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(54) MULTI-CHANNEL TRANSMITTER OPTICAL SUBASSEMBLY (TOSA) WITH OPPOSING PLACEMENT OF TRANSISTOR OUTLINE (TO) CAN LASER PACKAGES

(71) Applicant: **Applied Optoelectronics, Inc.**, Sugar Land, TX (US)

(72) Inventors: **I-Lung Ho**, Sugar Land, TX (US); **Kai-Sheng LIN**, Sugar Land, TX (US); **Chong WANG**, Stafford, TX (US)

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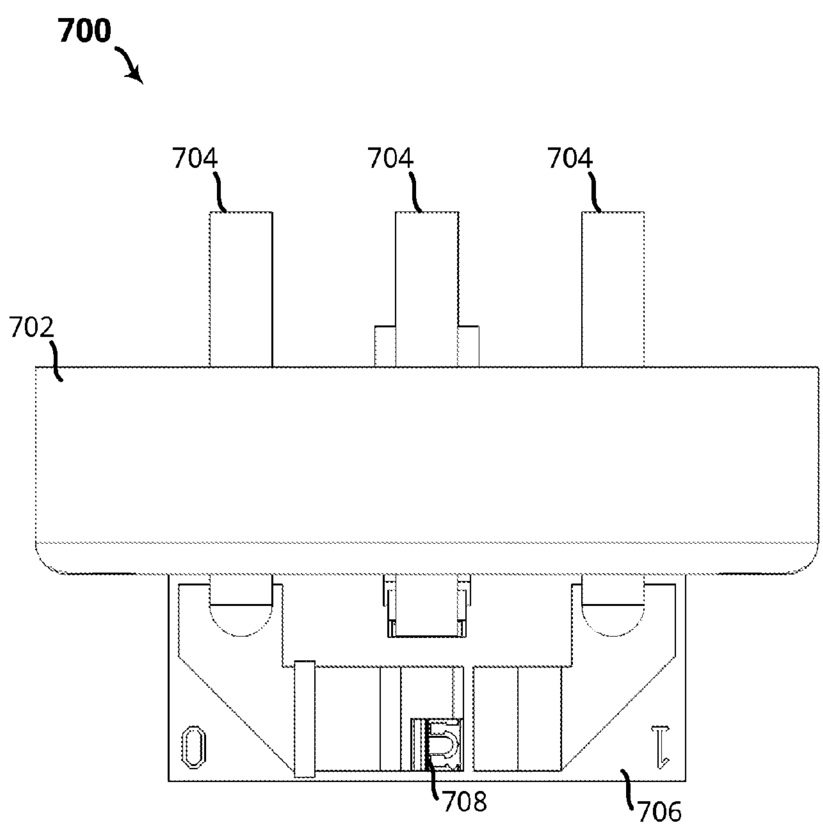
(57) **ABSTRACT**

A multi-channel transmitter optical subassembly (TOSA) including staggered transistor outline (TO) can laser package placement to provide enhanced coupling and optical power is disclosed, and may be used in an optical transceiver for transmitting an optical signal. The TOSA comprises a housing that includes plurality of sidewall openings with each sidewall opening configured to couple to a TO can laser package to provide coarse wavelength division multiplexing. The housing includes at least first and second sidewall openings on a first sidewall, and a third sidewall opening disposed on a sidewall opposing the first sidewall and being positioned at generally a mid-point between the first and second sidewall openings. This staggered and opposing sidewall opening arrangement allows an increased distance between adjacent sidewall openings, and thus, the TOSA may increase optical power and yield by providing additional space for performing post-attachment alignment of TO can laser packages.



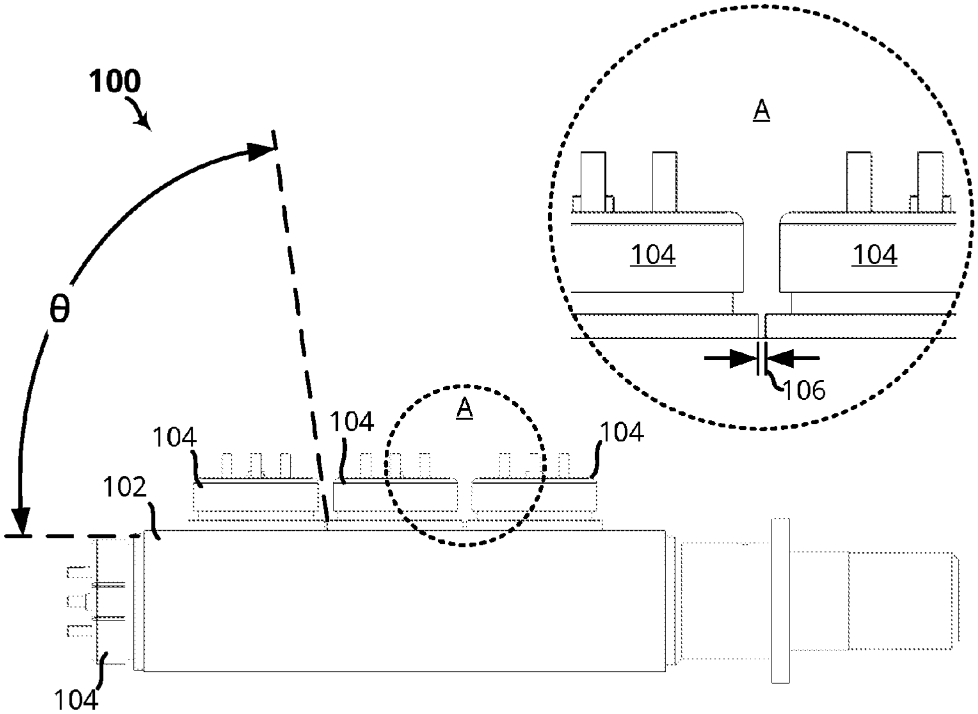


FIG. 1

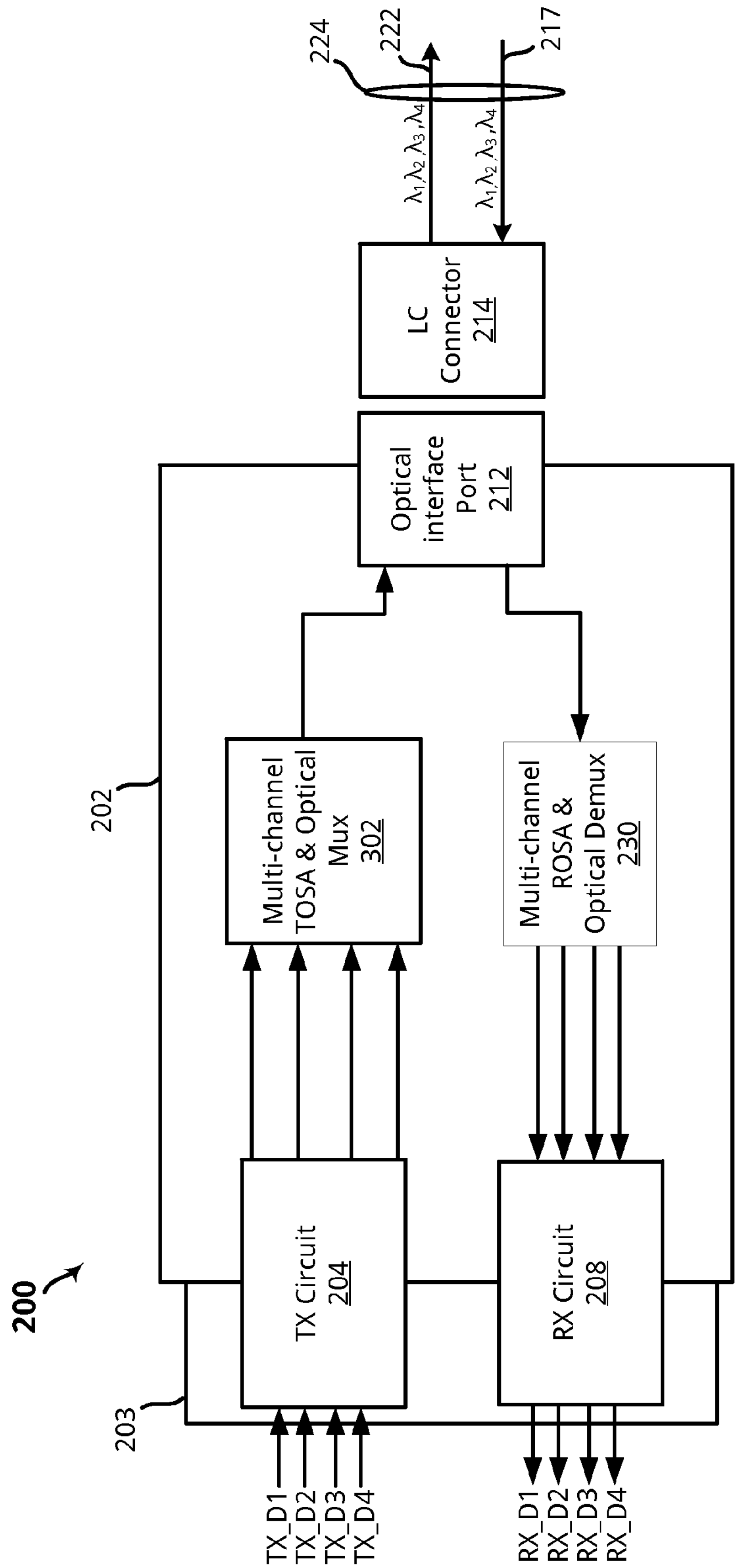

200
202
203
224
222
217
$\lambda_1,\lambda_2,\lambda_3,\lambda_4$
$\lambda_1,\lambda_2,\lambda_3,\lambda_4$
LC Connector 214
Optical interface Port 212
Multi-channel TOSA & Optical Mux 302
Multi-channel ROSA & Optical Demux 230
TX Circuit 204
RX Circuit 208
TX_D1
TX_D2
TX_D3
TX_D4
RX_D1
RX_D2
RX_D3
RX_D4

FIG. 2

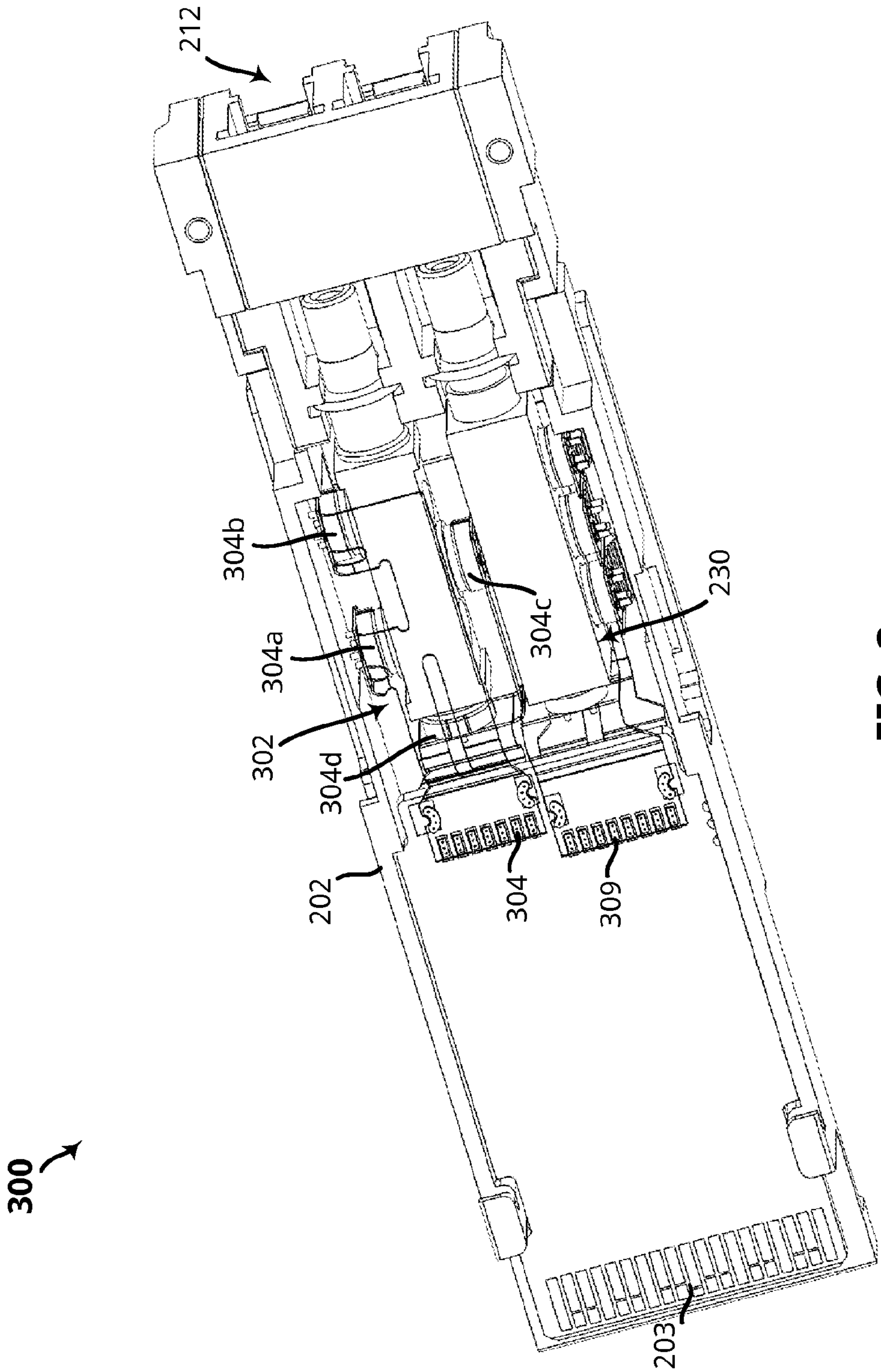


FIG. 3

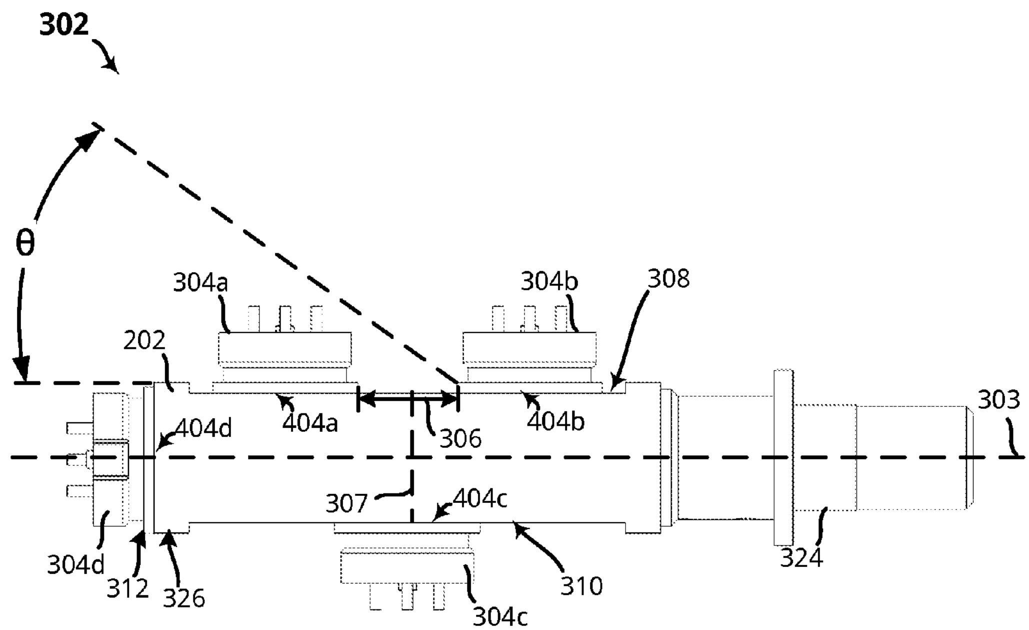

302
θ
304a
304b
308
202
303
404d
404a
306
404b
307
404c
304d
312
326
310
324
304c

FIG. 4A

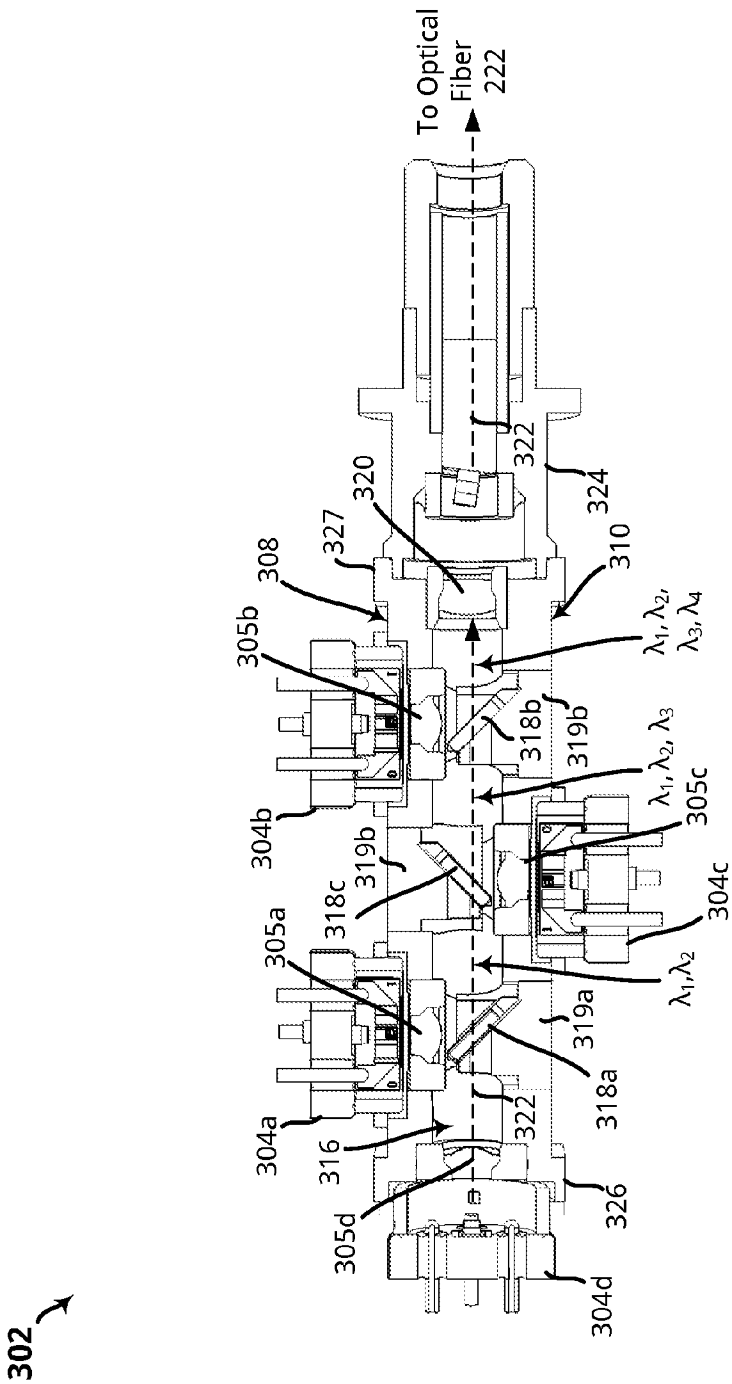

To Optical Fiber 222
320
322
324
327
308
310
305b
$\lambda_1, \lambda_2, \lambda_3, \lambda_4$
318b
319b
304b
$\lambda_1, \lambda_2, \lambda_3$
305c
319b
318c
304c
305a
λ_1,λ_2
319a
318a
322
304a
316
326
305d
304d
302

FIG. 4B

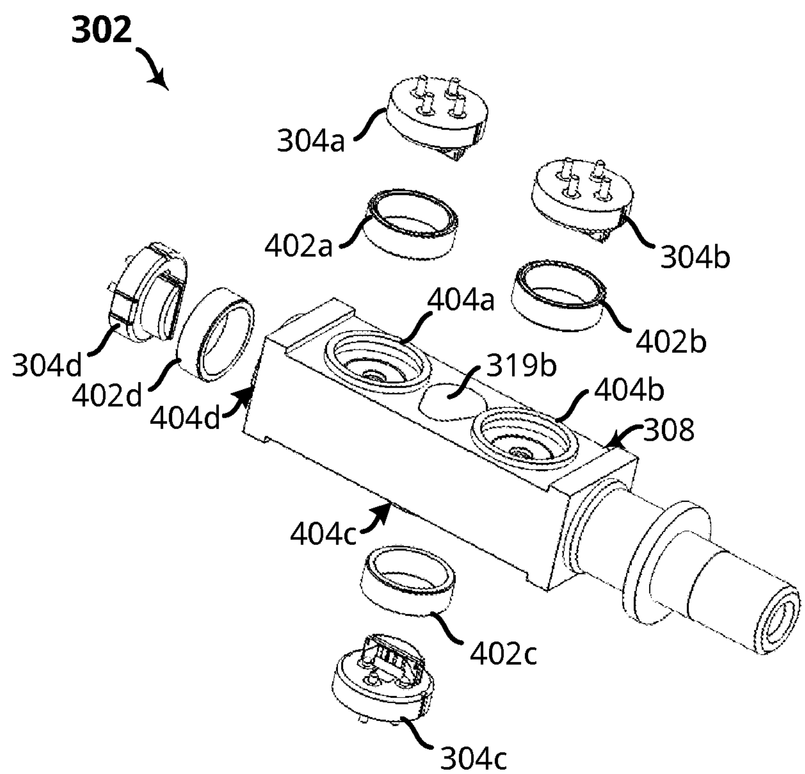

302
304a
304b
402a
402b
404a
304d
402d
319b
404b
404d
308
404c
402c
304c

FIG. 5

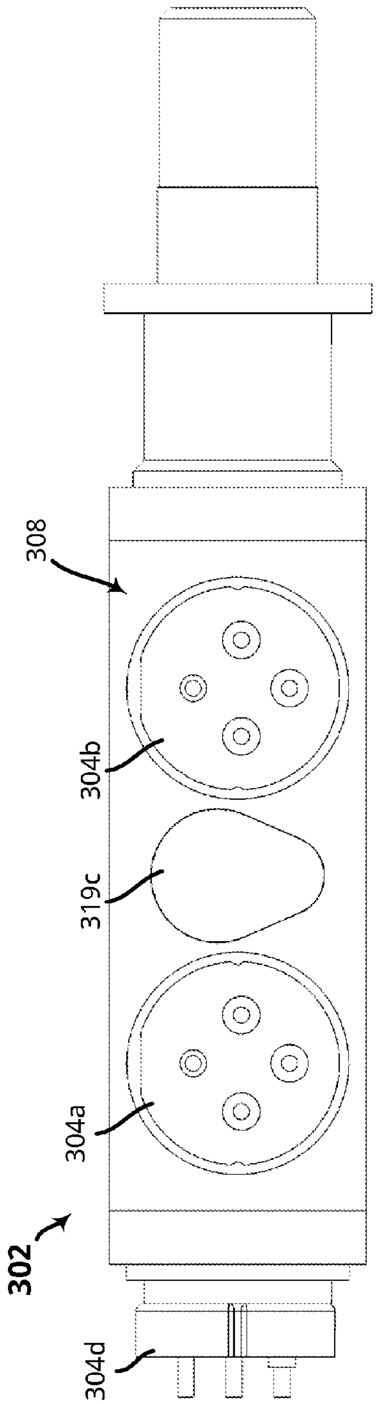


FIG. 6A

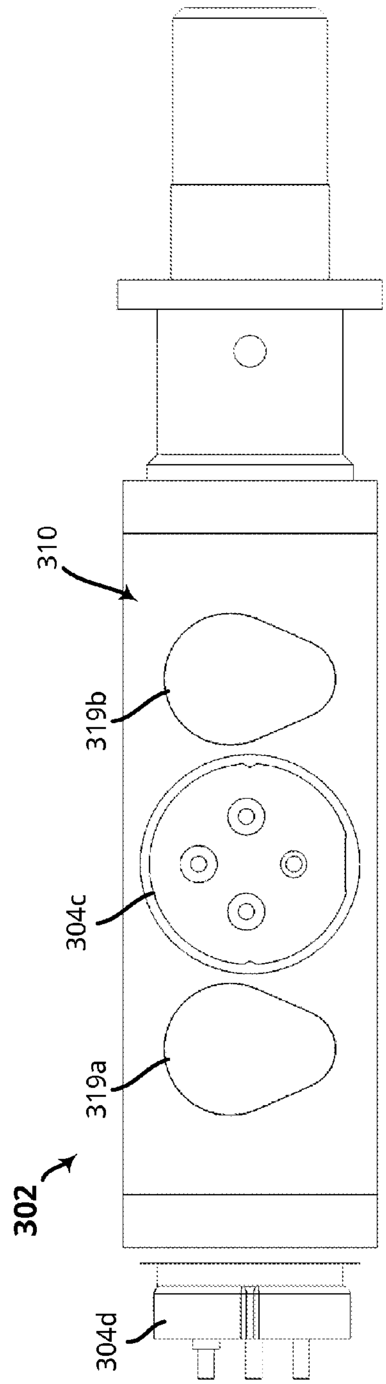


FIG. 6B

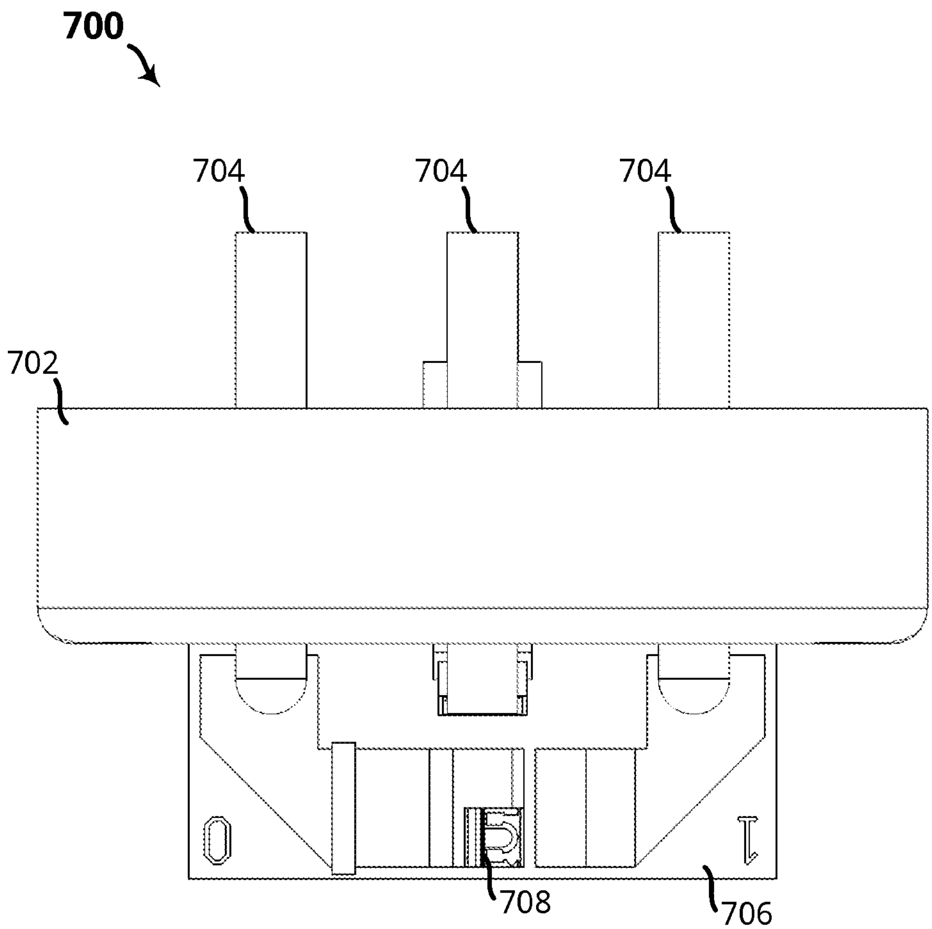


FIG. 7

MULTI-CHANNEL TRANSMITTER OPTICAL SUBASSEMBLY (TOSA) WITH OPPOSING PLACEMENT OF TRANSISTOR OUTLINE (TO) CAN LASER PACKAGES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is related to co-pending U.S. application Ser. No. ______ (Attorney Docket No. PAT257US) titled "Receiver Optical Subassembly Housing With Sidewall Receptacle To Provide Electrical Isolation Between An Adjacent Transmitter Optical Subassembly in a Transceiver Housing" filed concurrently herewith, which is herein incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to laser packages, and more particularly, to a transmitter optical subassembly (TOSA) with opposing placement of transistor outline (TO) can laser packages for coarse wavelength division multiplexing (CWDM) for use in an optical transceiver.

BACKGROUND INFORMATION

[0003] Optical transceivers are used to transmit and receive optical signals for various applications including, without limitation, internet data center, 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.

[0004] Optical transceiver modules can include one or more transmitter optical subassemblies (TOSAs) and receiver optical subassemblies (ROSAs). TOSAs, for example, can include a plurality of transistor outline (TO) can laser packages, and can also provide electrical connections and optical couplings to the laser diode within those laser packages. One technique for fixedly attaching a TO can laser package to TOSA housing includes using laser welding. During the welding process, however, rapid solidification of a welded region and associated material shrinkage may cause post-weld-shift (PWS). PWS, even in the order of a few micrometers, can result in total loss of optical power. Techniques for correction of PWS can include so-called "laser hammering" that seeks to counteract misalignment through additional laser welds to "hammer" fibers into an optimized alignment. This is accomplished, essentially, by adding additional successive laser welds in particular locations to use the effects of PWS to "pull" fibers out of misalignment. A light measurement may be taken between each successive weld to determine a resulting optical power. Correction of PWS has become increasingly more complex and expensive during manufacturing because optical transceivers continue to scale down in size, and in particular, have less area available for laser welding/attachment of laser packages.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] These and other features and advantages will be better understood by reading the following detailed description, taken together with the drawings wherein:

[0006] FIG. **1** is a perspective view of one approach to a multi-channel TOSA with multiple TO can laser packages.

[0007] FIG. **2** schematically illustrates an embodiment of an optical transceiver including a multi-channel TOSA and multi-channel receiver optical subassembly (ROSA).

[0008] FIG. **3** is a perspective view of an example small form-factor (SFF) pluggable transceiver with a multi-channel TOSA including TO can laser packages and a multi-channel ROSA, in accordance with an embodiment of the present disclosure.

[0009] FIG. **4**A is a perspective view of an embodiment of the multi-channel TOSA for use in the optical transceiver module shown in FIG. **3**.

[0010] FIG. **4**B is a cross-sectional view of the multi-channel TOSA of FIG. **4**A, in accordance with an embodiment of the present disclosure.

[0011] FIG. **5** shows an exploded view of the multi-channel TOSA of FIGS. **3**-**4**B, in accordance with an embodiment of the present disclosure.

[0012] FIGS. **6**A and **6**B show perspective views of a first sidewall and second sidewall of the multi-channel TOSA of FIGS. **3**-**4**B, respectively, in accordance with an embodiment of the present disclosure.

[0013] FIG. **7** shows a perspective view of one example TO can laser package for use in the multi-channel TOSA of FIGS. **3**-**5**.

DETAILED DESCRIPTION

[0014] A multi-channel transmitter optical subassembly (TOSA) including staggered TO laser can package placement to provide enhanced coupling and optical power is disclosed, and may be used in an optical transceiver for transmitting an optical signal at multiple different channel wavelengths. The TOSA comprises a housing made of metal or other thermally conductive material, and includes a plurality of sidewall openings disposed thereon. Each sidewall opening is configured to couple to TO can laser packages and provide coarse wavelength division multiplexing (CWDM). The housing includes at least a first and second sidewall opening on a first sidewall of the housing, and a third sidewall opening disposed on an opposite sidewall opposing the first and second sidewall opening. The third sidewall opening is positioned at generally a mid-point between the first and second sidewall openings such that an axis extending tangent from the third sidewall opening contacts the second and third sidewall opening. The first and second sidewall openings are separated by a distance generally equal to at least half the diameter of each of the respective sidewall openings. This staggered and opposing sidewall opening arrangement allows an increased distance between adjacent sidewall openings, without reducing the channel allocation for the TOSA. Thus the multi-channel TOSA provides additional space for performing post-attachment alignment of TO can laser packages through laser hammering, and other such alignment techniques, which simplifies those attachment/alignment processes to reduce error rates, and increase yield.

[0015] As previously discussed, optical components such as TOSAs continue to scale down in size, and as a result, face numerous non-trivial issues related to maintaining optical power, yield, and reliability. For example, FIG. **1** shows one example of a multi-channel TOSA **100** compatible with a Small Form-factor Pluggable (SFFP) transceiver. As shown the multi-channel TOSA **100** includes four (4) TO can laser packages **104** arranged on an upper side-wall of housing **102**, thus providing 4 wavelengths/channels for CWDM. To comport with form factor requirements governed by SFFP standards, such as the Quad Small Form-factor Pluggable (QSFP) standard, the distance between adjacent TO can laser packages **104** is relatively small with dimension **106** being generally 0.1 mm. This means that the approach chosen to fixedly attach TO can laser packages **104** must effectively operate within this relatively small dimension with little room for error.

[0016] One suitable approach to fixedly attaching TO can laser packages includes laser welding using a pulsed neodymium-doped yttrium aluminium garnet (Nd:YAG) laser. A Nd:YAG laser can achieve optical alignment and with submicron tolerances over the lifetime of the TOSA **100**, but manufacturing is complex using such a laser due to the small dimension **106** between TO can laser packages **104**. For example, as shown by angle θ, a laser welding system has approximately 87°±1° relative to the surface of the house **102** to generate welds. To correct for misalignment caused by PWS and to bring TO can laser packages **104** into optical alignment, additional successive welds are added at specific positions, which is generally referred to as laser hammering. When those welds fall within dimension **106**, for example, the welding process is more complex and time consuming. In a more general sense, the cost and time associated with each manufacturing TOSA **100** is increased by the relatively tiny tolerances afforded by dimension **106**.

[0017] Thus, in accordance with an embodiment, a multi-channel TOSA including staggered TO can laser package placement to provide additional space between adjacent TO can laser packages is provided herein. In some cases, the multi-channel TOSA disclosed herein includes at least twice the distance between adjacent TO can laser packages versus other TOSA approaches, such as the one shown in FIG. **1**, thus providing additional space, and importantly, a wide-range of angles in which to perform initial laser welds and subsequent "hammer" welds to ensure optimized optical alignment. The multi-channel TOSA disclosed herein can be utilized within, for example, transceivers that implement QSFP standards (e.g., 40 GB-LR), and other similarly constrained or otherwise small form-factor transceivers.

[0018] 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.

[0019] Now turning to FIG. **2** there is an optical transceiver **200** consistent with embodiments of the present disclosure. In more detail, the optical transceiver **200** 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 10 Gbps per channel. In one example, the channel wavelengths λ_1, λ_2, λ_3, λ_4 may be 1270 nm, 1290 nm, 1080 nm, and 1330 nm, respectively. The optical transceiver **200** may also be capable of transmission distances of 2 km to at least about 10 km. The optical transceiver **200** may be used, for example, in internet data center applications or fiber to the home (FTTH) applications. In an embodiment, the optical transceiver **200** implements the specification SFF-8436 titled "QSFP+ 10 Gbs 4× PLUGGABLE TRANSCEIVER Rev 4.8" (hereinafter QSFP+), published on Oct. 31, 2013 by the Electronic Industries Alliance (EIA).

[0020] This embodiment of the optical transceiver **200** includes a multi-channel TOSA **302** for transmitting optical signals on different channel wavelengths and a multi-channel receiver optical subassembly (ROSA) **230** for receiving optical signals on different channel wavelengths. The multi-channel TOSA **302** and the multi-channel ROSA **230** are located in a transceiver housing **202**. A transmit connecting circuit **204** and a receive connecting circuit **208** provide electrical connections to the multi-channel TOSA **302** and the multi-channel ROSA **230**, respectively, within the housing **202** and communicate with external systems via data bus **203**. In some cases, data bus **203** is a 38-pin connector that comports with physical connector QSFP standards and data communication protocols.

[0021] In any event, the transmit connecting circuit **204** is electrically connected to the electronic components (e.g., TO can laser packages) in the multi-channel TOSA **302**, and the receive connecting circuit **208** is electrically connected to the electronic components (e.g., the photodiode packages) in the multi-channel ROSA **230**. The transmit connecting circuit **204** and the receive connecting circuit **208** include at least conductive paths to provide electrical connections and may also include additional circuitry. The multi-channel TOSA **302** transmits and multiplexes multiple channel wavelengths and is coupled to an optical interface port **212**. The optical interface port **212** may comprise an LC connector receptacle, although other connector types are also within the scope of this disclosure. For example, the optical interface port **212** may comprise a multi-fiber push on (MPO) connector receptacle.

[0022] In cases where the optical interface port **212** comprises a duplex, or bi-directional, LC receptacle, the LC connector receptacle provides optical connections to the multi-channel TOSA **302**, and provides optical connections to the multi-channel ROSA **230**. The LC connector receptacle may be configured to receive and be coupled to a mating LC connector **214** such that the transmit optical fiber **222** of the external fibers **224** optically couples to the multi-channel TOSA **302**, and the receive optical fiber **217** of the external fibers **224** optically couples to the multi-channel ROSA **230**.

[0023] The multi-channel TOSA **302** includes multiple TO can laser packages, discussed in greater detail below, and optics for producing assigned channel wavelengths and coupling the same into the transmit optical fiber **222**. In particular, the lasers in the multi-channel TOSA **302** convert electrical data signals (TX_D1 to TX_D4) received via the transmit connecting circuit **204** into modulated optical signals transmitted over the transmit optical fiber **222**. The lasers may include, for example, distributed feedback (DFB) lasers with diffraction gratings. The multi-channel TOSA **302** may also include monitor photodiodes for monitoring the light emitted by the lasers. The multi-channel TOSA **302** 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.

[0024] The multi-channel ROSA **230** includes, for example, photodiodes, mirrors and filters that can de-multiplex different channel wavelengths in a received optical signal. The multi-channel ROSA **230** can detect, amplify, and convert such optical signals received from the external optical fibers **224**, and can provide the converted optical signals as electrical data signals (RX_D**1** to RX_D**4**) that are output via the receive connecting circuit **208**.

[0025] This embodiment of the optical transceiver **200** includes 4 channels and may be configured for coarse wavelength division multiplexing (CWDM), although other numbers of channels are possible.

[0026] Referring to FIG. **3**, an example small form-factor (SFF) pluggable optical transceiver **300** with a multi-channel TOSA including TO can laser packages and multi-channel ROSA is described and shown in greater detail. The embodiment shown in FIG. **3** is one example of the optical transceiver **200** of FIG. **2** implemented in a small form-factor. For example, the optical transceiver **300** may implement the QSFP+ specification. The optical transceiver **300** includes the transceiver housing **202**, a multi-channel TOSA **302** in one region of the housing **202**, and a multi-channel ROSA **230** located in another region of the housing **202**. As shown, the TO can laser package **304**c of the multi-channel TOSA **302** directly contacts a surface of the ROSA **230**. The multi-channel TOSA **302** is electrically connected to transmit flexible printed circuits (FPCs) **304** and optically coupled to the LC connector port **212** at an end of the housing **202**. The multi-channel ROSA **230** is electrically connected to a receive flexible printed circuit (FPC) **309** and optically coupled to the LC connector port **212** at the end of the housing **202**.

[0027] The multi-channel TOSA **302** includes TO can laser packages **304***a*, **304***b*, **304***c*, and **304***d*, with each containing optical components such as a laser diode. The TO can laser packages can provide, for example, output power from 1.85 mW to 2 W, although other output power is within the scope of this disclosure. The TO can laser packages may provide a broad spectrum of channel wavelengths, or configured to provide a relatively narrow spectrum of channel wavelengths such as a single channel wavelength. In some cases, the TO can laser packages provide center wavelengths 375 nm to 1650 nm, for example. In an embodiment, the TO can laser packages are Ø3.8 mm, Ø5.6 mm, or Ø9 mm TO cans, although other configurations are also within the scope of this disclosure. For instance, the TO can laser packages can include Ø9.5 mm and TO-46 cans.

[0028] One specific example of a TO can laser package **700** is shown in FIG. **7**. As shown, the TO can laser package **700** includes a housing **702**, connector pins **704**, and a header **706** with a laser diode **708**. The connector pins **704** couple to the transmit FPC **304**, and the multi-channel TOSA **302** optically couples an associated channel wavelength of the laser diode **708** to the transmit optical fiber **222** of the external fibers **224** (FIG. **2**) via collimating lenses, filters, and other optics such as a focusing lens, as discussed in greater detail below with reference to FIG. **4**B.

[0029] Returning to FIG. **3**, the multi-channel TOSA **302** includes TO can laser packages **304***a*-**304***d* fixedly attached in a staggered manner, with TO can laser package **304***c* being disposed on opposing sidewall to that of TO can laser packages **304***a* and **304***b*, as discussed in greater detail below.

[0030] Referring to FIG. **4**A, one embodiment of a multi-channel TOSA **302** for use in the optical transceiver module shown in FIG. **3** is shown in greater detail. As shown, the multi-channel TOSA **302** includes a housing **202** with first and second sidewalls **308** and **310**, respectively, positioned on opposite sides of the housing **202** and extending generally in parallel along a first major axis **303** from a first end **326** to a second end **327**, and forming a compartment defined by an inner surface within the housing **202**. The first sidewall **308** includes at least first and second sidewall openings **404***a* and **404***b* (also shown with additional detail in FIG. **5**) and the second sidewall **310** includes at least a third sidewall opening **404***c* being positioned generally at a midpoint **307** located between the sidewall openings **404***a* and **404***b* of the first sidewall **308**. The multi-channel TOSA **302** includes first and second TO can laser packages **304***a* and **304***b* fixedly attached to the first and second openings **404***a* and **404***b* of the first sidewall **308**, respectively, and a third TO can laser package **304***c* fixedly attached to the third sidewall opening **404***c* opposing the first and second TO can laser packages **304***a* and **304***b*. The housing **202** further includes an end sidewall **312** at the first end **326** and adjoining the first and second sidewalls **308** and **310**, the end sidewall **312** including a fourth sidewall opening **404***d* and a fourth TO can laser package **304***d* fixedly attached thereto.

[0031] As shown, the dimension **306** includes a distance of at least about 3 mm along the surface of the first sidewall **308** between adjacent TO can laser packages **304***a* and **304***b*. In some cases, dimension **306** includes a length of 2 mm to 5 mm, for example. As will be appreciated in light of this disclosure, dimension **306** departs from other TOSA approaches, such as discussed above with regard to FIG. **1**, that have a minimal spacing between TO can laser packages. This increased dimension **306** advantageously allows laser welds to be formed without the cost and complexity normally associated with having tight tolerances between laser packages. For example, and as shown in FIG. **4**A, angle θ is generally 30° relative to the housing **202**. This means that laser welding systems can perform welding at multiple angles from, for example, 30° tot 36°, for example. In other cases, the angle θ allows laser welding systems to weld at less than 30°.

[0032] Referring to FIG. **4**B, there is a cross-sectional view of the multi-channel TOSA **302** of FIG. **3**. As shown, the housing **202** also forms an internal cavity **316**, or compartment, that defines a light path **322** that extends through filters **318***a*, **318***b* and **318***c*, respectively, before encountering focusing lens **320**. The filters **318***a*-**318***c* are positioned on filter holders **319***a*, **319***b*, and **319***c*, respectively. An optical coupling receptacle **324** extends from the second end **327** for optically coupling the light of TO can laser packages **304***a*-**304***d* to the transmit optical fiber **222**. Thus the filters **318***a*-**318***d*, the lens **320**, the optical coupling receptacle **324** are generally aligned or positioned along a longitudinal axis provided by the light path **322**. This combination of filters may be accurately described as multiplexing optics and can provide coarse wavelength division multiplexing (CWDM) in an optical signal. Multiplexing different channel wavelengths using this configuration will now be discussed in the context of a four (4) channel TOSA configuration, such as shown in FIG. **4**B.

[0033] Each of the TO can laser packages **304***a*-**304***d* can be associated with different channel wavelengths. For example, the channel wavelengths (λ**1**, λ**2**, λ**3**, λ**4**) associated with TO can laser packages **304***a*-**304***d* may be 1290 nm, 1330 nm, 1310 nm, and 1270 nm, respectively. To multiplex these different channel wavelengths into a signal optically coupled to transmit optical fiber **222**, the housing includes TO can laser package **304***d* configured to direct light coaxially along light path **322** into the compartment **316**. In turn, the filter **318***a* positioned adjacent the TO can laser package **304***d* can provide wavelength-dependent transmission such that only the channel wavelength λ**1**, associated with the TO can laser package **304***d*, pass through filter **318***a*. The filter **318***a* may also provide wavelength-dependent reflectivity such that only channel wavelength λ**2** is reflected therefrom. At this point, the light along light path **322** includes, essentially, channel wavelengths λ**1** and λ**2**. After those channel wavelengths pass through filter **318***c*, they converge with wavelength λ**3**, which is provided by the filter **318***c* reflecting only channel wavelength λ**3** from the light directed by TO laser package **304***c*. At this point the light along light path **322** now includes, essentially, channel wavelengths λ**1**, λ**2** and λ**3**. After those channel wavelengths pass through filter **318***b*, they converge with channel wavelength λ**4**, which is provided by the filter **318***b* reflecting only channel wavelength λ**4** from the light directed by TO laser package **304***b*. As shown, collimating lenses **305***a*-**305***d* collimate light emitted by each TO can laser package. Thus at focusing lens **320**, the resulting optical signal includes multiple different multiplexed channel wavelengths (e.g., λ**1**, λ**2**, λ**3**, λ**4**) and is optically coupled to the transmit optical fiber **222**.

[0034] As should be appreciated, the multi-channel TOSA **302** may include additional channels and is not necessarily limited to the four (4) shown in FIG. **4**B. That is, additional TO can laser packages may be disposed along the sidewalls of housing **202**. For instance, the first sidewall **308** may include 3 or more TO can laser packages. Each of those TO can laser packages may be disposed with spacing similar to the embodiment shown in FIG. **4**B. On the opposing sidewall, such as second sidewall **310**, TO can laser packages may be fixedly attached such that they are disposed generally coextensive or otherwise overlapping with the area between each of the TO can laser packages of the first sidewall **308**. This staggered/opposing arrangement may be repeated for N number of optical channels, depending on a desired configuration.

[0035] Moreover, it should be appreciated in light of this disclosure that placement of the TO can laser packages are not necessarily limited to the embodiment shown. For example, TO can laser package **304***c* may be fixedly attached to a sidewall that is perpendicular (or at a right angle) to the TO can laser packages **304***a* and **304***b*.

[0036] Referring now to FIG. **5**, there is an exploded view of the multi-channel TOSA **302**, in accordance with an embodiment of the present disclosure. As shown, each of the TO can laser packages **304***a*-**304***d* include an associated welding ring **402***a*, **402***b*, **402***c*, and **402***d*, respectively. These welding rings **402***a*-**402***d* allow the TO can laser packages **304***a*-**304***d* to be placed over and fixedly attached to sidewall openings **404***a*, **404***b*, **404***c* and **404***d*, respectively. As previously discussed, laser welding is one approach that is particularly well suited for ensuring optical efficiency (power) and reliable operation over a lifetime of the multi-channel TOSA **302**.

[0037] Note that an outer surface of the filter holder **319***b* is substantially flat, and co-planar with an outer surface of the first sidewall **308**. This advantageously provides a generally flat area that does not otherwise obstruct access when attaching TO can laser packages **304***a* and **304***b* during manufacturing. FIG. **6**A further illustrates how filter holder **319***c* resides between TO can laser packages **304***a* and **304***b*, but is coplanar or otherwise flat against the first sidewall **308**. On the other hand, FIG. **6**B illustrates how filter holders **319***a* and **319***b* are generally flat and also do not obstruct access to the area around TO can laser package **304***c* along the second sidewall **310**. As shown in FIG. **6**A and **6**B, the multi-channel TOSA **302** may have a relatively small size. In some embodiments, the long axis of the housing may be 15 mm, or less.

[0038] The multi-channel TOSA **302** may be formed as one piece or as multiple pieces attached together. Although the illustrated embodiment shows the multi-channel TOSA **302** with a particular shape, other shapes and configurations are also possible. In other embodiments, for example, the housing **202** may be generally cylindrical.

[0039] The increased distance between the TO can laser packages **304***a*-**304***d* advantageously provides for increased tolerances when fixedly attaching the same to sidewall openings **404***a*-**404***d* of the housing **202**. This increased area allows for a laser welding system to have a wide-range of angles in which to generate welds, and thus, increase yield and reliability of the multi-channel TOSA **302** because of reduced error rates and faster time between establishing initial laser welds and optimizing optical efficiency through laser hammering. In addition, an increased surface area between TO can laser packages improves transfer or heat conduction, and thus, facilitates more effective heat dissipation than other approaches to TOSA packages (e.g., such as shown in FIG. **1**).

Further Example Embodiments

[0040] In accordance with one aspect of the present disclosure, a transmitter optical subassembly (TOSA) including a plurality of transistor outline (TO) can laser packages is disclosed. The TOSA may comprise a housing including at least a first and second sidewall on opposite sides of the housing and extending along a first major axis from a first end to a second end, and forming a compartment defined by an inner surface therein, the first sidewall including at least first and second sidewall openings, the second sidewall including at least a third sidewall opening being positioned generally at a midpoint between the first and second sidewall openings, and at least first and second TO can laser packages fixedly attached to the first and second sidewall opening of the first sidewall, respectively, and a third TO can laser package fixedly attached to the third sidewall opening and opposing the first and second TO can laser packages.

[0041] In one aspect, the housing may further include a third sidewall at the first end and adjoining the first and second sidewall, the third sidewall including a fourth sidewall opening and a fourth TO can laser package fixedly attached thereto.

[0042] In one aspect, the TOSA may comprise a plurality of welding rings, wherein the plurality of TO can laser packages are fixedly attached to respective sidewalls of the housing by the plurality of welding rings via laser welds.

[0043] In one aspect, the compartment may define a light path, the light path extending from the first end to at least the second end.

[0044] In one aspect, each of the plurality of TO can laser packages may include a laser diode optically aligned to direct light into the compartment.

[0045] In one aspect, the TOSA may further comprise filters aligned with the TO can laser packages to pass and reflect laser light at associated channel wavelengths.

[0046] In one aspect, each filter may include an associated filter holder, each of the filter holders being fixedly attached to a sidewall of the housing and providing a substantially flat surface between adjacent TO can laser packages along an outer edge of the housing.

[0047] In one aspect, the compartment may include a focusing lens aligned with a light path at the second end of the housing.

[0048] In one aspect, the first and second TO can laser packages may be greater than 1 mm apart.

[0049] In one aspect, the second end may include an optical coupling receptacle configured to optically couple a signal having multiple different channel wavelengths to a transmit optical fiber.

[0050] In accordance with another aspect of the present disclosure, an optical transceiver module is disclosed. The optical transceiver may comprise a transceiver housing, a transmitter optical subassembly (TOSA) having a plurality of transistor outline (TO) can laser packages fixedly attached thereto and located in the transceiver housing for transmitting optical signals at different channel wavelengths, the TOSA comprising a housing including at least a first and second sidewall on opposite sides of the housing and extending along a first major axis from a first end to a second end, and forming a compartment defined by an inner surface therein, the first sidewall including at least first and second sidewall openings, the second sidewall including at least a third sidewall opening being positioned generally at a midpoint between the first and second sidewall openings, and at least first and second transistor outline TO can laser packages fixedly attached to the first and second sidewall opening of the first sidewall, respectively, and a third TO can laser package fixedly attached to the third sidewall opening and opposing the first and second TO can laser packages, a multi-channel receiver optical assembly (ROSA) located in the transceiver housing for receiving optical signals at different channel wavelengths.

[0051] In one aspect, the optical transceiver may further comprise a transmit connecting circuit electrically connected to the TOSA, and a receive connecting circuit electrically connected to the ROSA.

[0052] In one aspect, the TOSA may further comprise filters within the compartment configured to provide a multiplexed optical signal having multiple different wavelengths.

[0053] In one aspect, the TOSA may further comprise a third sidewall at the first end and adjoining the first and second sidewall, the third sidewall including a fourth sidewall opening and a fourth TO can laser package fixedly attached thereto.

[0054] In one aspect, each of the first, second, third and fourth TO can laser packages may be associated with a channel wavelength of 1290 nm, 1330 nm, 1310 nm, and 1270 nm, respectively.

[0055] In one aspect, the TOSA further may comprise a plurality of welding rings, wherein each of the plurality of TO can laser packages are fixedly attached to respective sidewalls of the TOSA housing by the plurality of welding rings via laser welds.

[0056] In one aspect, the transceiver may be a Quad Small Form-factor Pluggable (QSFP) transceiver module and the TOSA is configured to transmit at four different channel wavelengths at transmission rates of at least about 10 Gbps per channel and transmission distances of 2 km to at least about 10 km.

[0057] In one aspect, the third TO can laser package may directly contact a surface of the ROSA.

[0058] In one aspect, the first and second TO can laser packages of the TOSA may be greater than **1** mm apart.

[0059] In one aspect, the second end of the TOSA may include an optical coupling receptacle configured to optically couple a signal having multiple different channel wavelengths to a transmit optical fiber.

[0060] 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.

1. A transmitter optical subassembly (TOSA) including a plurality of transistor outline (TO) can laser packages, the TOSA comprising:

a housing including at least a first and second sidewall on opposite sides of the housing and extending along a first major axis from a first end to a second end, and forming a compartment defined by an inner surface therein, the first sidewall including at least first and second sidewall openings, the second sidewall including at least a third sidewall opening being positioned generally at a midpoint between the first and second sidewall openings;

at least first and second TO can laser packages coupled to the first and second sidewall opening of the first sidewall, respectively, and a third TO can laser package coupled to the third sidewall opening and opposing the first and second TO can laser packages;

at least a first filter holder coupled to the first sidewall between the first and second sidewall openings of the first and second TO can laser packages, respectively, and wherein the first filter holder provides a substantially flat surface along an outer edge of the housing between the first and second TO can laser packages; and

a first filter coupled to the first filter holder.

2. The TOSA of claim **1**, further comprising a third sidewall at the first end and adjoining the first and second sidewall, the third sidewall including a fourth sidewall opening and a fourth TO can laser package coupled thereto.

3. The TOSA of claim **1**, further comprising a plurality of welding rings, wherein the plurality of TO can laser packages are coupled to respective sidewalls of the housing by the plurality of welding rings via laser welds.

4. The TOSA of claim 1, wherein the compartment defines a light path, the light path extending from the first end to at least the second end.

5. The TOSA of claim 4, wherein each of the plurality of TO can laser packages includes a laser diode optically aligned to direct light into the compartment.

6. The TOSA of claim 1, further comprising:

a second and third filter holder coupled to the third sidewall on opposite sides of the third TO can laser packages relative to each other; and

a second and a third filter coupled to the second and third filter holders, respectively, wherein each of the first, second and third filters are configured to align with an associated TO can laser package to pass and reflect laser light at associated channel wavelengths.

7. The TOSA of claim 6, wherein each of the second and third filter holders provide a substantially flat surface along an outer edge of the housing.

8. The TOSA of claim 1, wherein the compartment includes a focusing lens aligned with a light path at the second end of the housing.

9. The TOSA of claim 1, wherein the first and second TO can laser packages are greater than 1 mm apart.

10. The TOSA of claim 1, wherein the second end includes an optical coupling receptacle configured to optically couple a signal having multiple different channel wavelengths to a transmit optical fiber.

11. An optical transceiver module comprising:

a transceiver housing;

a transmitter optical subassembly (TOSA) having a plurality of transistor outline (TO) can laser packages coupled thereto and located in the transceiver housing for transmitting optical signals at different channel wavelengths, the TOSA comprising:

a housing including at least a first and second sidewall on opposite sides of the housing and extending along a first major axis from a first end to a second end, and forming a compartment defined by an inner surface therein, the first sidewall including at least first and second sidewall openings, the second sidewall including at least a third sidewall opening being positioned generally at a midpoint between the first and second sidewall openings; and

at least first and second transistor outline TO can laser packages coupled to the first and second sidewall opening of the first sidewall, respectively, and a third TO can laser package coupled to the third sidewall opening and opposing the first and second TO can laser packages;

a multi-channel receiver optical assembly (ROSA) located in the transceiver housing for receiving optical signals at different channel wavelengths; and

wherein the third TO can laser package of the TOSA directly contacts a surface of the multi-channel ROSA.

12. The optical transceiver of claim 11, further comprising a transmit connecting circuit electrically connected to the TOSA, and a receive connecting circuit electrically connected to the ROSA.

13. The optical transceiver of claim 11, wherein the TOSA further comprises a plurality of filters within the compartment configured to provide a multiplexed optical signal having multiple different wavelengths.

14. The optical transceiver of claim 11, wherein the TOSA further comprises a third sidewall at the first end and adjoining the first and second sidewall, the third sidewall including a fourth sidewall opening and a fourth TO can laser package coupled thereto.

15. The optical transceiver of claim 14, wherein each of the first, second, third and fourth TO can laser packages are associated with a channel wavelength of 1290 nm, 1330 nm, 1310 nm, and 1270 nm, respectively.

16. The optical transceiver of claim 11, the TOSA further comprises a plurality of welding rings, wherein each of the plurality of TO can laser packages are coupled to respective sidewalls of the TOSA housing by the plurality of welding rings via laser welds.

17. The optical transceiver of claim 11, wherein the transceiver is a Quad Small Form-factor Pluggable (QSFP) transceiver module and the TOSA is configured to transmit at four different channel wavelengths at transmission rates of at least about 10 Gbps per channel and transmission distances of 2 km to at least about 10 km.

18. (canceled)

19. The optical transceiver of claim 11, wherein the first and second TO can laser packages of the TOSA are greater than 1 mm apart.

20. The optical transceiver of claim 11, wherein the second end of the TOSA includes an optical coupling receptacle configured to optically couple a signal having multiple different channel wavelengths to a transmit optical fiber.

21. The TOSA of claim 1, wherein the first sidewall includes a first step portion adjacent the first end of the housing that defines at least one surface, and wherein the substantially flat surface provided by the first filter holder along an outer edge of the housing is offset relative to the at least one surface defined by the first step portion.

22. The TOSA of claim 21, wherein the third sidewall includes a second step portion adjacent the first end of the housing, the first and second step portions defining a tapered region that extends between the first and second ends of the housing.

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