple optical signals at different channel wavelengths (e.g., λ_{L1}, λ_{L2}, . . . λ_{Ln}) and to combine the optical signals into the downstream WDM optical signal carried on the trunk optical fiber or path **114**. Each of the OLT multi-channel optical transceivers **102*a***, **102*b*** may include a multi-channel transmitter optical subassembly (TOSA) **120** for generating and combining the optical signals at the multiple channel wavelengths. The OLT **110** may also be configured to separate optical signals at different channel wavelengths (e.g., λ_{C1}, λ_{C2}, . . . λ_{Cn}) from an upstream WDM optical signal carried on the trunk path **114** and to receive the separated optical signals. Each of the OLT multi-channel optical transceivers **102*a***, **102*b*** may thus include a multi-channel receiver optical subassembly (ROSA) **130** for separating and receiving the optical signals at multiple channel wavelengths.

One embodiment of the multi-channel TOSA **120** includes an array of lasers **122**, such as laser diodes, which may be modulated by respective RF data signals (TX_D**1** to TX_Dm) to generate the respective optical signals. The lasers **122** may be modulated using various modulation techniques including external modulation and direct modulation. An optical multiplexer **124**, such as an arrayed waveguide grating (AWG), combines the optical signals at the different respective downstream channel wavelengths (e.g., λ_{L1}, λ_{L2}, . . . λ_{Lm}). The TOSA **120** may also include a temperature control system for controlling temperature of both the lasers **122** and the multiplexer **124** to maintain a desired wavelength precision or accuracy and for isolating one or more components from external heat, as described in greater detail below.

In some embodiments, the lasers **122** may be tunable lasers that generate the optical signals at the respective channel wavelengths. In other embodiments, the lasers **122** may generate optical signals over a band of channel wavelengths and filtering and/or multiplexing techniques may be used to produce the assigned channel wavelengths. Examples of optical transmitters including a laser array and AWG are disclosed in greater detail in U.S. patent application Ser. No. 13/543,310 (U.S. Patent Application Pub. No. 2013/0016971), U.S. patent application Ser. No. 13/357,130 (U.S. Patent Application Pub. No. 2013/0016977), and U.S. patent application Ser. No. 13/595,505 (U.S. Patent Application Pub. No. 2013/0223844), all of which are fully incorporated herein by reference. In the illustrated embodiment, the OLT **110** further includes a multiplexer **104** for multiplexing the multiplexed optical signal from the multi-channel TOSA **120** in the multi-channel transceiver **102*a*** with a multiplexed optical signal from a multi-channel TOSA in the other multi-channel transceiver **102*b*** to produce the downstream aggregate WDM optical signal.

One embodiment of the multi-channel ROSA **130** includes a demultiplexer **132** for separating the respective upstream channel wavelengths (e.g., λ_{C1}, λ_{C2}, . . . λ_{Cn}). An array of photodetectors **134**, such as photodiodes, detects the optical signals at the respective separated upstream channel wavelengths and provides the received data signals (RX_D**1** to RX_Dm). In the illustrated embodiment, the OLT **110** further includes a demultiplexer **106** for demultiplexing the upstream WDM optical signal into first and second WDM optical signals provided to the respective multi-channel ROSA in each of the transceivers **102***a*, **102***b*. The OLT **110** also includes a diplexer **108** between the trunk path **114** and the multiplexer **104** and the demultiplexer **106** such that the trunk path **114** carries both the upstream and the downstream channel wavelengths. The transceivers **102***a*, **102***b* may also include other components, such as laser drivers, transimpedance amplifiers (TIAs), and control interfaces, used for transmitting and receiving optical signals.

In one example, each of the multi-channel optical transceivers **102***a*, **102***b* may be configured to transmit and receive 16 channels such that the WDM-PON **100** supports **32** downstream L-band channel wavelengths and 32 upstream C-band channel wavelengths. In one example, the downstream L-band link between the OLT transceivers **102***a*, **102***b* and the ONUs **112-1** to **112-***n* may support a power budget of at least about 26 dB and the upstream C-band link between the ONUs **112-1** to **112-***n* and the OLT transceivers **102***a*, **102***b* may support a power budget of at least about 23 dB. One example of the WDM-PON **100** may operate at 1.25 Gbaud using 8B/10B encoded on-off keying as the modulation scheme. Other data rates and modulation schemes may also be used.

As mentioned above, the upstream and downstream channel wavelengths may span a range of channel wavelengths on the 100 GHz ITU grid. Each of the transceivers **102***a*, **102***b*, for example, may cover 16 channel wavelengths in the L-band for the TOSA and 16 channel wavelengths in the C-band for the ROSA such that the transceivers **102***a*, **102***b* together cover 32 channels. Thus, the multiplexer **104** may combine 16 channels from one transceiver **102***a* with 16 channels from the other transceiver **102***b*, and the demultiplexer **106** may separate a 32 channel WDM optical signal into two 16 channel WDM optical signals. To facilitate use of the multiplexer **104** and the demultiplexer **106**, the range of channel wavelengths may skip channels (e.g., 2 channels) in the middle of the range. According to one example of a multi-channel optical transceiver used in the WDM-PON **100**, the desired wavelength precision or accuracy is ±0.05 nm, the desired operating temperature is between −5 and 70° C., and the desired power dissipation is about 16.0 W.

Referring to FIGS. **2** and **3**, one embodiment of a multi-channel optical transceiver module **202** including a thermally isolated multi-channel TOSA **220** is shown and described in greater detail. As discussed above, multiple multi-channel transceiver modules may be used in an OLT of a WDM-PON to cover a desired channel range. The transceiver module **202** and the multi-channel TOSA **220** within the transceiver module **202** may thus be designed to have a relatively small form factor with minimal space. The multi-channel optical transceiver module **202** generally provides an optical input and output at one end **204** and electrical input and output at another end **206**. The transceiver module **202** includes a transceiver housing **210** containing the thermally isolated multi-channel TOSA **220**, a multi-channel ROSA **230**, and a dual fiber type direct link adapter **250** directly linked to the TOSA **220** and the ROSA **230** for providing the optical input and output.

The dual fiber type direct link adapter **250** is coupled to the TOSA **220** and to the ROSA **230** with respective optical fibers **222**, **232** to provide the direct link between the adapter **250** and both the TOSA **220** and the ROSA **230**. The dual fiber type direct link adapter **250** is also configured to receive pluggable optical connectors, such as LC connectors (not shown), to connect the TOSA **220** and ROSA **230**, respectively, to fiber optic cables (not shown). When the pluggable optical connectors are plugged into the dual fiber type direct link adapter **250**, the adapter **250** establishes an optical coupling between the TOSA **220** and the ROSA **230** and the respective optical fibers in the fiber-optic cables, which carry the optical signals to and from the transceiver.

The thermally isolated multi-channel TOSA **220** includes an array of lasers (not shown in FIGS. **2** and **3**) coupled to an AWG **225**. A temperature control system, as will be described in greater detail below, controls the temperature of both the laser array and the AWG **225** using the same temperature control device. In one example, the temperature is maintained in a range between −5 and 70° C. to maintain a wavelength precision or accuracy of about ±0.05 nm. The temperature control system also provides thermal isolation to isolate at least the lasers from heat external to the TOSA **220**.

The transceiver module **202** may also include one or more printed circuit boards **208** coupled to the TOSA **220** and/or ROSA **230**. The printed circuit board(s) **208** may include circuitry and electronic components such as laser drivers, transimpedance amplifiers (TIAs), and control interfaces. The TOSA **220** is coupled to conductive leads **224** for carrying the electronic signals including the data to be transmitted by the TOSA **220**. The ROSA **230** is coupled to the conductive leads **234** for carrying the electronic signals including the data received by the ROSA **230**.

A top housing portion **212** encloses the TOSA **220**, the ROSA **230**, the adapter **250**, the optical fibers **222**, **232**, and other components within the housing **210**. The transceiver housing **210** may have a width of less than about 55 mm, a length of less than about 130 mm, and a height of less than about 10 mm. More specifically, one example of a transceiver housing **210** may have a width of 54.6 mm, a length of 110 mm, and a height of about 9.8 mm. Within the transceiver module **202**, the thermally isolated multi-channel TOSA **220** has a width, a height and length capable of fitting within the transceiver housing **210**.

Referring to FIGS. **4** and **5**, an embodiment of the thermally isolated multi-channel TOSA **220** is described in greater detail. This embodiment of the thermally isolated multi-channel TOSA **220** includes an array of lasers **226-1** to **226-***n* (only laser **226-1** is shown in detail) optically coupled to the AWG **225**. The lasers **226-1** to **226-***n* may be optically coupled to the AWG **225**, for example, using low bending loss optical fibers (not shown). Each laser **226-1** may be provided as a laser package including, but not limited to, a laser diode chip mounted on a laser mounting structure. The laser package may also include optical components, such as a lens for optically coupling the laser light into a respective one of the optical fibers, and/or optoelectronic components, such as a monitor photodiode. The AWG **225** may include an AWG chip such as the type used for WDM, Coarse WDM (CWDM), or Dense (DWDM) multiplexing or demultiplexing.

In this embodiment, the array of lasers **226-1** to **226-***n* are supported on a laser array tray **240** and the AWG **225** is supported on an AWG tray **242**. Both the laser array tray **240** and the AWG tray **242** may be thermally coupled to the same temperature control device **260** such that the temperature control device **260**, the laser array tray **240** and the AWG tray

242 provide a temperature control system for the TOSA within a relatively small space. The temperature control device 260 may be a thermoelectric cooler, such as a Peltier device, for cooling the array of lasers 226-1 to 226-*n* and the AWG 225. In this embodiment, the AWG tray 242 supports the AWG 225 above the lasers 226-1 to 226-*n*. By using the same temperature control device and supporting the AWG 225 above the lasers 226-1 to 226-*n*, the desired temperature range can be maintained with relatively low power consumption and within a relatively small space.

In the illustrated embodiment, the AWG tray 242 includes a supporting portion 244 that supports the AWG 225 and side portions 246, 248 that hold the supporting portion 244 above the lasers 226-1 to 226-*n*. The laser array tray 240 may be a relatively flat plate that fits between the side portions 246, 248 such that both the laser array tray 240 and the side portions 246, 248 of the AWG tray 242 are separately thermally coupled to the temperature control device 260 (e.g., to the cold side of a TEC). The laser array tray 240 and the side portions 246, 248 of the AWG tray 242 may each directly contact the temperature control device 260 or may be thermally coupled through another thermally conductive material. Because a larger surface area of the laser array tray 240 is thermally coupled to the temperature control device 260, the temperature of the lasers 226-1 to 226-*n* may be controlled more precisely. Although the illustrated embodiment shows a particular shape for the trays 240, 242, other shapes may also be used to support the lasers 226-1 to 226-*n* and the AWG 225 and to provide thermal coupling to the same temperature control device 260. Each of the trays 240, 242 may also be formed as one piece or multiple pieces.

Both of the trays 240, 242 may be made of a thermally conductive material having a thermal conductivity greater than 60 W/(m·K) and more specifically greater than 80 W/(m·K). The trays 240, 242 may be made, for example of copper or zinc. At least a portion of the trays 240, 242 may also be gold plated, for example, to facilitate soldering to the trays 240, 242. In one example, the laser array tray 240 is made of AlN with a thermal conductivity of about 170 W/(m·K) and the AWG tray 242 is made of copper with Au plating and having a thermal conductivity of greater than 300 W/(m·K).

As shown in greater detail in FIGS. 6 and 7, the thermally isolated multi-channel TOSA 220 may also include a thermal isolation bar 270 thermally coupled to the temperature control device 260 (e.g., to the cold side of a TEC). In particular, the thermal isolation bar 270 may directly contact the temperature control device 260 or may contact the laser array tray 240. In the illustrated embodiment, the thermal isolation bar 270 extends across the array of lasers 226-1 to 226-*n* from one side to the other side of the TOSA 220. In other embodiments, the thermal isolation bar 270 may include multiple sections and/or may extend across only a portion of the TOSA 220. Each of the lasers 226 (and/or other optoelectronic components) is wire bonded with at least one wire 272 to a conductive pad 271 on the thermal isolation bar 270. Although a single laser 226 is shown with a single wire 272, multiple wires 272 may be used to wire bond each of the lasers (e.g., lasers 226-1 to 226-*n* shown in FIG. 4) to separate conductive pads on the thermal isolation bar 270. Although the thermal isolation bar 270 is shown having a rectangular shape, other shapes and configurations are possible.

The thermal isolation bar 270 provides an electrical connection between the lasers 226 and external circuitry, such as the printed circuit board 208. As shown, for example, the thermal isolation bar 270 is wire bonded with wires 274 to conductive pads 280 located on a TOSA housing portion 282. The conductive pads 280 are electrically connected to circuitry, for example, via conductive traces or paths 284 extending through the housing portion 282 and via the conductive leads 224 (see FIG. 5). Multiple wires 274 may be used between respective conductive pads 271 on the thermal isolation bar 270 and the conductive pads 280 on the housing portion 282 to provide multiple electrical connections between each of the lasers in a laser array and the circuitry. Although a specific arrangement providing an electrical connection to external circuitry is illustrated and described, other arrangements may also provide an electrical connection to the circuitry.

Because the thermal isolation bar 270 is thermally coupled to the temperature control device 260, the temperature of the thermal isolation bar 270 may be controlled (e.g., by cooling or heating) to prevent heat from being conducted from the pads 280, which are linked to the external environment, to the lasers 226. The thermal isolation bar 270 thus isolates the lasers 226 from the external heat generated in the environment external to the TOSA 220 while allowing the lasers 226 to be electrically connected to circuitry outside of the TOSA 220. The thermal isolation bar 270 may be made of a thermally conductive material having a thermal conductivity greater than 60 W/(m·K), such as, for example, aluminum nitride (AlN). The conductive traces or paths on the thermal isolation bar 270 may include gold, for example, to facilitate solderability.

Accordingly, a thermally isolated multi-channel TOSA, consistent with embodiments described herein, allows multiple lasers in the TOSA to be electrically connected with circuitry outside of the TOSA while preventing heat from being conducted to the lasers via the electrical connections. Thus, the multi-channel TOSA may provide precise channel wavelengths by controlling temperature with relatively low power consumption and in a relatively small space.

Consistent with an embodiment, a multi-channel transceiver module includes a transceiver housing and a thermally isolated multi-channel transmitter optical subassembly (TOSA) located in the transceiver housing. The TOSA is configured to transmit a wavelength division multiplexed (WDM) optical signal on multiple channel wavelengths. The TOSA includes an array of lasers configured to generate laser light, wherein each of the lasers is associated with different respective optical channels. The TOSA also includes a temperature control device and a thermal isolation bar thermally coupled to the temperature control device. The thermal isolation bar is wire bonded to the lasers and electrically connected to circuitry outside of the TOSA such that the thermal isolation bar electrically connects the lasers to the circuitry outside of the TOSA while preventing external heat from being conducted to the lasers from outside the TOSA. The multi-channel transceiver module further includes a multi-channel receiver optical subassembly (ROSA) located in the transceiver housing. The ROSA is configured to receive a wavelength division multiplexed (WDM) optical signal on multiple channel wavelengths.

Consistent with another embodiment, a thermally isolated multi-channel transmitter optical subassembly (TOSA) includes a TOSA housing and an array of lasers located in the TOSA housing and configured to generate laser light, wherein each of the lasers are associated with different respective optical channels. The thermally isolated multi-channel TOSA also includes an arrayed waveguide grating (AWG) located in the TOSA housing and optically coupled to the array of lasers. The AWG is configured to combine the laser light at different respective channel wavelengths. The thermally isolated multi-channel TOSA further includes a

temperature control device located in the TOSA housing and a thermal isolation bar located in the TOSA housing and thermally coupled to the temperature control device. The thermal isolation bar is wire bonded to the lasers and electrically connected to circuitry outside of the TOSA housing such that the thermal isolation bar electrically connects the lasers to the circuitry while preventing external heat from being conducted to the lasers from outside the TOSA.

Consistent with a further embodiment, an optical line terminal includes at least first and second multi-channel transceivers. Each of the multi-channel transceivers includes a transceiver housing and a thermally isolated multi-channel transmitter optical subassembly (TOSA) located in the transceiver housing. The TOSA is configured to transmit a wavelength division multiplexed (WDM) optical signal on multiple channel wavelengths. The TOSA includes an array of lasers configured to generate laser light, wherein each of the lasers is associated with different respective optical channels. The TOSA also includes a temperature control device and a thermal isolation bar thermally coupled to the temperature control device. The thermal isolation bar is wire bonded to the lasers and electrically connected to circuitry outside of the TOSA such that the thermal isolation bar electrically connects the lasers to the circuitry outside of the TOSA while preventing external heat from being conducted to the lasers from outside the TOSA. The multi-channel transceiver module further includes a multi-channel receiver optical subassembly (ROSA) located in the transceiver housing. The ROSA is configured to receive a wavelength division multiplexed (WDM) optical signal on multiple channel wavelengths.

While the principles of the invention 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 invention. Other embodiments are contemplated within the scope of the present invention 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 invention, which is not to be limited except by the following claims.

What is claimed is:

1. A multi-channel transceiver module comprising:
- a transceiver housing;
- a thermally isolated multi-channel transmitter optical subassembly (TOSA) located in the transceiver housing, the TOSA being configured to transmit a wavelength division multiplexed (WDM) optical signal on multiple channel wavelengths, the TOSA comprising:
  - an array of lasers configured to generate laser light, wherein each of the lasers is associated with different respective optical channels;
  - a temperature control device; and
  - a thermal isolation bar thermally coupled to the temperature control device, wherein the thermal isolation bar is wire bonded to the lasers and electrically connected to circuitry outside of the TOSA such that the thermal isolation bar electrically connects the lasers to the circuitry outside of the TOSA while preventing external heat from being conducted to the lasers from outside the TOSA; and
- a multi-channel receiver optical subassembly (ROSA) located in the transceiver housing, the ROSA being configured to receive a wavelength division multiplexed (WDM) optical signal on multiple channel wavelengths.

2. The multi-channel transceiver module of claim **1** wherein the temperature control device is a thermoelectric cooler.

3. The multi-channel transceiver module of claim **1** wherein the thermal isolation bar is wire bonded to conductive pads on a housing portion of the TOSA.

4. The multi-channel transceiver module of claim **3** wherein the conductive pads are electrically connected to respective conductive leads extending from the TOSA.

5. The multi-channel transceiver module of claim **1** further comprising an arrayed waveguide grating (AWG) coupled to each of the lasers and configured to combine the laser light at different respective channel wavelengths.

6. The multi-channel transceiver module of claim **5** wherein the AWG is supported above the array of lasers.

7. The multi-channel transceiver module of claim **1** wherein the thermal isolation bar is made of a material having a thermal conductivity greater than 60 W/(m·K).

8. The multi-channel transceiver module of claim **1** wherein the thermal isolation bar is made of aluminum nitride.

9. The multi-channel transceiver module of claim **1** wherein the thermal isolation bar extends across the TOSA.

10. A thermally isolated multi-channel transmitter optical subassembly (TOSA) comprising:
- a TOSA housing;
- an array of lasers located in the TOSA housing and configured to generate laser light, wherein each of the lasers are associated with different respective optical channels;
- an arrayed waveguide grating (AWG) located in the TOSA housing and optically coupled to the array of lasers, the AWG being configured to combine the laser light at different respective channel wavelengths;
- a temperature control device located in the TOSA housing; and
- a thermal isolation bar located in the TOSA housing and thermally coupled to the temperature control device, wherein the thermal isolation bar is wire bonded to the lasers and electrically connected to circuitry outside of the TOSA housing such that the thermal isolation bar electrically connects the lasers to the circuitry while preventing external heat from being conducted to the lasers from outside the TOSA.

11. The thermally isolated multi-channel TOSA of claim **10**, wherein the thermal isolation bar is wire bonded to conductive pads on a portion of the TOSA housing.

12. The thermally isolated multi-channel TOSA of claim **10**, wherein the temperature control device is a thermoelectric cooler.

13. The thermally isolated multi-channel TOSA of claim **12** further comprising:
- a laser array tray supporting the array of lasers and thermally coupled to the temperature control device; and
- an AWG tray supporting the AWG above the lasers and thermally coupled to the temperature control device.

14. The thermally isolated multi-channel TOSA of claim **13** wherein the AWG tray includes a supporting portion and side portions extending from the supporting portion to contact the temperature control device, wherein the side portions hold the supporting portion above the array of lasers.

15. The thermally isolated multi-channel TOSA of claim **13** wherein the laser array tray is made of a material having a thermal conductivity greater than 60 W/(m·K), and wherein the AWG tray is made of a material having a thermal conductivity greater than 60 W/(m·K).

16. The thermally isolated multi-channel TOSA of claim **10** wherein the thermal isolation bar is made of a material having a thermal conductivity greater than 60 W/(m·K).

17. The thermally isolated multi-channel TOSA of claim **10** wherein the thermal isolation bar is made of aluminum nitride.

18. An optical line terminal comprising:

at least first and second multi-channel transceivers, each of the multi-channel transceivers comprising:

a transceiver housing;

a thermally isolated multi-channel transmitter optical subassembly (TOSA) located in the transceiver housing, the TOSA being configured to transmit a wavelength division multiplexed (WDM) optical signal on multiple channel wavelengths, the TOSA comprising:

an array of lasers configured to generate laser light, wherein each of the lasers are associated with different respective optical channels;

a temperature control device; and

a thermal isolation bar thermally coupled to the temperature control device, wherein the thermal isolation bar is wire bonded to the lasers and electrically connected to circuitry outside of the TOSA such that the thermal isolation bar electrically connects the lasers to the circuitry outside of the TOSA while preventing external heat from being conducted to the lasers from outside the TOSA; and

a multi-channel receiver optical subassembly (ROSA) located in the transceiver housing, the ROSA being configured to receive a wavelength division multiplexed (WDM) optical signal on multiple channel wavelengths.

19. The optical line terminal of claim **18** wherein the temperature control device is a thermoelectric cooler.

20. The optical line terminal of claim **18** wherein the thermal isolation bar is wire bonded to conductive pads on a housing portion of the TOSA.

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