

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ACCELIGHT TECHNOLOGIES, INC.,
Petitioner

v.

APPLIED OPTOELECTRONICS, INC.,
Patent Owner.

IPR2025-01570
U.S. Patent No. 10,788,690

**DECLARATION OF ARPITA BHATTACHARYYA IN SUPPORT
OF PETITIONER'S MOTION FOR JOINDER UNDER
35 U.S.C. § 315(c) AND 37 C.F.R. §§42.22 AND 42.122(b)**

I, Arpita Bhattacharyya declare that:

1. I am a registered patent attorney of record in the above-captioned proceeding for Petitioner Accelight Technologies, Inc. (“Petitioner” or “Accelight”) and have full knowledge of the issues involved herein.

2. In *Applied Optoelectronics, Inc. v. Accelight Technologies, Inc.*, Case No. 4:24-cv-09041 (N.D. Cal. Dec. 13, 2024), Patent Owner (“AOI”) has asserted six patents against Petitioner Accelight Technologies, Inc., including U.S. Patent No. 10,788,690 at issue in Accelight’s Petition in IPR2025-01570. Judge Haywood S. Gilliam is presiding over that district court action. Petitioner was served with the complaint in that district court action on December 18, 2025, and therefore, Petitioner is not time-barred under 35 U.S.C. § 315(b) and 37 C.F.R. § 42.101(b). Attached hereto as **Exhibit A** is a true and correct copy of the as-filed certificate of service in that district court action, stating that Petitioner was served with the complaint on December 18, 2024. **Although Petitioner is not time-barred or otherwise estopped from filing its own IPR petition, Petitioner will not file another IPR petition challenging the ’690 Patent if its copy-cat IPR Petition (IPR2025-01570) is granted and the proceeding is joined with the CIG USA IPR.**

3. Attached hereto as **Exhibit B** is a true and correct copy of the docket report for *Applied Optoelectronics, Inc. v. Cambridge Industries USA, Inc.*, Case

No. 3:24-cv-01010 (N.D. Cal. Feb. 20, 2024), downloaded on September 23, 2025. ECF No. 41 of that docket states: “ORDER. The parties have advised the Court of the institution of IPR proceedings for a majority of claims in the case. Dkt. No. 40. The case is stayed in all respects pending further order. The claims construction hearing set for April 10, 2025, is vacated. The parties will file a joint status report on the PTAB proceedings every 90 days starting on July 7, 2025. Signed by Judge James Donato on 4/4/2025.”

4. Attached hereto as **Exhibit C** is a true and correct copy of the Notice to Court of Filing of Petitions for *Inter Partes* Review filed in *Applied Optoelectronics, Inc. v. Cambridge Industries USA, Inc.*, Case No. 3:24-cv-01010 (N.D. Cal. Mar. 19, 2025), ECF No. 40, a joint notice by the parties that CIG USA filed IPR petitions against five patents, including the ’690 patent, out of the eight patents AOI is asserting against CIG USA in that action.

5. Attached hereto as **Exhibit D** is a true and correct copy of the First Amended Complaint filed in *Applied Optoelectronics, Inc. v. Accelight Technologies, Inc.*, Case No. 4:24-cv-09041 (N.D. Cal. Feb. 19, 2025), ECF No. 21, asserting infringement of the ’690 patent and other patents.

6. Attached hereto as **Exhibit E** is a true and correct copy of a printout of statistics downloaded from Docket Navigator identifying Judge Gilliam’s dispositions of motions to stay district court actions in view of IPR and *ex parte*

reexamination proceedings (downloaded from Docket Navigator on September 18, 2025). Docket Navigator's statistics show that Judge Gilliam has granted all such motions to stay since 2019, and five out of six such motions in 2015. Similar statistics for Judge Gilliam's decisions granting such stays were discussed and relied upon by the Director in *Twitch Interactive, Inc. v. RazDog Holdings LLC*, IPR2025-00307, Paper No. 18, at 2-3 (May 16, 2025), denying Patent Owner's request for discretionary denial. A true and correct copy of that PTAB decision denying discretionary denial is attached as **Exhibit F**.

7. As another example, in *Apple Inc. v. Alivacor, Inc.*, No. 22-cv-07608-HSG (N.D. Cal. Dec. 29, 2023), ECF No. 89, Judge Gilliam granted a pre-institution motion to stay that action pending five IPRs filed on the asserted patents. A true and correct copy of that decision is attached hereto as **Exhibit G**.

8. In *Cooler Master Co. v. Asetek Danmark A/S*, No. 21-cv-04627-HSG (N.D. Cal. June 14, 2022), ECF No. 42, Judge Gilliam granted a motion stay that action pending IPR proceedings. A true and correct copy of that decision is attached hereto as **Exhibit H**.

9. In *Google LLC v. EcoFactor, Inc.*, No. 21-cv-03220-HSG (N.D. Cal. Jan. 8, 2024), ECF No. 153, Judge Gilliam granted a motion to stay that case pending *ex parte* reexamination, after having previously stayed that action pending IPR

proceedings (as explained in that same order). A true and correct copy of that decision is attached hereto as **Exhibit I**.

10. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like are punishable by fine, imprisonment, or both under Section 1001 of Title 18 of the United States Code.

Date: September 25, 2025

Respectfully submitted,

/ Arpita Bhattacharyya /

Arpita Bhattacharyya, Reg. No. 63,681
Bhattacharyya-ptab@perkinscoie.com
Counsel for Petitioner

PERKINS COIE LLP
3150 Porter Drive
Palo Alto, California 94304
Tel. No. 650-838-4300

CERTIFICATE OF SERVICE

I hereby certify that on September 25, 2025 true and correct copies of the foregoing **DECLARATION OF ARPITA BHATTACHARYYA IN SUPPORT OF PETITIONER'S MOTION FOR JOINDER UNDER 35 U.S.C. § 315(c) AND 37 C.F.R. §§42.22 AND 42.122(b)** and any accompanying exhibits were caused to be served by FedEx on the following counsel:

APPLIED OPTOELECTRONICS, INC.
13115 Jess Pirtle Blvd.
Sugar Land, TX 77478

A courtesy copy was also sent via electronic mail to Patent Owner's litigation counsel listed below:

Jo Dale Carothers
jcarothers@weintraub.com
Eric A. Caligiuri
ecaligiuri@weintraub.com

Date: September 25, 2025

Respectfully submitted,

/Arpita Bhattacharyya/
Arpita Bhattacharyya, Reg. No. 63,681
Bhattacharyya-ptab@perkinscoie.com
Counsel for Petitioner

PERKINS COIE LLP
3150 Porter Drive
Palo Alto, California 94304
Tel. No. 650-838-4300

EXHIBIT A

UNITED STATES DISTRICT COURT

for the

Northern District of California

APPLIED OPTOELECTRONICS, INC.

Plaintiff(s)

v.

ACCELIGHT TECHNOLOGIES, INC.

Defendant(s)

Civil Action No. 3:24-cv-09041-LJC

SUMMONS IN A CIVIL ACTION

To: *(Defendant's name and address)* ACCELIGHT TECHNOLOGIES, INC.
 5674 Stoneridge Drive, #109
 Pleasanton, CA 94588

A lawsuit has been filed against you.

Within 21 days after service of this summons on you (not counting the day you received it) — or 60 days if you are the United States or a United States agency, or an officer or employee of the United States described in Fed. R. Civ. P. 12 (a)(2) or (3) — you must serve on the plaintiff an answer to the attached complaint or a motion under Rule 12 of the Federal Rules of Civil Procedure. The answer or motion must be served on the plaintiff or plaintiff's attorney, whose name and address are:

Jo Dale Carothers, SBN 228703
 Eric A. Caligiuri, SBN 260442
 Weintraub Tobin Chediak Coleman Grodin
 Law Corporation
 475 Sansome Street, Suite 510
 San Francisco, CA 94111

If you fail to respond, judgment by default will be entered against you for the relief demanded in the complaint. You also must file your answer or motion with the court.

Date: December 16, 2024



CLERK OF COURT
 Mark B. Busby

Angel N. J.

Signature of Clerk or Deputy Clerk

AO 440 (Rev. 06/12) Summons in a Civil Action (Page 2)

Civil Action No. 3:24-cv-09041-LJC

PROOF OF SERVICE*(This section should not be filed with the court unless required by Fed. R. Civ. P. 4 (l))*

This summons for *(name of individual and title, if any)* Accelight Technologies, Inc. was received by me on *(date)* Dec 18, 2024, 10:55 am.

- ☐ I personally served the summons on the individual at *(place)* _____ on *(date)* _____; or
- ☐ I left the summons at the individual's residence or usual place of abode with *(name)* _____, a person of suitable age and discretion who resides there, on *(date)* _____, and mailed a copy to the individual's last known address; or
- ☒ I served the summons on *(name of individual)* Registered Agent Solutions, Inc., Agent for Service of Process, by serving Jeffrey Kurtz, Intake Specialist Authorized to Accept per SOS 1505 Cert., who is designated by law to accept service of process on behalf of *(name of organization)* Accelight Technologies, Inc. on *(date)* Wed, Dec 18 2024; or
- ☐ I returned the summons unexecuted because: _____; or
- ☐ Other: _____; or

My fees are \$ 0.00 for travel and \$ 153.00 for services, for a total of \$ 153.00.

I declare under penalty of perjury that this information is true.

Date: December 18, 2024

Server's signature

Stephen Glaeser, On Behalf of: (OnDemand Legal, Inc., RPS Corp
Reg. No.: 2021-23, Sacramento County) RPS# 2013-44,
Sacramento County

Printed name and title

901 H Street Suite 107, Sacramento, CA 95814

Server's address

Additional information regarding attempted service, etc.:

Document List: Summons in a Civil Action; Complaint for Patent Infringement; Civil Cover Sheet; Plaintiff Applied Optoelectronics, Inc.'s Corporate Disclosure Statement [FRCP, Rule 7.1] and Certificate of Interested Entities or Persons [Civil L.R. 3-15]; Order Setting Initial Case Management Conference and ADR Deadlines; Report on the Filing or Determination of an Action Regarding a Patent or Trademark; Standing Order for All Judges of the Northern District of California Contents of Join Case Management Statement

1) Successful Attempt: Dec 18, 2024, 12:02 pm PST at 720 14th Street, Sacramento, CA 95814 received by Registered Agent Solutions, Inc., Agent for Service of Process, by serving Jeffrey Kurtz, Intake Specialist Authorized to Accept per SOS 1505 Cert.

ODL: 267725

EXHIBIT B

**U.S. District Court
California Northern District (San Francisco)
CIVIL DOCKET FOR CASE #: 3:24-cv-01010-JD**

Applied Optoelectronics, Inc. v. Cambridge Industries USA, Inc. Date Filed: 02/20/2024
Assigned to: Judge James Donato Jury Demand: Plaintiff
Cause: 35:271 Patent Infringement Nature of Suit: 830 Patent
Jurisdiction: Federal Question

Plaintiff

Applied Optoelectronics, Inc.

represented by **Jo Dale Carothers**
Weintraub Tobin
1130 Wall Street
#953
La Jolla, CA 92037
858-432-5740
Email: jcarothers@weintraub.com
LEAD ATTORNEY
ATTORNEY TO BE NOTICED

Eric Anthony Caligiuri
Weintraub Tobin Chediak Coleman
Grodin
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Fax: 415-433-3883
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ATTORNEY TO BE NOTICED

V.

Defendant

Cambridge Industries USA, Inc.

represented by **Nicola Anthony Pisano**
Cozen O'Connor
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San Diego, CA 92101
619-685-1714
Fax: 619-866-6355
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LEAD ATTORNEY
ATTORNEY TO BE NOTICED

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ATTORNEY TO BE NOTICED

Scott Adam Penner
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Suite 1610
San Diego, CA 92101
619-685-1724
Fax: 619-866-6357

Email: spenner@cozen.com
ATTORNEY TO BE NOTICED

Counter-claimant

Cambridge Industries USA, Inc.

represented by **Nicola Anthony Pisano**
(See above for address)
LEAD ATTORNEY
ATTORNEY TO BE NOTICED

Regis Calvin Worley , Jr.
(See above for address)
ATTORNEY TO BE NOTICED

Scott Adam Penner
(See above for address)
ATTORNEY TO BE NOTICED

V.

Counter-defendant

Applied Optoelectronics, Inc.

represented by **Jo Dale Carothers**
(See above for address)
LEAD ATTORNEY
ATTORNEY TO BE NOTICED

Eric Anthony Caligiuri
(See above for address)
ATTORNEY TO BE NOTICED

Date Filed	#	Docket Text
02/20/2024	<u>1</u>	COMPLAINT FOR PATENT INFRINGEMENT against All Defendants (Filing fee \$ 405, receipt number ACANDC-19141719.). Filed by Applied Optoelectronics, Inc.. (Attachments: # <u>1</u> Civil Cover Sheet)(Carothers, Jo Dale) (Filed on 2/20/2024) (Entered: 02/20/2024)
02/20/2024	<u>2</u>	Proposed Summons. (Carothers, Jo Dale) (Filed on 2/20/2024) (Entered: 02/20/2024)
02/20/2024	<u>3</u>	Rule 7.1 Disclosures by Applied Optoelectronics, Inc. (Carothers, Jo Dale) (Filed on 2/20/2024) (Entered: 02/20/2024)
02/21/2024	<u>4</u>	Case assigned to Magistrate Judge Virginia K. DeMarchi. Counsel for plaintiff or the removing party is responsible for serving the Complaint or Notice of Removal, Summons and the assigned judge's standing orders and all other new case documents upon the opposing parties. For information, visit <i>E-Filing A New Civil Case</i> at http://cand.uscourts.gov/ecf/caseopening . Standing orders can be downloaded from the court's web page at www.cand.uscourts.gov/judges . Upon receipt, the summons will be issued and returned electronically. A scheduling order will be sent by Notice of Electronic Filing (NEF) within two business days. Consent/Declination due by 3/6/2024. (as, COURT STAFF) (Filed on 2/21/2024) (Entered: 02/21/2024)
02/21/2024	<u>5</u>	CONSENT/DECLINATION to Proceed Before a US Magistrate Judge by Applied Optoelectronics, Inc... (Carothers, Jo Dale) (Filed on 2/21/2024) (Entered: 02/21/2024)
02/21/2024	<u>6</u>	CLERK'S NOTICE OF IMPENDING REASSIGNMENT TO A U.S. DISTRICT COURT JUDGE: The Clerk of this Court will now randomly reassign this case to a District Judge because either (1) a party has not consented to the jurisdiction of a Magistrate Judge, or (2) time is of the essence in deciding a pending judicial action for which the necessary consents to Magistrate Judge jurisdiction have not been secured. You will be informed by separate notice of the district judge to whom this case is reassigned.

		ALL HEARING DATES PRESENTLY SCHEDULED BEFORE THE CURRENT MAGISTRATE JUDGE ARE VACATED AND SHOULD BE RE-NOTICED FOR HEARING BEFORE THE JUDGE TO WHOM THIS CASE IS REASSIGNED. <i>This is a text only docket entry; there is no document associated with this notice. (amk, COURT STAFF) (Filed on 2/21/2024) (Entered: 02/21/2024)</i>
02/22/2024	<u>7</u>	ORDER REASSIGNING CASE. Case reassigned using a proportionate, random, and blind system pursuant to General Order No. 44 to Judge James Donato for all further proceedings. Notice: The assigned judge participates in the Cameras in the Courtroom Pilot Project. See General Order No. 65 and http://cand.uscourts.gov/cameras. Judge Magistrate Judge Virginia K. DeMarchi no longer assigned to case. Reassignment Order signed by Clerk on 2/22/2024. (Attachments: # <u>1</u> Notice of Eligibility for Video Recording)(bw, COURT STAFF) (Filed on 2/22/2024) (Entered: 02/22/2024)
02/22/2024	<u>8</u>	Summons Returned Unexecuted by Applied Optoelectronics, Inc. as to All Defendants. (Carothers, Jo Dale) (Filed on 2/22/2024) (Entered: 02/22/2024)
02/22/2024	<u>9</u>	Proposed Summons. (Carothers, Jo Dale) (Filed on 2/22/2024) (Entered: 02/22/2024)
02/23/2024	<u>10</u>	Initial Case Management Scheduling Order with ADR Deadlines: Case Management Statement due by 5/16/2024. Initial Case Management Conference set for 5/23/2024 at 10:00 AM in San Francisco, Courtroom 11, 19th Floor. Notice: The assigned judge participates in the Cameras in the Courtroom Pilot Project. See General Order No. 65 and http://cand.uscourts.gov/cameras. (Attachments: # <u>1</u> Notice of Eligibility for Video Recording)(slh, COURT STAFF) (Filed on 2/23/2024) (Entered: 02/23/2024)
02/23/2024	<u>11</u>	Summons Issued as to Cambridge Industries USA, Inc. (slh, COURT STAFF) (Filed on 2/23/2024) (Entered: 02/23/2024)
02/28/2024	<u>12</u>	SUMMONS Returned Executed by Applied Optoelectronics, Inc.. Cambridge Industries USA, Inc. served on 2/23/2024, answer due 3/15/2024. (Carothers, Jo Dale) (Filed on 2/28/2024) (Entered: 02/28/2024)
03/11/2024	<u>13</u>	STIPULATION <i>To Extend Time To Respond To Complaint</i> filed by Cambridge Industries USA, Inc.. (Pisano, Nicola) (Filed on 3/11/2024) (Entered: 03/11/2024)
03/11/2024	<u>14</u>	Certificate of Interested Entities by Cambridge Industries USA, Inc. identifying Corporate Parent CIG Shanghai Co., Ltd. for Cambridge Industries USA, Inc.. (Pisano, Nicola) (Filed on 3/11/2024) (Entered: 03/11/2024)
03/11/2024	<u>15</u>	NOTICE of Appearance by Nicola Anthony Pisano (Pisano, Nicola) (Filed on 3/11/2024) (Entered: 03/11/2024)
03/11/2024	<u>16</u>	NOTICE of Appearance by Scott Adam Penner (Penner, Scott) (Filed on 3/11/2024) (Entered: 03/11/2024)
03/11/2024	<u>17</u>	NOTICE of Appearance by Regis Calvin Worley, Jr (Worley, Regis) (Filed on 3/11/2024) (Entered: 03/11/2024)
04/11/2024	<u>18</u>	MOTION to Dismiss filed by Cambridge Industries USA, Inc.. Motion to Dismiss Hearing set for 5/16/2024 10:00 AM in San Francisco, Courtroom 11, 19th Floor. Responses due by 4/25/2024. Replies due by 5/2/2024. (Attachments: # <u>1</u> Declaration Declaration of Nicola A. Pisano, # <u>2</u> Exhibit Exhibit A, # <u>3</u> Proposed Order Proposed Order)(Pisano, Nicola) (Filed on 4/11/2024) (Entered: 04/11/2024)
04/25/2024	<u>19</u>	FIRST AMENDED COMPLAINT <i>FOR PATENT INFRINGEMENT</i> against Cambridge Industries USA, Inc.. Filed by Applied Optoelectronics, Inc. (Carothers, Jo Dale) (Filed on 4/25/2024) Modified on 4/26/2024 (slh, COURT STAFF). (Entered: 04/25/2024)
05/02/2024	<u>20</u>	ADR Certification (ADR L.R. 3-5 b) of discussion of ADR options (Carothers, Jo Dale) (Filed on 5/2/2024) (Entered: 05/02/2024)

05/02/2024	<u>21</u>	ADR Certification (ADR L.R. 3–5 b) of discussion of ADR options (Pisano, Nicola) (Filed on 5/2/2024) (Entered: 05/02/2024)
05/07/2024	<u>22</u>	ORDER. In light of plaintiff Applied Optoelectronics' amended complaint, Dkt. No. 19, defendant Cambridge Industries' motion to dismiss, Dkt. No. 18, is terminated without prejudice. The motion hearing set for May 16, 2024, is vacated. Signed by Judge James Donato on 5/7/2024. (This is a text-only entry generated by the court. There is no document associated with this entry.) (jdlc3, COURT STAFF) (Filed on 5/7/2024) (Entered: 05/07/2024)
05/09/2024	<u>23</u>	*Erroneous Entry – Please see document <u>24</u> MOTION to Dismiss <i>Partial Motion to Dismiss Under Fed. R. Civ. P. 12(b)(6) Or, In the Alternative, Dismiss Under Fed. R. Civ. P. 12(c)</i> filed by Cambridge Industries USA, Inc.. Motion to Dismiss Hearing set for 6/13/2024 10:00 AM in San Francisco, Courtroom 11, 19th Floor. Responses due by 5/23/2024. Replies due by 5/30/2024. (Attachments: # <u>1</u> Declaration of Gerald G. Wong, # <u>2</u> Proposed Order)(Pisano, Nicola) (Filed on 5/9/2024) Modified on 5/9/2024 (slh, COURT STAFF). (Entered: 05/09/2024)
05/09/2024	<u>24</u>	MOTION to Dismiss – <i>Partial Motion to Dismiss Under FRCP 12(b)(6) Or, In The Alternative, Dismiss Under FRCP 12(c)</i> (CORRECTION OF DOCKET # <u>23</u>) filed by Cambridge Industries USA, Inc.. Motion to Dismiss Hearing set for 6/13/2024 10:00 AM in San Francisco, Courtroom 11, 19th Floor. Responses due by 5/23/2024. Replies due by 5/30/2024. (Attachments: # <u>1</u> Declaration of Gerald G. Wong, # <u>2</u> Proposed Order)(Pisano, Nicola) (Filed on 5/9/2024) (Entered: 05/09/2024)
05/16/2024	<u>25</u>	JOINT CASE MANAGEMENT STATEMENT AND PROPOSED ORDER filed by Applied Optoelectronics, Inc.. (Carothers, Jo Dale) (Filed on 5/16/2024) (Entered: 05/16/2024)
05/23/2024	<u>26</u>	OPPOSITION/RESPONSE (re <u>24</u> MOTION to Dismiss <i>Partial Motion to Dismiss Under FRCP 12(b)(6) Or, In The Alternative, Dismiss Under FRCP 12(c)</i>) filed by Applied Optoelectronics, Inc.. (Attachments: # <u>1</u> Objection to Defendant's Declaration of Gerald Wong)(Carothers, Jo Dale) (Filed on 5/23/2024) (Entered: 05/23/2024)
05/24/2024	<u>27</u>	Minute Entry for proceedings held before Judge James Donato: Initial Case Management Conference held on 5/23/2024. Total Time in Court: 5 minutes. Court Reporter: Ruth Levine. (jdlc3, COURT STAFF) (Date Filed: 5/24/2024) (Entered: 05/24/2024)
05/30/2024	<u>28</u>	Statement (<i>Joint</i>) Designating a Private Mediator by Applied Optoelectronics, Inc.. (Carothers, Jo Dale) (Filed on 5/30/2024) (Entered: 05/30/2024)
05/30/2024	<u>29</u>	REPLY in Support (re <u>24</u> MOTION to Dismiss <i>Partial Motion to Dismiss Under FRCP 12(b)(6) Or, In The Alternative, Dismiss Under FRCP 12(c)</i>) filed by Cambridge Industries USA, Inc.. (Attachments: # <u>1</u> Response to Objection to Declaration of Gerald G. Wong)(Pisano, Nicola) (Filed on 5/30/2024) Modified on 6/4/2024 (slh, COURT STAFF). (Entered: 05/30/2024)
05/30/2024		CASE REFERRED to Private ADR. (cmf, COURT STAFF) (Filed on 5/30/2024) (Entered: 06/03/2024)
08/08/2024	<u>30</u>	CASE MANAGEMENT SCHEDULING ORDER: Close of Expert Discovery due by 12/29/2025. Close of Fact Discovery due by 9/29/2025. Designation of Experts due by 10/14/2025. Dispositive Motion due by 1/28/2026. Rebuttal Reports due by 11/28/2025. Claims Construction Hearing set for 4/10/2025 01:30 PM. Jury Selection set for 6/8/2026 09:00 AM in San Francisco, Courtroom 11, 19th Floor before Judge James Donato. Jury Trial set for 6/8/2026 09:00 AM in San Francisco, Courtroom 11, 19th Floor before Judge James Donato. Pretrial Conference set for 5/21/2026 01:30 PM in San Francisco, Courtroom 11, 19th Floor before Judge James Donato.. Signed by Judge James Donato on 8/7/2024. (lrc, COURT STAFF) (Filed on 8/8/2024) (Entered: 08/08/2024)
11/04/2024	<u>31</u>	ORDER. The request of defendant CIG to dismiss the willful infringement claim, Dkt. No. 24, is denied. Whether reviewed under Federal Rule of Civil Procedure 12(b)(6), or Rule 12(c), which does not appear to apply but was raised by CIG, the amended complaint plausibly alleges pre-lawsuit notice. See Dkt. No. 19 at

		6-7. CIG's factual objections may be raised later on a fully developed record as warranted by the evidence. See <i>Firstface Co. v. Apple, Inc.</i>, No. 18-cv-02245-JD, 2019 WL 1102374, at *2 (N.D. Cal. Mar. 8, 2019). Signed by Judge James Donato on 11/4/2024. (This is a text-only entry generated by the court. There is no document associated with this entry.) (jdlc3, COURT STAFF) (Filed on 11/4/2024) (Entered: 11/04/2024)
11/07/2024	<u>32</u>	ANSWER to First Amended Complaint and Demand for Jury Trial, and COUNTERCLAIM against Applied Optoelectronics, Inc. filed by Cambridge Industries USA, Inc.. (Pisano, Nicola) (Filed on 11/7/2024) (Entered: 11/07/2024)
11/15/2024	<u>33</u>	ANSWER to Counterclaim of <i>Cambridge Industries USA, Inc.</i> by Applied Optoelectronics, Inc.. (Caligiuri, Eric) (Filed on 11/15/2024) (Entered: 11/15/2024)
12/16/2024	<u>34</u>	JOINT CLAIM CONSTRUCTION AND PREHEARING STATEMENT filed by Applied Optoelectronics, Inc.. (Caligiuri, Eric) (Filed on 12/16/2024) (Entered: 12/16/2024)
01/30/2025	<u>35</u>	CLAIM CONSTRUCTION STATEMENT filed by Applied Optoelectronics, Inc.. (Caligiuri, Eric) (Filed on 1/30/2025) (Entered: 01/30/2025)
02/13/2025	<u>36</u>	RESPONSIVE CLAIM CONSTRUCTION BRIEF re <u>35</u> Claim Construction Statement filed by Cambridge Industries USA, Inc.. (Attachments: # <u>1</u> Declaration of Scott A. Penner, # <u>2</u> Exhibit 1, # <u>3</u> Exhibit 2, # <u>4</u> Exhibit 3, # <u>5</u> Exhibit 4, # <u>6</u> Exhibit 5, # <u>7</u> Exhibit 6, # <u>8</u> Exhibit 7, # <u>9</u> Exhibit 8, # <u>10</u> Exhibit 9)(Penner, Scott) (Filed on 2/13/2025) (Entered: 02/13/2025)
02/20/2025	<u>37</u>	<i>Plaintiff's Reply Claim Construction Brief</i> filed by Applied Optoelectronics, Inc.. (Caligiuri, Eric) (Filed on 2/20/2025) (Entered: 02/20/2025)
03/11/2025	<u>38</u>	***Filed-In-Error. Please Refer to Docket <u>39</u> *** <i>Statement that Patent Local Rule 3-10 Damages Contention Meeting Occurred</i> by Applied Optoelectronics, Inc.. (Carothers, Jo Dale) (Filed on 3/11/2025) Modified on 3/11/2025 (tn, COURT STAFF). (Entered: 03/11/2025)
03/11/2025	<u>39</u>	<i>Statement that Patent Local Rule 3-10 Damages Contention Meeting Occurred</i> CORRECTION OF DOCKET # <u>38</u> by Applied Optoelectronics, Inc.. (Carothers, Jo Dale) (Filed on 3/11/2025) (Entered: 03/11/2025)
03/19/2025	<u>40</u>	NOTICE by Cambridge Industries USA, Inc. <i>to Court of Filing of Petitions for Inter Partes Review</i> (Pisano, Nicola) (Filed on 3/19/2025) (Entered: 03/19/2025)
04/04/2025	41	ORDER. The parties have advised the Court of the institution of IPR proceedings for a majority of claims in the case. Dkt. No. 40. The case is stayed in all respects pending further order. The claims construction hearing set for April 10, 2025, is vacated. The parties will file a joint status report on the PTAB proceedings every 90 days starting on July 7, 2025. Signed by Judge James Donato on 4/4/2025. (This is a text-only entry generated by the court. There is no document associated with this entry.) (jdlc3, COURT STAFF) (Filed on 4/4/2025) (Entered: 04/04/2025)
07/07/2025	<u>42</u>	*Erroneous Entry - Please refer to document <u>43</u> STATUS REPORT Re: <i>Cambridge Industries USA, Inc. Petitions for Inter Partes Review</i> by Cambridge Industries USA, Inc. (Pisano, Nicola) (Filed on 7/7/2025) Modified on 7/10/2025 (slh, COURT STAFF). (Entered: 07/07/2025)
07/07/2025	<u>43</u>	STATUS REPORT Re: <i>Cambridge Industries USA, Inc. Petitions for Inter Partes Review</i> - (CORRECTION re docket #42) by Cambridge Industries USA, Inc. (Attachments: # <u>1</u> Attachment A, # <u>2</u> Attachment B, # <u>3</u> Attachment C)(Pisano, Nicola) (Filed on 7/7/2025) Modified on 7/10/2025 (slh, COURT STAFF). (Entered: 07/07/2025)

EXHIBIT C

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APPLIED OPTOELECTRONICS, INC.

**UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA
SAN FRANCISCO DIVISION**

APPLIED OPTOELECTRONICS, INC.,

Plaintiff,

v.

CAMBRIDGE INDUSTRIES USA, INC.,

Defendant.

Case No. 3:24-cv-01010-JD

**NOTICE TO COURT OF FILING OF
PETITIONS FOR *INTER PARTES* REVIEW**

Judge: Hon. James Donato

1 The parties, through their undersigned counsel, hereby inform that Court that on January 17,
2 2025, Cambridge Industries USA Inc. filed *Inter Partes* Review Petitions with the Patent and Trial
3 Appeal Board of the United States Patent and Trademark Office challenging patentability of all claims
4 of U.S. Patent Nos. 9,523,826 (“the ’826 patent”), 10,042,116 (“the ’116 patent”), 10,379,301 (“the ’301
5 patent”), 10,313,024 (“the ’024 patent”) and 10,788,690 (“the ’690 patent”), which are five of the eight
6 patents AOI asserts in the pending litigation.

7 Notices of Filing Date Accorded were mailed on February 28, 2025, in IPR2025-00433 (’826
8 patent), IPR2025-00434 (’301 patent), IPR2025-00435 (’116 patent), IPR2025-00436 (’024 patent) and
9 IPR2025-00437 (’690 patent), notifying Patent Owner, Applied Optoelectronics, Inc., that its
10 Preliminary Responses may be filed no later than May 28, 2025.

11 The Patent Trial and Appeal Board Consolidated Trial Practice Guide dated November 2019, at
12 page 5, provides that “The Board acting on behalf of the Director will determine whether to institute a
13 trial within three months of the date the patent owner’s preliminary response was due or was filed,
14 whichever is first.” Accordingly, the parties expect institution decisions by or around August 28, 2025.

15 The parties wanted to inform the Court at this time about the filing of the Inter Partes Review
16 petitions and will continue to update this Court regarding their status. Plaintiff further would like the
17 Court to consider whether it might wish either to stay the case now or to delay the claim construction
18 hearing scheduled for April 10, 2025, until after the date of the institution decision for purposes of
19 judicial efficiency and to avoid potential duplication of efforts.

1 DATED: March 19, 2025

Respectfully submitted,

2 **EVERSHEDS SUTHERLAND (US) LLP**

3 /s/ Nicola A. Pisano

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CAMBRIDGE INDUSTRIES USA INC.

12 DATED: March 19, 2025

Respectfully submitted,

13 **WEINTRAUB TOBIN CHEDIAK COLEMAN**
14 **GRODIN LAW CORPORATION**

15 By: /s/ Jo Dale Carothers

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APPLIED OPTOELECTRONICS, INC.

CERTIFICATE OF SERVICE

I hereby certify that I electronically filed the foregoing with the Clerk of the Court using the CM/ECF system which will send notification of such filing to the Electronic Service List for this case.

Executed on March 19, 2025.

EVERSHEDS SUTHERLAND (US) LLP

/s/ Nicola A. Pisano

Nicola A. Pisano (CA Bar No. 151282)

NicolaPisano@eversheds-sutherland.com

Attorneys for Defendant

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Attorneys for Plaintiff
Applied Optoelectronics, Inc.

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA

APPLIED OPTOELECTRONICS, INC.,

Plaintiff,

vs.

ACCELIGHT TECHNOLOGIES, INC.

Defendant.

Case No.: 4:24-cv-09041-HSG

**FIRST AMENDED COMPLAINT FOR
PATENT INFRINGEMENT**

DEMAND FOR JURY TRIAL

For its first amended complaint (“First Amended Complaint”) against Defendant Accelight Technologies, Inc., (“ATI” or “Defendant”), Plaintiff Applied Optoelectronics, Inc. (“AOI” or “Plaintiff”) alleges on personal knowledge as to its own activities and on information and belief as to the activities of others as follows:

THE PARTIES

1. Plaintiff AOI is a Delaware Corporation with its principal place of business located at 13139 Jess Pirtle Blvd., Sugar Land, Texas 77478.

2. On information and belief, Defendant Accelight Technologies, Inc., is a California Corporation with its principal place of business located at 5674 Stoneridge Drive, #109, Pleasanton, CA 94588.

///

1 3. On information and belief, ATI is registered to do business in the State of
2 California, has designated an agent for service of process in the State of California, and has a
3 physical office located in the State of California and specifically in this district.

4 **NATURE OF ACTION**

5 4. This is an action alleging patent infringement by Defendant ATI of the following
6 United States Patents: U.S. Patent No. 9,523,826 (the “’826 Patent”), entitled “Pluggable optical
7 transceiver module,” and issued on December 20, 2016; U.S. Patent No. 10,042,116 (the “’116
8 Patent”), entitled “Techniques for direct optical coupling of photodetectors to optical
9 demultiplexer outputs and an optical transceiver using the same,” and issued on August 7, 2018;
10 U.S. Patent No. 9,448,367 (the “’367 Patent”), entitled “Multi-Channel Optical Transceiver
11 Module Including Dual Fiber Type Direct Link Adapter for Optically Coupling Optical
12 Subassemblies in the Transceiver Module,” and issued on September 20, 2016; U.S. Patent
13 No. 10,379,301 (the “’301 Patent”), entitled “Multi-channel parallel optical receiving device,” and
14 issued on August 13, 2019; U.S. Patent No. 10,313,024 (the “’024 Patent”), entitled “Transmitter
15 Optical Subassembly With Trace Routing To Provide Electrical Isolation Between Power And RF
16 Traces,” and issued on June 4, 2019; and U.S. Patent No. 10,788,690 (the “’690 Patent”), entitled
17 “Optical Isolator Array For Use In An Optical Subassembly Module,” and issued on
18 September 29, 2020 (collectively, the “Asserted Patents”). A true and correct copy of each of the
19 Asserted Patents is attached hereto as **Exhibits A– F**.

20 5. Plaintiff AOI is the assignee and owner of record of the ’826 Patent, and all rights,
21 title, and interest in and to the ’826 Patent.

22 6. Plaintiff AOI is the assignee and owner of record of the ’116 Patent, and all rights,
23 title, and interest in and to the ’116 Patent.

24 7. Plaintiff AOI is the assignee and owner of record of the ’367 Patent, and all rights,
25 title, and interest in and to the ’367 Patent.

26 8. Plaintiff AOI is the assignee and owner of record of the ’301 Patent, and all rights,
27 title, and interest in and to the ’301 Patent.

28 ///

1 9. Plaintiff AOI is the assignee and owner of record of the '024 Patent, and all rights,
2 title, and interest in and to the '024 Patent.

3 10. Plaintiff AOI is the assignee and owner of record of the '690 Patent, and all rights,
4 title, and interest in and to the '690 Patent.

5 **JURISDICTION AND VENUE**

6 11. This is an action for patent infringement arising under the patent laws of the United
7 States, Title 35 of the United States Code, including without limitation 35 U.S.C. § 271(a) . This
8 Court has subject matter jurisdiction over this case pursuant to 28 U.S.C. §§ 1331 and 1338(a),
9 because this action arises under the patent laws of the United States, Title 35 of the United States
10 Code, including but not limited to 35 U.S.C. §§ 271(a), 281, 284 and 285.

11 12. This Court has personal jurisdiction over ATI. On information and belief, ATI
12 designs products in this state and district and sells and offers for sale goods to customers in this
13 state and district via its sales people and through its distributors, including without limitation at its
14 physical office located at 5674 Stoneridge Drive, #109, Pleasanton, CA 94588. On information
15 and belief, ATI is registered to do business in the State of California and has designated
16 Registered Agent Solutions, Inc., as an agent for service of process in the State of California. On
17 information and belief, ATI has at least one physical office located in the State of California and
18 specifically in this district at 5674 Stoneridge Drive, #109, Pleasanton, CA 94588.

19 13. Further, ATI's website at <https://www.accelight.com> lists its US address as
20 5674 Stoneridge Drive, #109, Pleasanton, CA 94588.

21 14. Venue is proper in the United States District Court for the Northern District of
22 California under 28 U.S.C. §§ 1391(b)-(d) and/or 1400(b) because, on information and belief, ATI
23 has committed acts of infringement in this district and has a regular and established place of
24 business in this district. On information and belief, ATI designs products and/or sells and offers
25 for sale infringing goods to customers in this state and district via its sales people and/or through
26 its distributors in this state and district, including without limitation at its physical office located in
27 this district at 5674 Stoneridge Drive, #109, Pleasanton, CA 94588. On information and belief,
28 ATI also imports infringing products into this district.

INTRADISTRICT ASSIGNMENT

15. This case is a patent infringement dispute that is appropriate for district-wide assignment.

AOI'S BUSINESS

16. AOI is a leading provider of fiber-optic networking products. It serves four growing end-markets: internet data centers (Data Center), Cable Television Broadband (CATV), fiber-to-the-home (FTTH), and telecommunications. AOI designs and manufactures a range of optical communications products employing our vertical integration strategy from laser chips, components, subassemblies and modules to complete turn-key equipment. AOI designs, manufactures, and integrates its own analog and digital lasers using a proprietary Molecular Beam Epitaxy (MBE) fabrication process, which it believes is unique in its industry. The lasers are proven to be reliable over time and highly tolerant of changes in temperature and humidity (delivering millions of hours service), making them well-suited to the CATV and FTTH markets where networking equipment is often installed outdoors.

17. AOI has a state-of-the-art semiconductor component fab at its USA Headquarters near Houston, Texas.

DEFENDANT'S INFRINGING ACTIVITIES

18. On information and belief, ATI, either directly or through other entities under its control, imports, uses, offers for sale, and/or sells infringing products, including without limitation the ATI 100G QSFP LR4, ATI 400G QSFP-DD SR8, ATI 100G QSFP28 CWDM4, ATI 400G QSFP-DD FR4, and ATI 400G QSFP-DD DR4 (the "Accused Products"). *See, e.g., Exhibits G through N.*

19. On information and belief, ATI infringes the Asserted Patents by engaging in acts constituting infringement under 35 U.S.C. § 271(a), including without limitation by making, using, selling and/or offering for sale in and/or importing into the United States without authority one or more Accused Products that infringe one or more claims of the Asserted Patents.

///

///

FIRST CAUSE OF ACTION

(Infringement of the '826 Patent under 35 U.S.C. § 271(a))

20. AOI incorporates by reference as if fully set forth herein the allegations in Paragraphs 1-19 of this First Amended Complaint.

21. On information and belief, ATI directly infringes under 35 U.S.C. § 271(a) one or more claims of the '826 Patent, by making, using, selling, offering for sale, and/or importing into the United States without authority products, including without limitation at least one or more of the Accused Products, that infringe one or more claims of the '826 Patent.

22. Defendant has directly infringed at least, for example, claim 1 of the '826 patent by making, using, selling, offering for sale, and/or importing into the United States without authority products, including without limitation at least one or more of the Accused Products.

23. The claim charts attached hereto as Exhibit G through I identifies on a limitation-by-limitation basis where each limitation of claims 1 and 7 of the '826 Patent is found within one or more of the Accused Products.

24. ATI does not have a license to any of Plaintiff's patents or technology, including without limitation the Asserted Patents.

25. ATI has knowledge and notice of the Asserted Patents and its infringement since at least, and through, the filing of the original complaint in this action.

26. As a direct and proximate result of ATI's infringement, since at least the filing of the original complaint in this action, AOI has suffered, and will continue to suffer, damage in an amount to be proved at trial.

27. As a result of the harm suffered as alleged herein, AOI is entitled to relief under the Patent Act, including damages adequate to compensate it for such infringement, but in no event less than a reasonable royalty.

28. On information and belief, unless enjoined by this Court, ATI will continue to do the acts complained herein, and unless restrained and enjoined will continue to do so, all to AOI's irreparable damage. It would be difficult to ascertain the amount of compensation which would afford AOI adequate relief for such future and continuing acts. AOI does not have an adequate

1 remedy at law to compensate it for injuries threatened. Thus, AOI is entitled to an injunction
2 against further infringement by ATI.

3 **SECOND CAUSE OF ACTION**

4 **(Infringement of the '116 Patent under 35 U.S.C. § 271(a))**

5 29. AOI incorporates by reference as if fully set forth herein the allegations in
6 Paragraphs 1–28 of this First Amended Complaint.

7 30. On information and belief, ATI directly infringes under 35 U.S.C. § 271(a) one or
8 more claims of the '116 Patent, by making, using, selling, offering for sale, and/or importing into
9 the United States without authority products, including without limitation at least one of the
10 Accused Products, that infringe one or more claims of the '116 Patent.

11 31. Defendant has directly infringed at least, for example, claim 1 of the '116 patent by
12 making, using, selling, offering for sale, and/or importing into the United States without authority
13 products, including without limitation at least one of the Accused Products.

14 32. The claim chart attached hereto as Exhibit J identifies on a limitation-by-limitation
15 basis where each limitation of claims 1 and 12 of the '116 Patent is found within one of the
16 Accused Products.

17 33. ATI does not have a license to any of Plaintiff's patents or technology, including
18 without limitation the Asserted Patents.

19 34. ATI has knowledge and notice of the Asserted Patents and their infringement since
20 at least, and through, the filing of the original complaint in this action.

21 35. As a direct and proximate result of ATI's infringement, since at least the filing of
22 the original complaint in this action, AOI has suffered, and will continue to suffer, damage in an
23 amount to be proved at trial.

24 36. As a result of the harm suffered as alleged herein, AOI is entitled to relief under the
25 Patent Act, including damages adequate to compensate it for such infringement, but in no event
26 less than a reasonable royalty.

27 37. On information and belief, unless enjoined by this Court, ATI will continue to do
28 the acts complained herein, and unless restrained and enjoined will continue to do so, all to AOI's

1 irreparable damage. It would be difficult to ascertain the amount of compensation which would
2 afford AOI adequate relief for such future and continuing acts. AOI does not have an adequate
3 remedy at law to compensate it for injuries threatened. Thus, AOI is entitled to an injunction
4 against further infringement by ATI.

5 **THIRD CAUSE OF ACTION**

6 **(Infringement of the '367 Patent under 35 U.S.C. § 271(a))**

7 38. AOI incorporates by reference as if fully set forth herein the allegations in
8 Paragraphs 1–37 of this First Amended Complaint.

9 39. On information and belief, ATI directly infringes under 35 U.S.C. § 271(a) one or
10 more claims of the '367 Patent, by making, using, selling, offering for sale, and/or importing into
11 the United States without authority products, including without limitation at least one of the
12 Accused Products, that infringe one or more claims of the '367 Patent.

13 40. Defendant has directly infringed at least, for example, claim 1 of the '367 patent by
14 making, using, selling, offering for sale, and/or importing into the United States without authority
15 products, including without limitation at least one of the Accused Products.

16 41. The claim chart attached hereto as Exhibit K identifies on a limitation-by-limitation
17 basis where each limitation of claim 1 of the '367 Patent is found within one of the Accused
18 Products.

19 42. ATI does not have a license to any of Plaintiff's patents or technology, including
20 without limitation the Asserted Patents.

21 43. ATI has knowledge and notice of the Asserted Patents and their infringement since
22 at least, and through, the filing of the original complaint in this action.

23 44. As a direct and proximate result of ATI's infringement, since at least the filing of
24 the original complaint in this action, AOI has suffered, and will continue to suffer, damage in an
25 amount to be proved at trial.

26 45. As a result of the harm suffered as alleged herein, AOI is entitled to relief under the
27 Patent Act, including damages adequate to compensate it for such infringement, but in no event
28 less than a reasonable royalty.

70. ATI has knowledge and notice of the Asserted Patents and their infringement since at least, and through, the filing of the original complaint in this action.

71. As a direct and proximate result of ATI's infringement, since at least the filing of the original complaint in this action, AOI has suffered, and will continue to suffer, damage in an amount to be proved at trial.

72. As a result of the harm suffered as alleged herein, AOI is entitled to relief under the Patent Act, including damages adequate to compensate it for such infringement, but in no event less than a reasonable royalty.

73. On information and belief, unless enjoined by this Court, ATI will continue to do the acts complained herein, and unless restrained and enjoined will continue to do so, all to AOI's irreparable damage. It would be difficult to ascertain the amount of compensation which would afford AOI adequate relief for such future and continuing acts. AOI does not have an adequate remedy at law to compensate it for injuries threatened. Thus, AOI is entitled to an injunction against further infringement by ATI.

PRAYER FOR RELIEF

WHEREFORE, Plaintiff respectfully prays that the Court grant the following relief:

- A. For judgment that ATI has infringed and continues to infringe the '826 Patent;
- B. For judgment that the '826 Patent is valid and enforceable;
- C. For a preliminary and permanent injunction prohibiting ATI, and all persons or entities acting in concert with ATI, from infringing the '826 Patent;
- D. For judgment that ATI has infringed and continues to infringe the '116 Patent;
- E. For judgment that the '116 Patent is valid and enforceable;
- F. For a preliminary and permanent injunction prohibiting ATI, and all persons or entities acting in concert with ATI, from infringing the '116 Patent;
- G. For judgment that ATI has infringed and continues to infringe the '367 Patent;
- H. For judgment that the '367 Patent is valid and enforceable;
- I. For a preliminary and permanent injunction prohibiting ATI, and all persons or entities acting in concert with ATI, from infringing the '367 Patent;

J. For judgment that ATI has infringed and continues to infringe the '301 Patent;

K. For judgment that the '301 Patent is valid and enforceable;

L. For a preliminary and permanent injunction prohibiting ATI, and all persons or entities acting in concert with ATI, from infringing the '301 Patent;

M. For judgment that ATI has infringed and continues to infringe the '024 Patent;

N. For judgment that the '024 Patent is valid and enforceable;

O. For a preliminary and permanent injunction prohibiting ATI, and all persons or entities acting in concert with ATI, from infringing the '024 Patent;

P. For judgment that ATI has infringed and continues to infringe the '690 Patent;

Q. For judgment that the '690 Patent is valid and enforceable;

R. For a preliminary and permanent injunction prohibiting ATI, and all persons or entities acting in concert with ATI, from infringing the '690 Patent;

S. An award of damages adequate to compensate Plaintiff for the infringement, as well as prejudgment and post-judgment interest from the date the infringement began, but in no event less than a reasonable royalty as permitted by 35 U.S.C. § 284;

T. A finding that this case is exceptional and an award of interest, costs, expenses, and attorneys' fees incurred by Plaintiff in prosecuting this action as provided by 35 U.S.C. § 285;

U. For any other orders necessary to accomplish complete justice between the parties; and

V. For such other and further relief as this Court or a jury may deem just and proper.

JURY DEMAND

Pursuant to Rule 38 of the Federal Rules of Civil Procedure, Plaintiff demands a trial by jury on all cause of actions and issues so triable.

Dated: February 19, 2025

WEINTRAUB TOBIN CHEDIAK COLEMAN GRODIN

By: /s/ Jo Dale Carothers
Jo Dale Carothers

Attorneys for Plaintiff Applied Optoelectronics, Inc.

Exhibit A



US009523826B2

(12) **United States Patent**
Tsai et al.

(10) **Patent No.:** **US 9,523,826 B2**

(45) **Date of Patent:** **Dec. 20, 2016**

(54) **PLUGGABLE OPTICAL TRANSCEIVER MODULE**

(71) Applicant: **Applied Optoelectronics, Inc.**, New Taipei (TW)

(72) Inventors: **Chao-Hung Tsai**, New Taipei (TW);
Chien-Te Lin, New Taipei (TW);
Che-Shou Yeh, New Taipei (TW)

(73) Assignee: **Applied Optoelectronics, Inc.**, Sugar Land, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 88 days.

(21) Appl. No.: **14/504,500**

(22) Filed: **Oct. 2, 2014**

(65) **Prior Publication Data**

US 2015/0093083 A1 Apr. 2, 2015

(30) **Foreign Application Priority Data**

Oct. 2, 2013 (TW) 102135723 A

(51) **Int. Cl.**
G02B 6/42 (2006.01)

(52) **U.S. Cl.**
CPC **G02B 6/423** (2013.01); **G02B 6/4246** (2013.01); **G02B 6/4261** (2013.01); **G02B 6/4284** (2013.01); **G02B 6/4292** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,201,520 B2 *	4/2007	Mizue	G02B 6/4292
			385/92
2011/0081114 A1 *	4/2011	Togami	G02B 6/4246
			385/76

* cited by examiner

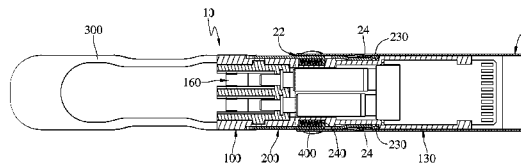
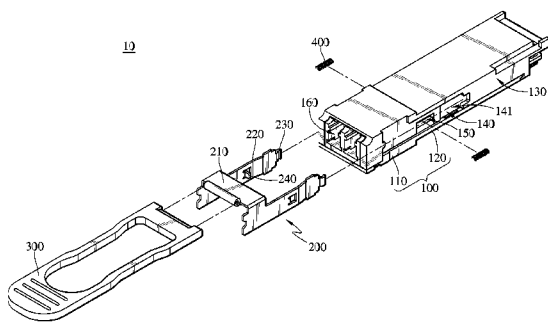
Primary Examiner — Michelle R Connelly

(74) *Attorney, Agent, or Firm* — Grossman Tucker Perreault & Pfeleger, PLLC; Norman S. Kinsella

(57) **ABSTRACT**

A pluggable optical transceiver module for inserted into plugging slot includes main body and sliding component. The main body has opposite two side surfaces and two sliding slots. The two sliding slots are located at the two side surfaces. The sliding component includes linkage arm and two extending arms. The two extending arms are connected to the linkage arm. Each extending arm has a second fastening part. The main body is between the two extending arms. The two extending arms are disposed on the two sliding slots to have fastening position and releasing position. Two first fastening parts are fastened to the two second fastening parts when the two extending arms are located at fastening position. The two second fastening parts press the two first fastening parts, respectively, for the two first fastening parts being farther from each other when the two extending arms are located at releasing position.

7 Claims, 8 Drawing Sheets



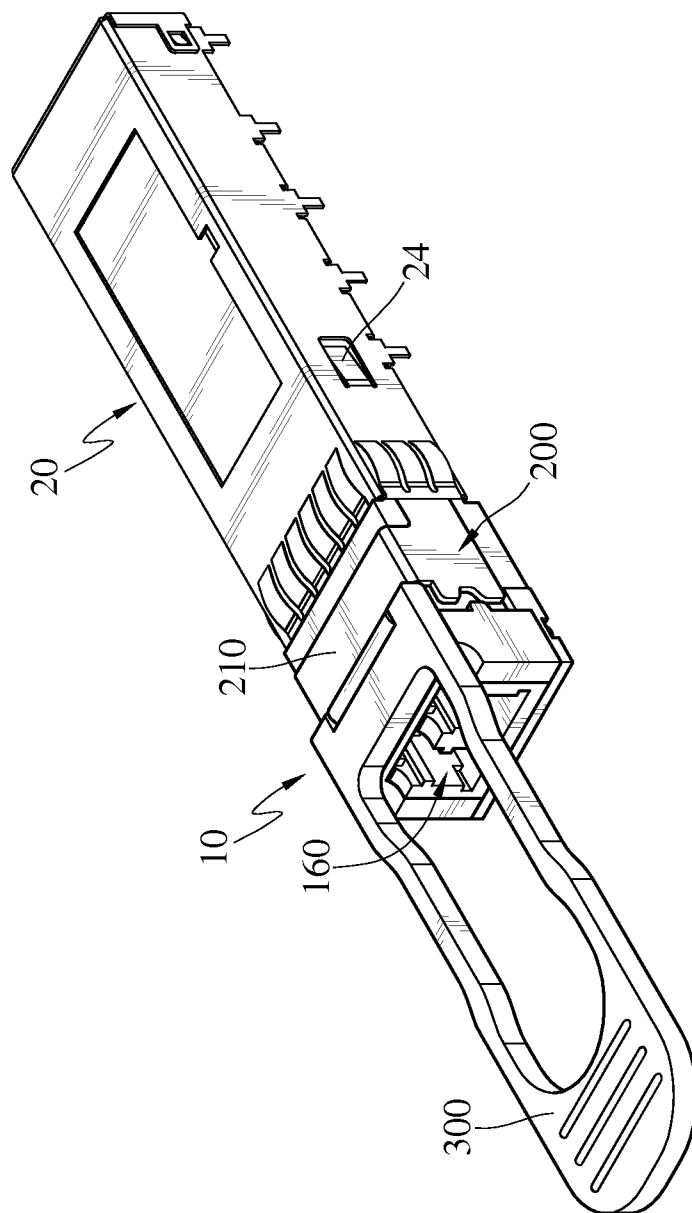


FIG. 1

U.S. Patent

Dec. 20, 2016

Sheet 2 of 8

US 9,523,826 B2

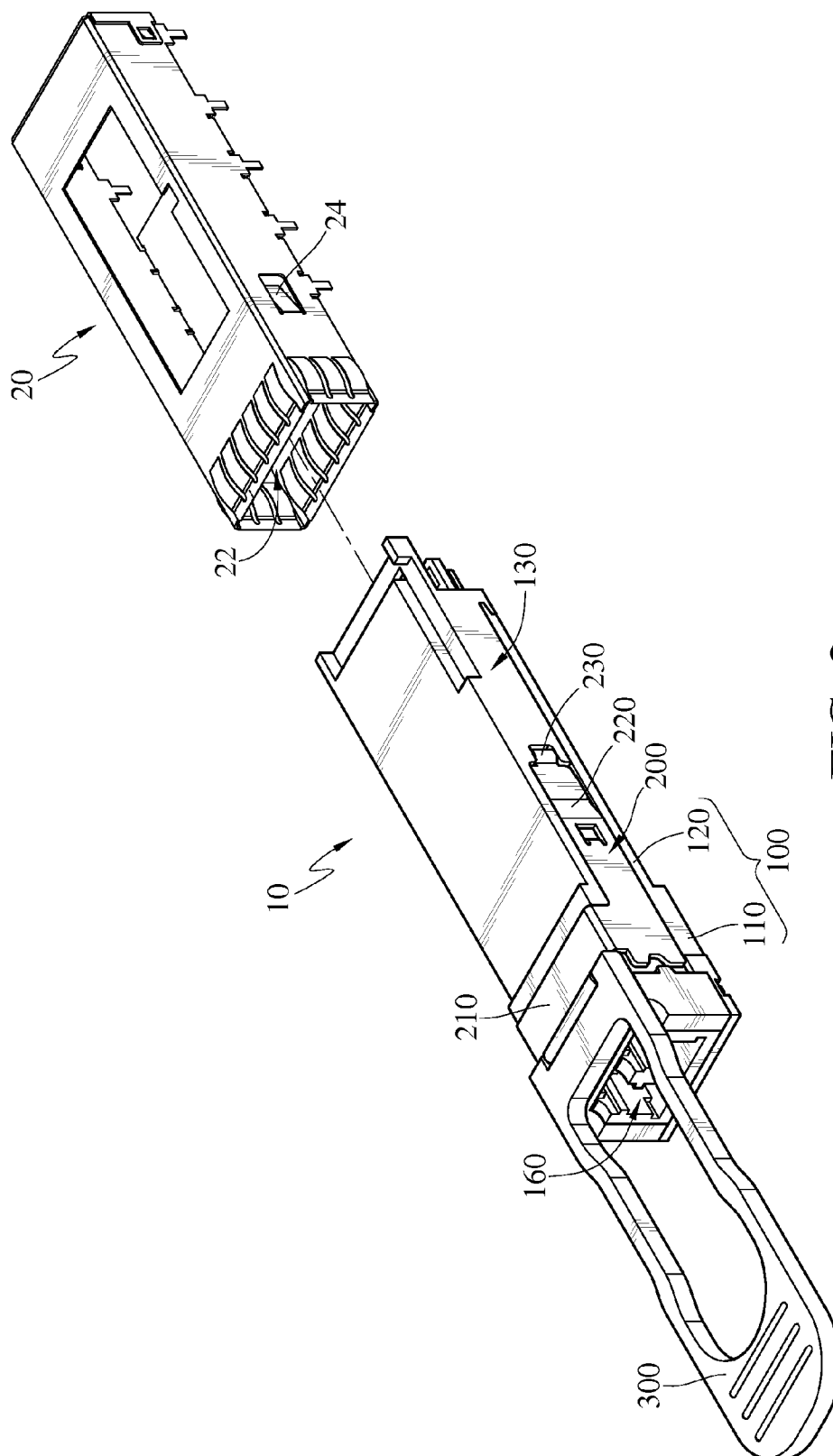


FIG. 2

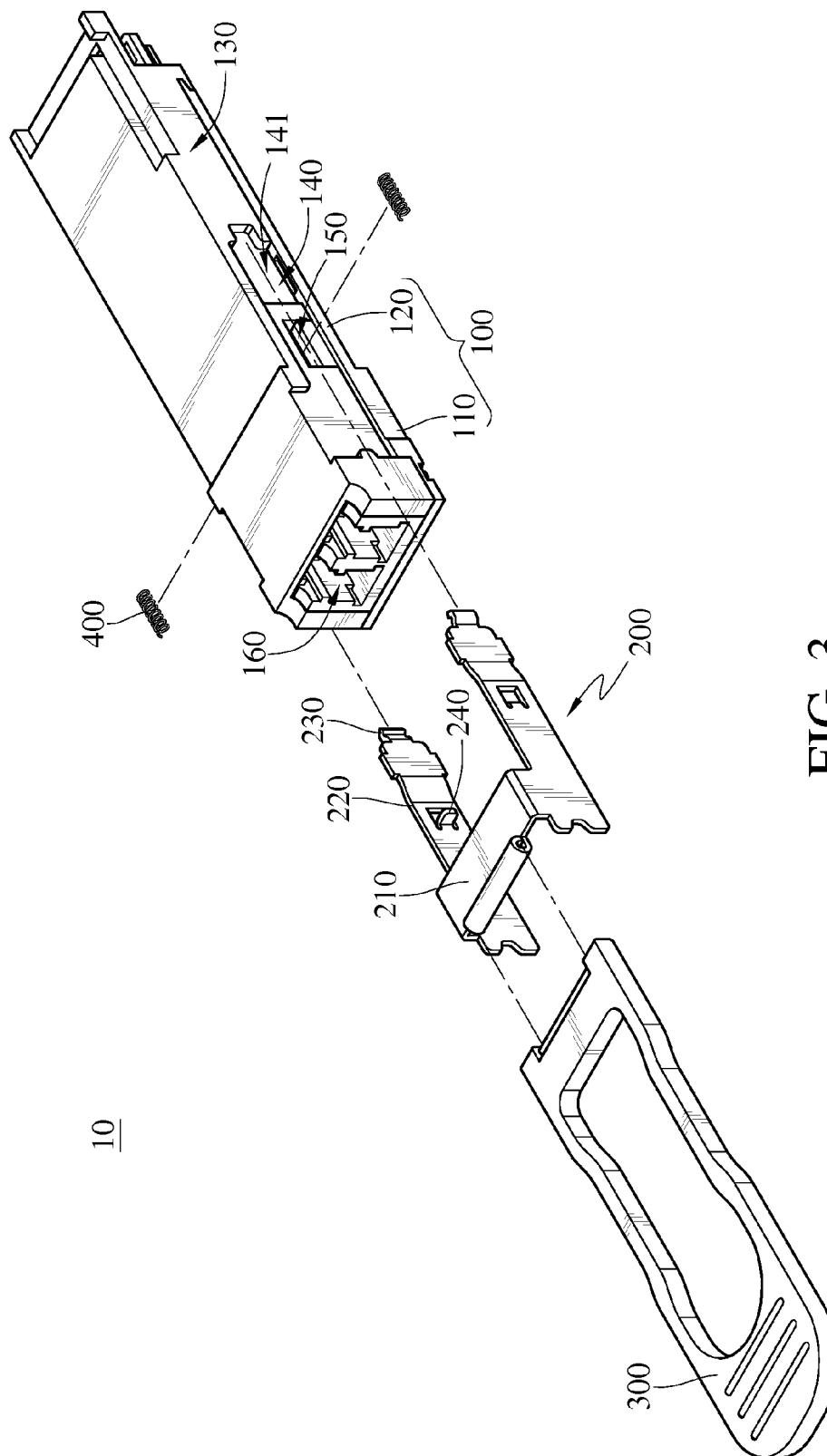


FIG. 3

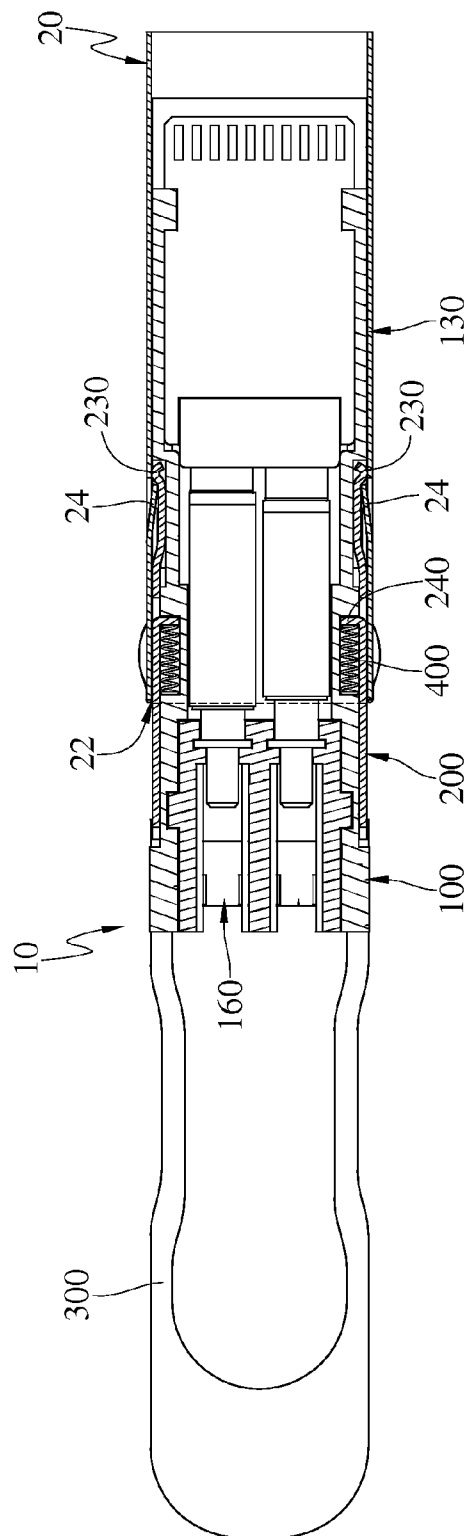


FIG. 4A

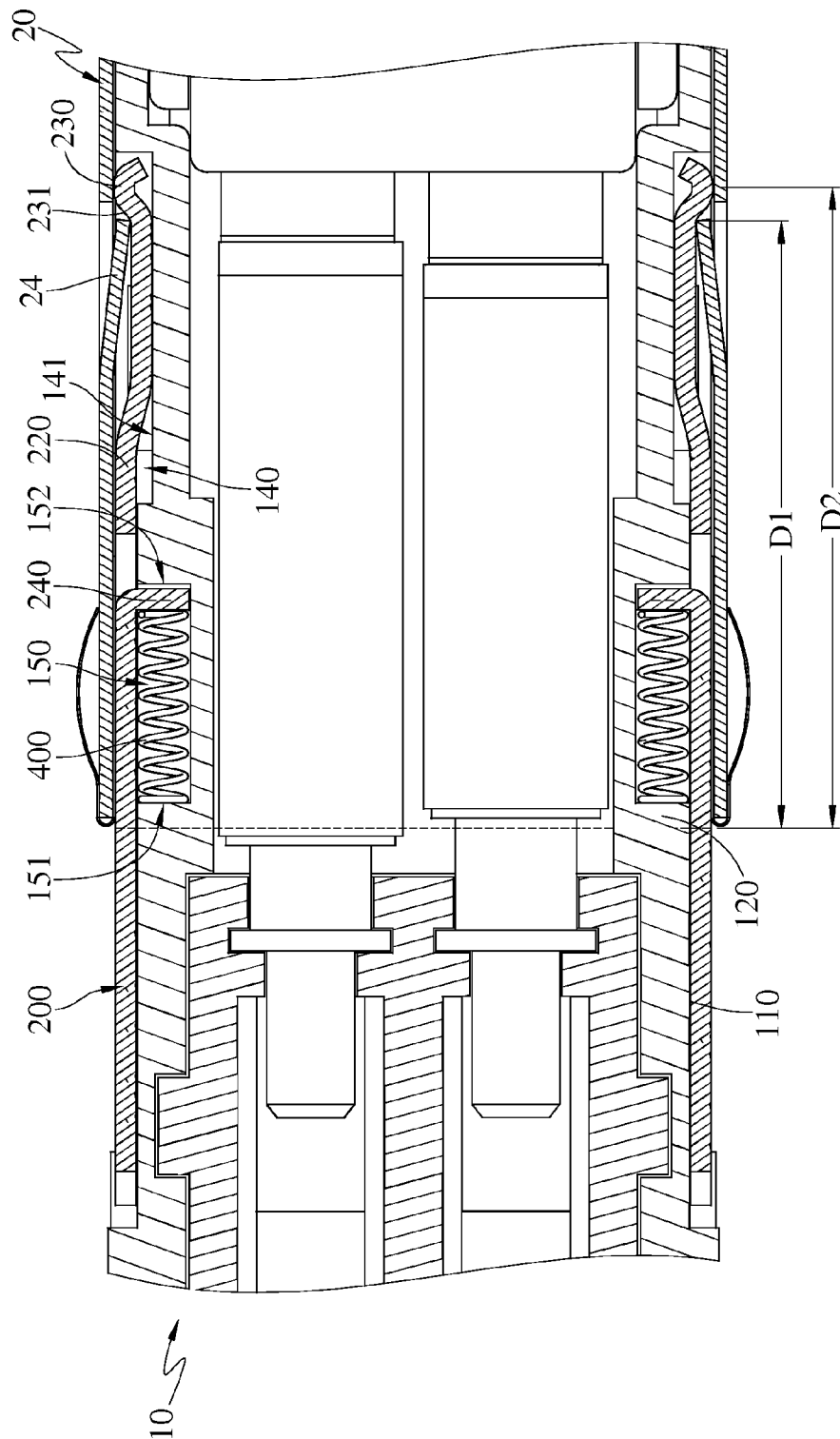


FIG. 4B

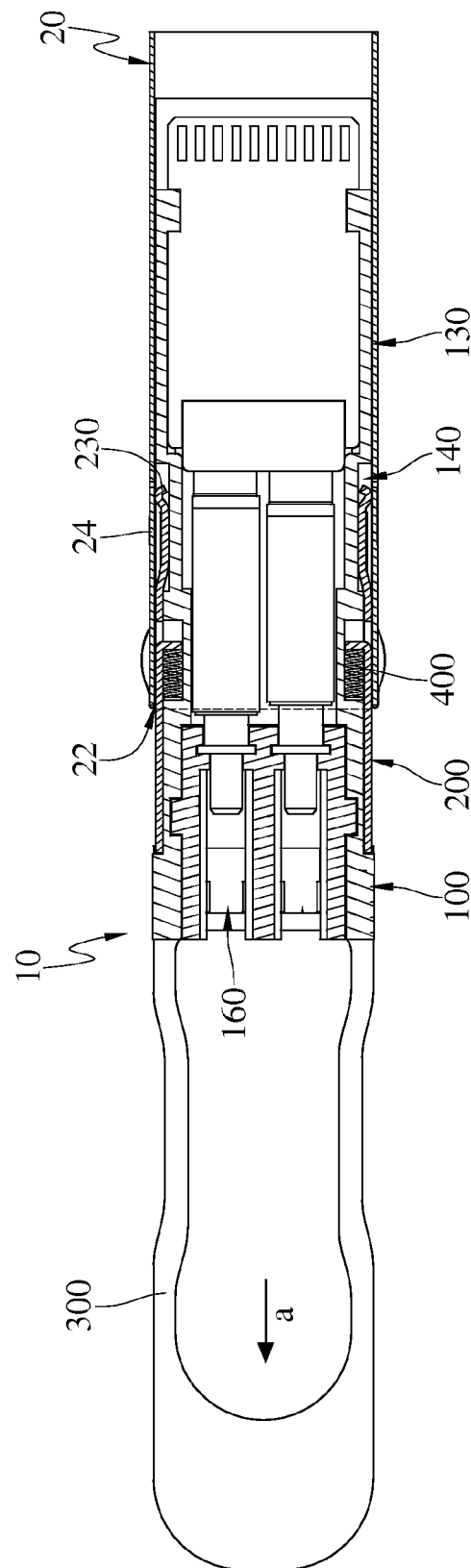


FIG. 5A

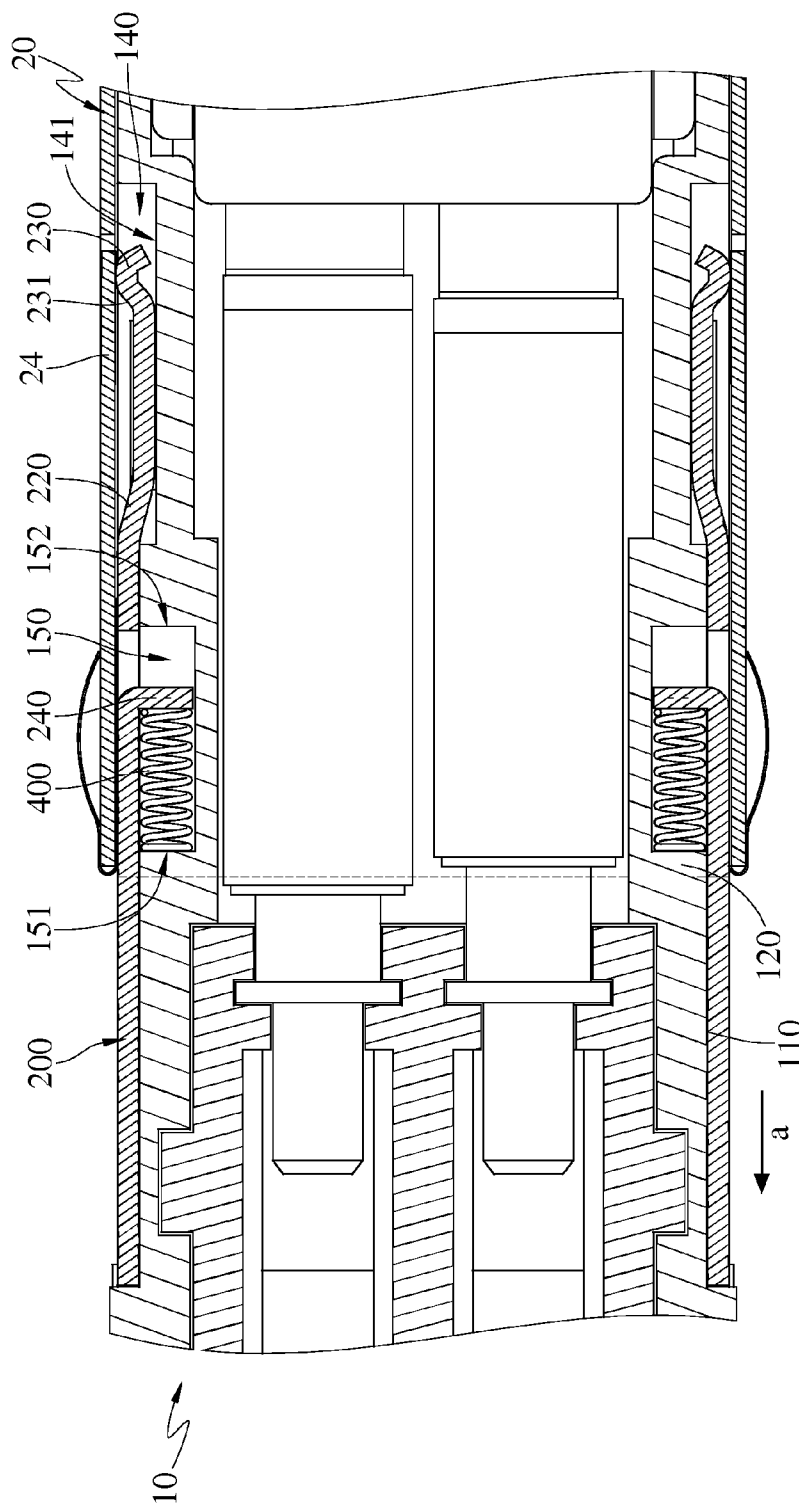


FIG. 5B

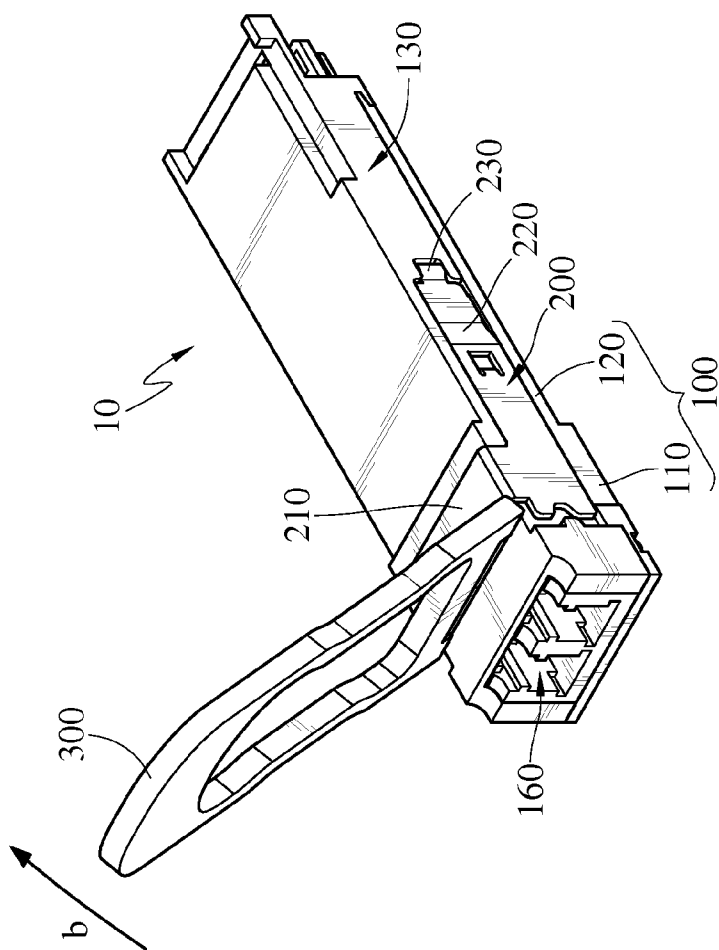


FIG. 6

US 9,523,826 B2

1

PLUGGABLE OPTICAL TRANSCEIVER MODULE

CROSS-REFERENCE TO RELATED APPLICATIONS

This non-provisional application claims priority under 35 U.S.C. §119(a) on Patent Application No(s) 102135723, filed in Taiwan, R.O.C. on Oct. 2, 2013, the entire contents of which are hereby incorporated by reference.

TECHNICAL FIELD

The disclosure relates to an optical communication component, more particularly to a pluggable optical transceiver module.

BACKGROUND

An optical transceiver module is generally installed in an electronic communication facility in the modern high speed communication networks. In order to make the electronic communication facility flexible and easy to repair, the optical transceiver module is inserted into a corresponding socket disposed in the communication facility in a pluggable manner. In general, the socket is disposed on a circuit board. In order to define the electrical-to-mechanical interface of the optical transceiver module and the corresponding socket, different specifications have been provided such as XFP (10 Gigabit Small Form Factor Pluggable) used in 10 GB/s communication rate and QSFP (Quad Small Form-factor Pluggable).

A fastening mechanism is disposed in the socket corresponding to the optical transceiver module so that the optical transceiver module is securely fixed to the socket by the fastening mechanism. Therefore, it is indispensable that the optical transceiver module must have a releasing mechanism. This makes the optical transceiver module slip out from the socket by easily removing the lock.

On the other hand, a common communication facility, such as a hub, usually comprises at least one optical transceiver module for converting optical signals into electronic signals. When the common communication facility is used for a long time, dusts may drop on the surface of common communication facility. Thus, dusts may also drop on the optical transceiver module without any appropriate protection when the optical fiber cable is connected or removed from the optical transceiver module. Consequently, the dusts may damage the optical transceiver module and affect the transmission of the signals.

In view of this, it is important to improve the convenient connection and disconnection between the optical transceiver module and the socket and its dust-proof function.

SUMMARY

The disclosure provides a pluggable optical transceiver module configured to be inserted into a plugging slot. The pluggable optical transceiver module comprises a main body and a sliding component. The main body has two side surfaces opposite to each other and two sliding slots. The two sliding slots are located at the two side surfaces. The main body is configured to be inserted into the plugging slot. The sliding component comprises a linkage arm and two extending arms. The two extending arms are connected to two ends of the linkage arm, respectively. Each extending arm has a second fastening part. The main body is between

2

the two extending arms. The two extending arms are slidably disposed on the two sliding slots to have a fastening position and a releasing position. Two first fastening parts are fastened to the two second fastening parts when the two extending arms are located at the fastening position. The two second fastening parts press the two first fastening parts, respectively, to make the two first fastening parts be farther away from each other when the two extending arms are located at the releasing position.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure will become more fully understood from the detailed description and the drawings given herein below for illustration only, thus does not limit the present disclosure, wherein:

FIG. 1 is a perspective view of a pluggable optical transceiver module according to a first embodiment;

FIG. 2 is an exploded view of the pluggable optical transceiver module in FIG. 1;

FIG. 3 is another exploded view of the pluggable optical transceiver module in FIG. 1;

FIG. 4A is a cross-sectional view of the pluggable optical transceiver module in FIG. 1 when a sliding component is located at a fastening position;

FIG. 4B is a partial enlarged view of the pluggable optical transceiver module in FIG. 4A;

FIG. 5A is a cross-sectional view of the pluggable optical transceiver module in FIG. 1 when the sliding component is located at a releasing position;

FIG. 5B is a partial enlarged view of the pluggable optical transceiver module in FIG. 5A; and

FIG. 6 is a perspective view of the pluggable optical transceiver module in FIG. 2 when a pull handle pivots on a main body.

DETAILED DESCRIPTION

In the following detailed description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the disclosed embodiments. It will be apparent, however, that one or more embodiments may be practiced without these specific details. In other instances, well-known structures and devices are schematically shown in order to simplify the drawings.

FIG. 1 is a perspective view of a pluggable optical transceiver module according to a first embodiment. FIG. 2 is an exploded view of the pluggable optical transceiver module in FIG. 1. In the first embodiment, a pluggable optical transceiver module 10 is configured to be inserted into a socket 20 to convert optical signals into electronic signals. The socket 20 has a plugging slot 22 and two first fastening parts 24. Each first fastening part 24 is elastic. One end of the first fastening part 24 is connected to a case of the socket 20 and the other end of the first fastening part 24 is located in the plugging slot 22. In this embodiment, the first fastening part 24 is an elastic slice.

FIG. 3 is another exploded view of FIG. 1. FIG. 4A is a cross-sectional view of FIG. 1 when a sliding component is located at a fastening position. FIG. 4B is a partial enlarged view of FIG. 4A. The pluggable optical transceiver module 10 comprises a main body 100, a sliding component 200, a pull handle 300 and two elastic components 400. The main body 100 comprises a head part 110 and an inserted part 120 that are connected to each other. The inserted part 120 is configured to be inserted into the plugging slot 22 of the

US 9,523,826 B2

3

socket 20. The main body 100 has two side surfaces 130, two sliding slots 140 and two limiting spaces 150. The two side surfaces 130 are located at opposite two sides of the head part 110 and the inserted part 120, respectively. The two sliding slots 140 are located at the two side surfaces 130, respectively, and extend from the head part 110 to the inserted part 120. Each sliding slot 140 has a bottom surface 141 which is, but not limited to, parallel to the side surface 130. In other embodiments, the slot bottom surface 141 encloses an acute angle with the side surface 130.

The two limiting spaces 150 are located at the bottom surfaces 141 of the two sliding slots 140, respectively. Each limiting space 150 has a first limiting surface 151 and a second limiting surface 152. Both of the first limiting surface 151 and the second limiting surface 152 are connected to the bottom surface 141. The first limiting surface 151 is closer to the head part 110 than the second limiting surface 152.

Moreover, the main body 100 is configured to accommodate a photoelectric conversion circuit (not shown in the figures). Both of the two sliding slots 140 and the two limiting spaces 150 do not penetrate through the inner surface of the main body 100. Therefore, the main body 100 protects the photoelectric conversion circuit from being contaminated by atmospheric dust.

The head part 110 has at least one optical fiber terminal 160. An optical fiber plug may plug into the photoelectric conversion circuit in the main body 100 through the optical fiber terminal 160.

The sliding component 200 comprises a linkage arm 210 and two extending arms 220. The two extending arms 220 are connected to two ends of the linkage arm 210, respectively. The main body 100 is between the two extending arms 220. The two extending arms 220 are slidably disposed on the two sliding slots 140, respectively. Each extending arm 220 has a second fastening part 230 and a limited part 240. The second fastening part 230 extends along a direction far away from the side surface 130. Each second fastening part 230 has a fastening surface 231 located at one side of the second fastening part 230 facing the head part 110. A distance D1 between one side of the fastening surface 231 which is close to the side surface 130 and the head part 110 is less than a distance D2 from another side of the fastening surface 231 which is far away from the side surface 130 from and the head part 110. That is, the fastening surface 231 is an inclined surface enclosing an acute angle with the side surface 130. The limited part 240 extends toward the side surface 130 and is located in the limiting space 150. The limited part 240 is able to slide between the first limiting surface 151 and the second limiting surface 152 relative to the main body 100. The sliding component is able to slide relative to the main body 100 to have a fastening position and a releasing position. The two first fastening parts 230 are farther from the head part 110 when the two extending arms 220 are located at the fastening position. The two first fastening parts 230 are closer to the head part 110 when the two extending arms 220 are located at the releasing position.

The pull handle 300 is pivoted on the linkage arm 210 of the sliding component 200 and extends outside from the main body 100. The pull handle 300 is able to pivot about the sliding component 200 to be in front of the head part 110 or on the top of the head part 110. In this embodiment, the pull handle 300 is configured to slide the sliding component 200 but the disclosure is not limited thereto. In other embodiments, the pluggable optical transceiver module 10 does not comprise the pull handle 300 and is able to be unplugged from the socket 20 by unplugging the linkage arm 210 directly. Furthermore, in this embodiment, the pull

4

handle 300 is pivoted on the linkage arm 210 but the disclosure is not limited thereto. In other embodiments, the pull handle 300 is welded to the linkage arm 210 or screwed to the linkage arm 210.

Moreover, the pull handle 300 is a band extending outside from the main body 100 in other embodiments. In detail, the band is made of soft rubber materials and rigid materials, which makes the band be highly tough and highly strengthened so that the band is difficult to be ruptured. Meanwhile, because the end of the band is soft rubber, the band has greater deformation so that the band may be temporarily deformed to be in accordance with the operation of the users.

Two elastic components 400 are located at the two limiting spaces 150, respectively. Each elastic component 400 is sandwiched between the first limiting surface 151 disposed on the limiting space 150 and the limited part 240 of the extending arm 220. The elastic component 400 normally presses the limited part 240 so that the second fastening part 230 is located at the fastening position. In this embodiment, both of the number of the limiting spaces 150 and that of the elastic components 400 are, for example, two. In other embodiments, both of the number of the limiting space 150 and that of the elastic component 400 are one.

FIG. 4A is a cross-sectional view of the pluggable optical transceiver module in FIG. 1 when a sliding component is located at a fastening position. FIG. 4B is a partial enlarged view of the pluggable optical transceiver module in FIG. 4A. FIG. 5A is a cross-sectional view of the pluggable optical transceiver module in FIG. 1 when the sliding component is located at a releasing position. FIG. 5B is a partial enlarged view of the pluggable optical transceiver module in FIG. 5A. As seen in FIG. 4A and FIG. 4B, the pluggable optical transceiver module 10 is inserted into the plugging slot 22 of the socket 20. The two first fastening parts 24 are fastened to the two second fastening parts 230 when the two elastic components 400 respectively press the two limited parts 240 to locate the two second fastening parts 230 at the fastening position. Therefore, the pluggable optical transceiver module 10 is stably inserted into the plugging slot 22 and electrically connected to the socket 20.

As seen in FIG. 5A and FIG. 5B, users is able to pull the pull handle 300 along the direction indicated by an arrow a when removing the pluggable optical transceiver module 10 from the socket 20. The sliding component 200 is slid by the pull handle 300 relative to the main body 200 to be located at the releasing position. Since the fastening surface 231 is an inclined surface, the two first fastening parts 24 pressed by the fastening surface 231 are far away from each other when the sliding component 200 slides along the direction indicated by the arrow a. That is, the two second fastening parts 230 open the two first fastening parts 24 to release the two first fastening parts 24 from the two second fastening parts 230. Therefore, it is more convenient to plug the pluggable optical transceiver module 10 into the socket 20 and unplug the pluggable optical transceiver module 10 from the socket 20.

FIG. 6 is a perspective view of the pluggable optical transceiver module in FIG. 2 when a pull handle pivots on the top of the main body 200. Users are able to apply a force to pull out the pluggable optical transceiver module 10 when the pull handle 300 is located in front of the head part 110. The pull handle 300 is pivoted about the sliding component 200 along the direction indicated by an arrow b to be located above the head part 110 when users insert an optical fiber plug (not shown in the figure) into the optical fiber terminal 160. Since the pull handle 300 does not interfere with the

US 9,523,826 B2

5

optical fiber plug, it is more convenient for the users to insert the optical fiber plug into the optical fiber terminal 160.

According to the pluggable optical transceiver module of the disclosure, by sliding the sliding component within the two sliding slots, a user is able to easily fasten or release the combination of the two first fastening parts and the two second fastening parts.

Moreover, the pull handle is pivoted about the sliding component so that the pull handle is located in front of the main body or on the top of the main body. Users are able to pull out the pluggable optical transceiver module when the pull handle is located in front of the main body. The pull handle does not interfere with the optical fiber plug when located on the main body. Therefore, it is more convenient for users to insert the optical fiber plug into the optical fiber terminal.

What is claimed is:

1. A pluggable optical transceiver module, for being inserted into a plugging slot of a socket, the socket comprising two first fastening parts located in the plugging slot, the pluggable optical transceiver module comprising:

a main body having two side surfaces that are opposite to each other and two sliding slots located at the two side surfaces, respectively, wherein the main body is configured to be inserted into the plugging slot, wherein the main body has at least one limiting space and two bottom surfaces forming the two sliding slots, respectively, the two bottom surfaces are parallel to the two side surfaces, the at least one limiting space is located at one of the two side surfaces;

a sliding component comprising a linkage arm and two extending arms, wherein the two extending arms are connected to two ends of the linkage arm, respectively, each extending arm has a second fastening part, the main body is between the two extending arms, the two extending arms are slidably disposed on the two sliding slots to have a fastening position and a releasing position, the two first fastening parts are fastened to the two second fastening parts when the two extending arms are located at the fastening position, and the two second fastening parts press the two first fastening parts, respectively, to make the two first fastening parts be farther away from each other when the two extending arms are located at the releasing position, wherein each extending arm has a limited part configured to move in the at least one limiting space; and

an elastic component, wherein the main body has a first limiting surface and a second limiting surface forming the limiting space, the first limiting surface is closer to the head part than the second limiting surface, and the elastic component is located in the limiting space and between the first limiting surface and the limited part and is covered by the extending arm such that the elastic component is confined by the main body and the sliding component.

2. The pluggable optical transceiver module according to claim 1, wherein the main body comprises a head part and an inserted part connected to each other, the inserted part is configured to be inserted into the socket, the two side surfaces are located at two sides of the head part and the inserted part opposite to each other, respectively, wherein both the two sliding slots extend from the head part towards the inserted part, and the two extending arms are able to slide

6

relative to the two sliding slots to have the fastening position which is farther away from the head part and the releasing position which is closer to the head part.

3. The pluggable optical transceiver module according to claim 2, wherein each second fastening part has a fastening surface, and a distance between one side of the fastening surface which is close to the side surface and the head part is less than a distance between another side of the fastening surface which is far away from the side surface and the head part.

4. The pluggable optical transceiver module according to claim 2, wherein the head part has at least one optical fiber terminal.

5. The pluggable optical transceiver module according to claim 1, further comprising two elastic components, wherein the number of the at least one limiting surface is two, the main body has two first limiting surfaces and two second limiting surfaces forming the two limiting spaces together, respectively, the two first limiting surfaces are closer to the head part than the two second limiting surfaces, the two elastic components are located in the two limiting spaces, respectively, and each elastic component is between the first limiting surface and the limited part.

6. The pluggable optical transceiver module according to claim 1, wherein the pluggable optical transceiver module further comprises a pull handle pivoted on the linkage arm of the sliding component.

7. A pluggable optical transceiver module, comprising:

a main body having a head part and an inserted part that are connected to each other, wherein the main body further comprises opposite two side surfaces and two sliding slots which are located at two sides of the head part and the inserted part opposite to each other, respectively, the two sliding slots are located at the two side surfaces, and the two sliding slots extend from the head part to the inserted part, respectively, wherein the main body has at least one limiting space and two bottom surfaces forming the two sliding slots, respectively, the two bottom surfaces are parallel to the two side surfaces, the at least one limiting space is located at one of the two side surfaces;

a sliding component comprising a linkage arm and two extending arms, wherein the linkage arm is connected between the two extending arms, each extending arm has a second fastening part, the main body is between the two extending arms, the two extending arms are able to slide relative to the two sliding slots to have a fastening position which is farther away from the head part and a releasing position which is closer to the head part, wherein each extending arm has a limited part configured to move in the at least one limiting space; and

an elastic component, wherein the main body has a first limiting surface and a second limiting surface forming the limiting space, the first limiting surface is closer to the head part than the second limiting surface, and the elastic component is located in the limiting space and between the first limiting surface and the limited part and is covered by the extending arm such that the elastic component is confined by the main body and the sliding component.

* * * * *

Exhibit B



US010042116B2

(12) **United States Patent**
Ho et al.

(10) **Patent No.:** **US 10,042,116 B2**

(45) **Date of Patent:** **Aug. 7, 2018**

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

USPC 398/135, 136, 137, 138, 139, 79, 82,
398/158.159, 85, 87, 84, 202, 208, 213,
398/214; 385/24, 37, 14, 43
See application file for complete search history.

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(73) Assignee: **Applied Optoelectronics, Inc.**, Sugar Land, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/137,823**

(22) Filed: **Apr. 25, 2016**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
H04J 14/02 (2006.01)
G02B 6/12 (2006.01)
G02B 6/42 (2006.01)

(52) **U.S. Cl.**
CPC **G02B 6/12016** (2013.01); **G02B 6/12011** (2013.01); **G02B 6/12019** (2013.01); **G02B 6/4246** (2013.01); **G02B 6/4292** (2013.01); **H04J 14/02** (2013.01)

(58) **Field of Classification Search**
CPC H04J 14/02; H04J 14/0282; H04J 14/0221; H04J 14/0202; H04B 10/40; H04B 10/506; H04B 10/503; H04B 10/504; G02B 6/4246; G02B 6/4293; G02B 6/4249

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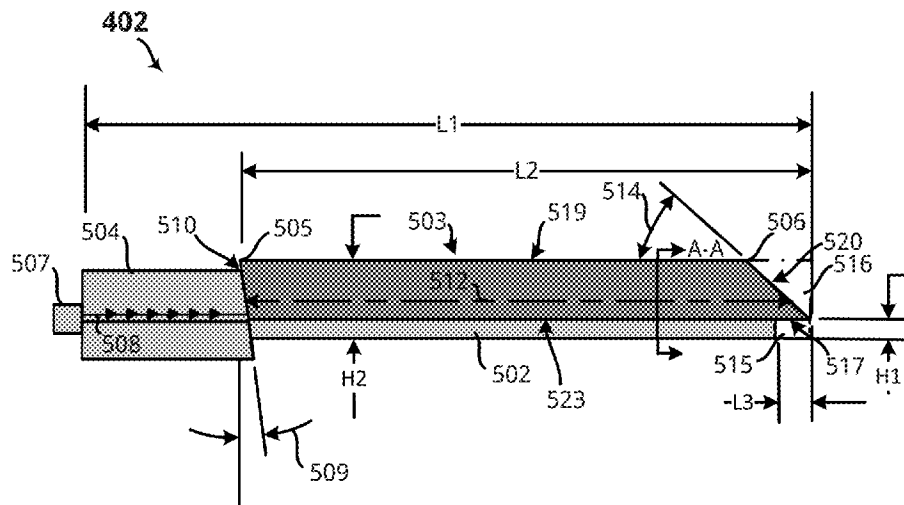
Primary Examiner — Hanh Phan

(74) *Attorney, Agent, or Firm* — Grossman Tucker Perreault & Pfleger, PLLC; Norman S. Kinsella

(57) **ABSTRACT**

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.

19 Claims, 7 Drawing Sheets



US 10,042,116 B2

Page 2

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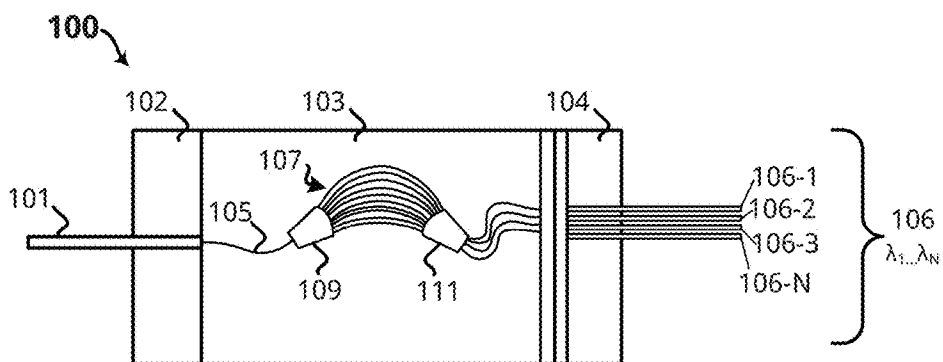


FIG. 1

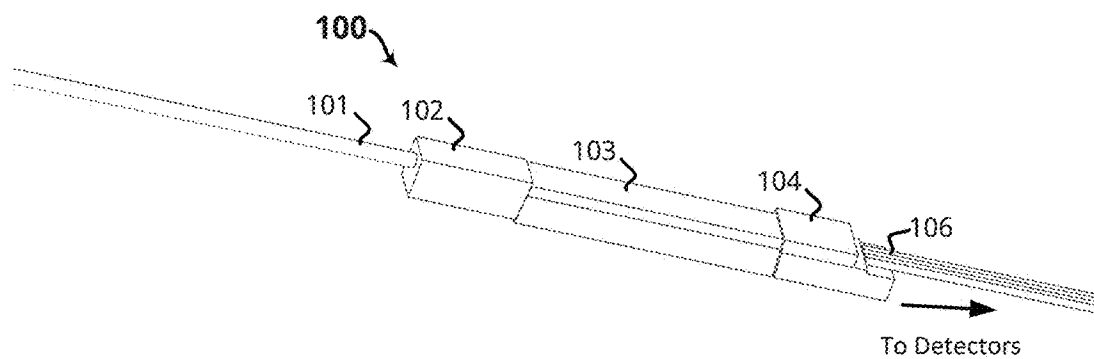


FIG. 2

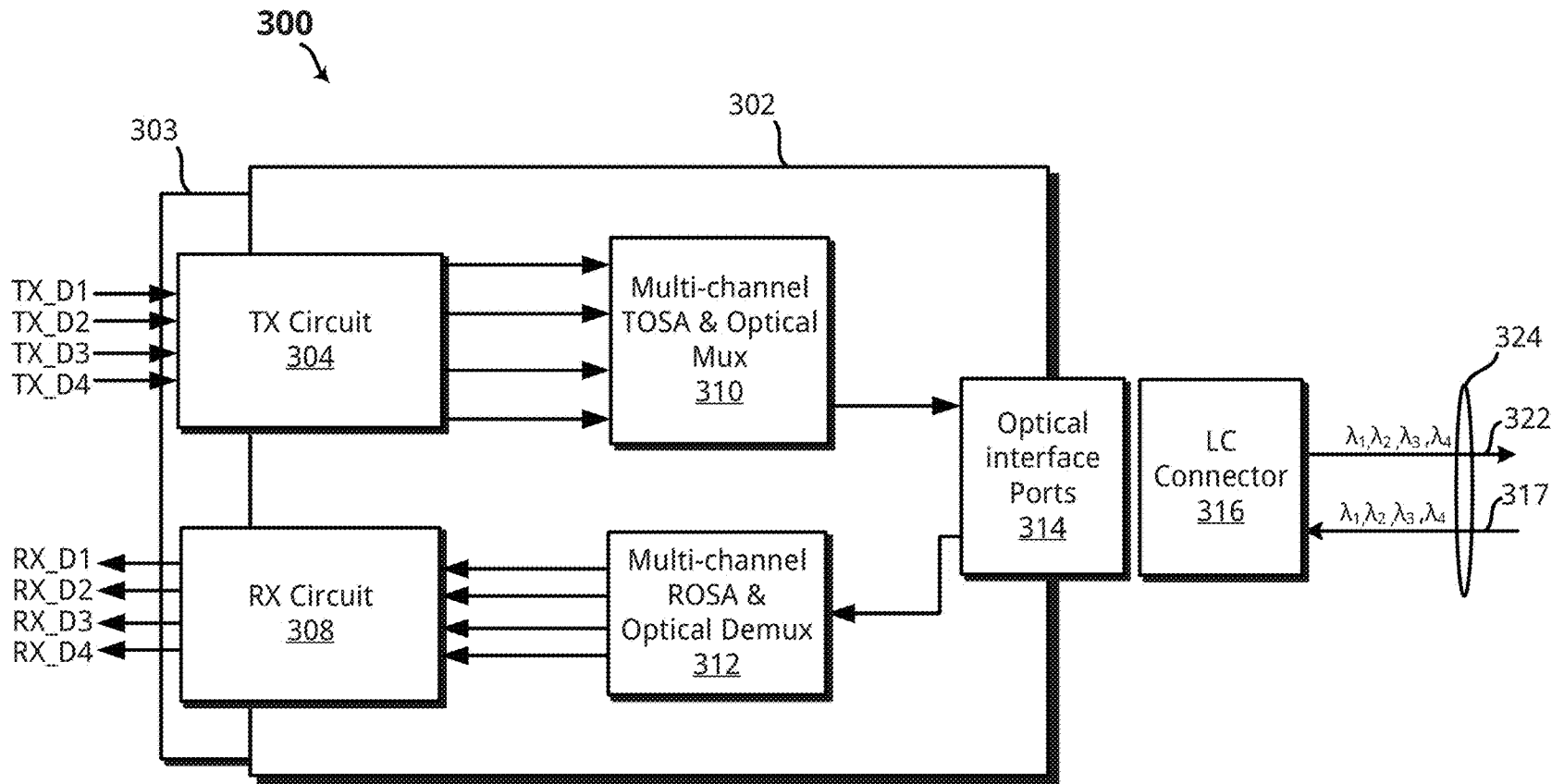


FIG. 3

U.S. Patent

Aug. 7, 2018

Sheet 3 of 7

US 10,042,116 B2

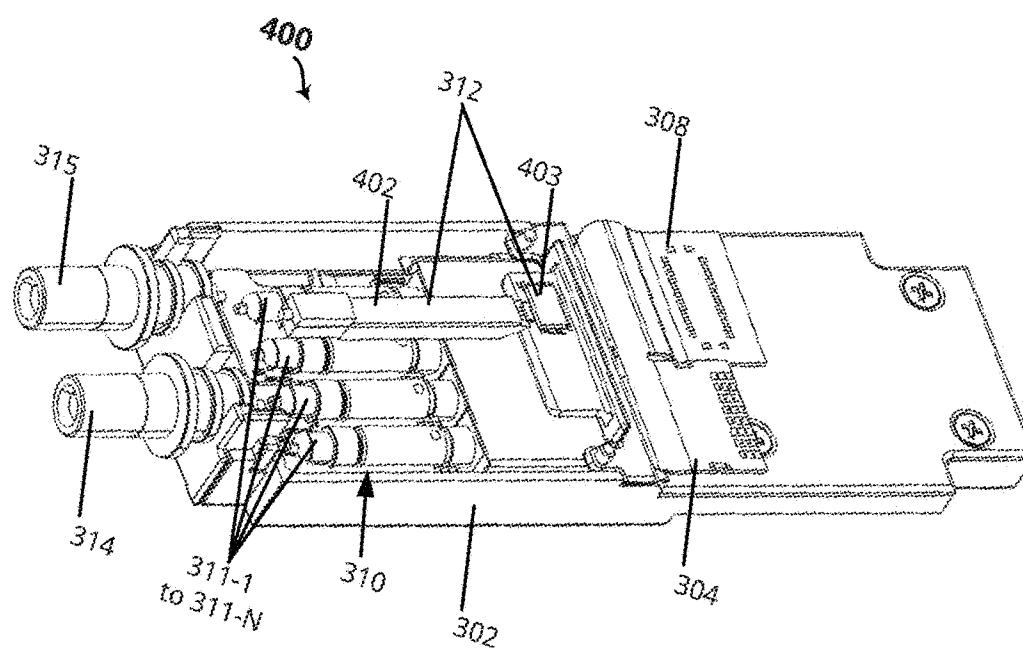


FIG. 4

U.S. Patent

Aug. 7, 2018

Sheet 4 of 7

US 10,042,116 B2

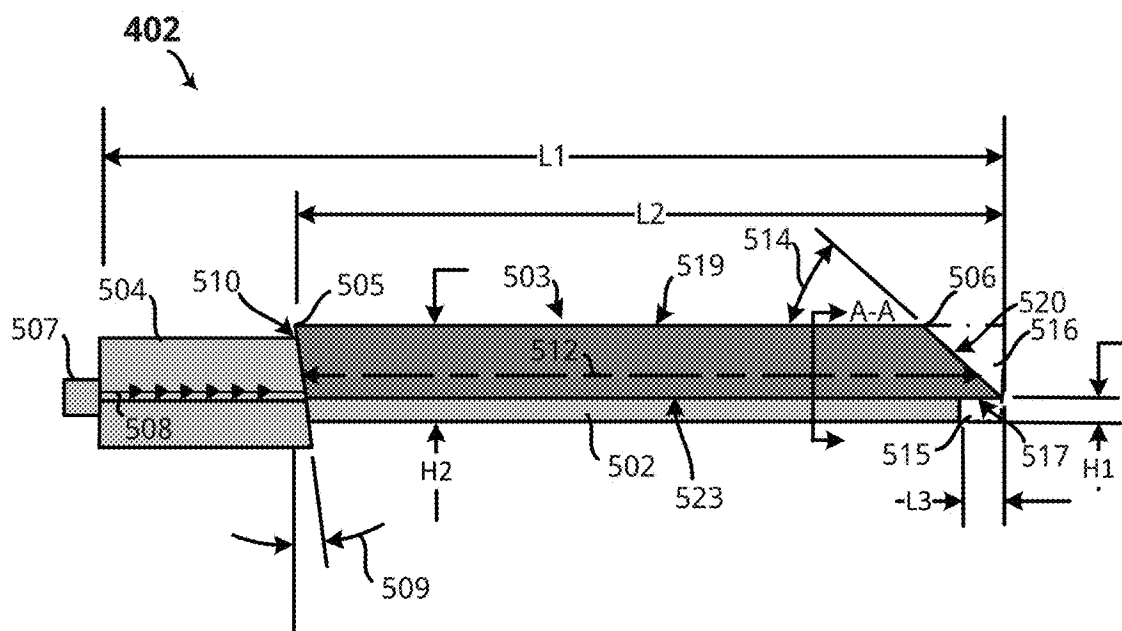


FIG. 5A

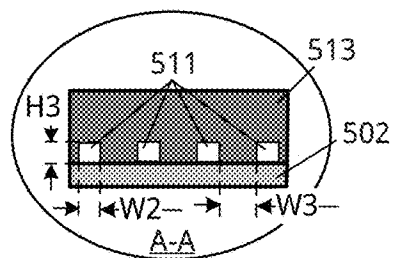


FIG. 5B

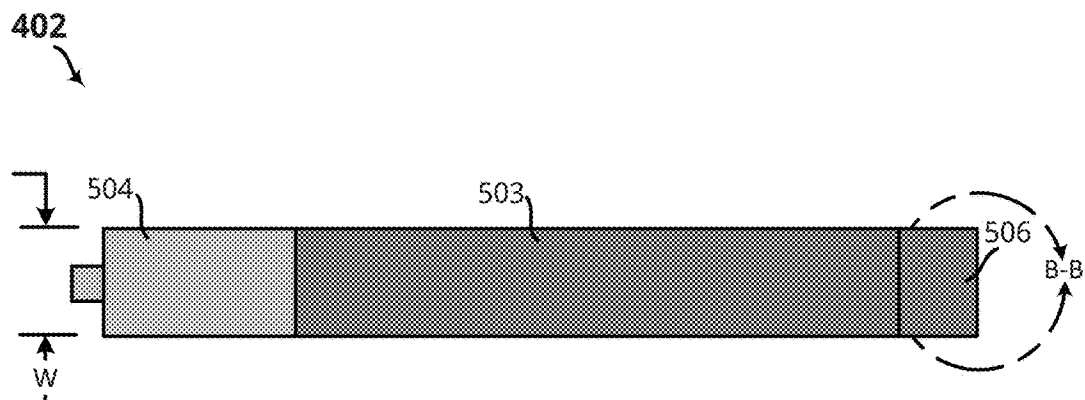


FIG. 6

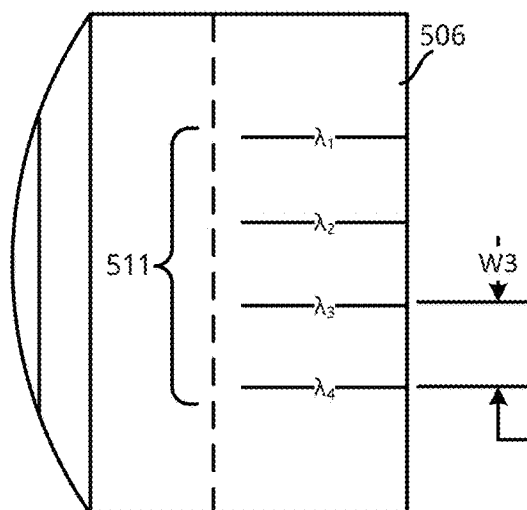


FIG. 7

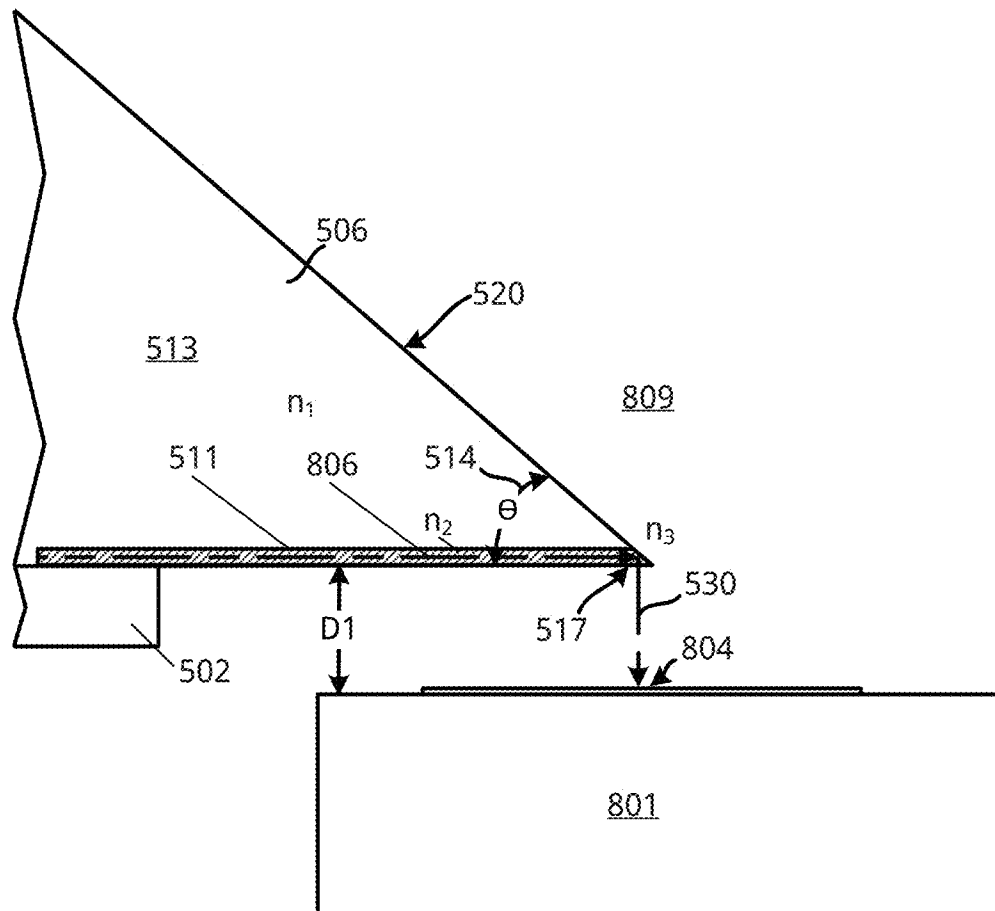


FIG. 8

U.S. Patent

Aug. 7, 2018

Sheet 7 of 7

US 10,042,116 B2

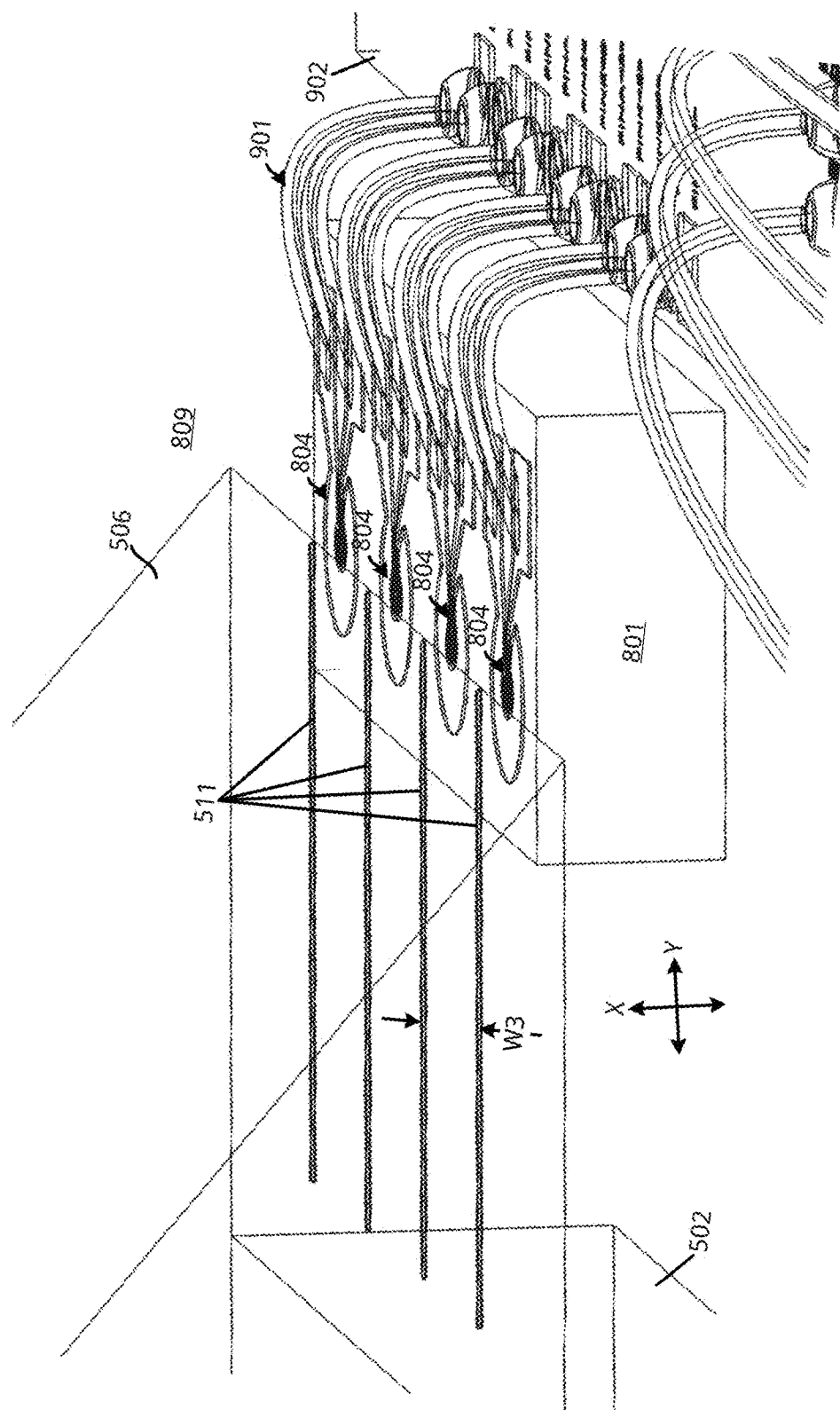


FIG. 9

US 10,042,116 B2

1

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

TECHNICAL FIELD

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

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

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 schematic diagram of an example arrayed waveguide grating (AWG) device.

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

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).

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.

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

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.

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

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.

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.

2

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.

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.

DETAILED DESCRIPTION

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.

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 λ_1 - λ_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.

The particular configuration illustrated in FIG. 1 is a 1×4 PLC demultiplexer (or demux), but other channel configurations, e.g., 1×8, 1×16, 2×8, 2×16, etc., should be apparent in 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).

US 10,042,116 B2

3

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 7 db 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 1.0 db, 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 1.0 db. Thus the overall insertion loss introduced by use of the fiber array 106 can total about 1.0 to 2.0 db, which can significantly reduce sensitivity of the ROSA device and consequently reduce overall transceiver performance.

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.

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 cladding layer may comprise silicon (Si) and the core material may comprise silicon dioxide (SiO₂), 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.

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.

The output coupling region of the AWG device can include output waveguides or output channels comprising

4

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 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.

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.

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 1 db to 2 db. To this end, the overall performance of the ROSA improves as the sensitivity of the ROSA is increased by the same amount, e.g., 1 db to 2 db. 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

US 10,042,116 B2

5

important when designing AWG devices for highly-constrained housings, e.g., small form-factor configurations.

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).

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

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 ($\lambda_1, \lambda_2, \lambda_3, \lambda_4$) and may be capable of transmission rates of at least about 25 gigabits (Gbs) per channel or more. In one example, the channel wavelengths $\lambda_1, \lambda_2, \lambda_3, \lambda_4$ 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 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 QSP+ 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.

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.

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

6

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.

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 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.

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.

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.

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) 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 advanta-

US 10,042,116 B2

7

geous 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.

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 10 km 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 25 Gb/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.

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** 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, 25 nm 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., 2 nm to 4 nm). 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.

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

8

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.

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** 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**.

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 (SiO₂), 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.

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. Like-

US 10,042,116 B2

9

wise, the cladding layer **513** can be formed from sequentially deposited/grown layers of silica or other suitable cladding material.

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.

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, $\pm 2\%$. 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 the region indicated at **515**. Formation of the AWG chip **503** can include removing a portion of the 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.

In an embodiment, the AWG device **402** can include an overall length **L1** of about 13 mm. 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 10 mm, and a height **H2** of about 1.30 mm including the substrate **502**, and about 1 mm without. To this end, the substrate can include a height **H1** of about 0.3 mm. The region generally indicated at **515**, and more particularly the output interface region **517**, can include a length **L3** of about 0.60 mm.

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 1.5 mm. 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

10

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 0.25 mm, although other channel spacing arrangements will be apparent in light of this disclosure.

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 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.

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 n_2 and n_3 . The resulting angle of reflection may be calculated based on Snell's Law:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \quad \text{Equation (1)}$$

Where n_1 is the refractive index of a first medium, n_2 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:

$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2} \quad \text{Equation (2)}$$

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

US 10,042,116 B2

11

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.

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 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 0.25 mm 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

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.

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 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

12

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

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.

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.

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 substrate;
 - a planar lightwave circuit (PLC) disposed on the substrate, the PLC coupled to the first end and 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 exposed output interface region of the AWG chip, wherein the exposed output interface region emits the received light from the AWG chip on the same side as the substrate without passing the received light through the substrate.
2. The AWG chip of claim 1, wherein the exposed 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 exposed output interface region.
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

US 10,042,116 B2

13

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 6, wherein the external medium comprises a material having an index of refraction of about 1.0.

8. 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.

9. 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.

10. The AWG chip of claim 1, wherein the AWG chip is configured as a $1 \times N$ 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;

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, wherein the first end for coupling to the optical coupling receptacle includes an angled surface to reduce back reflections of an optical signal launched into the AWG chip;

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

14

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 the output interface region of the AWG chip is an exposed region adjacent an air gap, and wherein the 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.

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.

* * * * *

Exhibit C



US009448367B2

(12) **United States Patent**
Ho et al.

(10) **Patent No.:** **US 9,448,367 B2**
(45) **Date of Patent:** **Sep. 20, 2016**

(54) **MULTI-CHANNEL OPTICAL TRANSCEIVER MODULE INCLUDING DUAL FIBER TYPE DIRECT LINK ADAPTER FOR OPTICALLY COUPLING OPTICAL SUBASSEMBLIES IN THE TRANSCEIVER MODULE**

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(73) Assignee: **Applied Optoelectronics, Inc.**, Sugar Land, TX (US)

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G02B 6/38 (2006.01)
G02B 6/42 (2006.01)

(52) **U.S. Cl.**
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USPC 385/53–78
See application file for complete search history.

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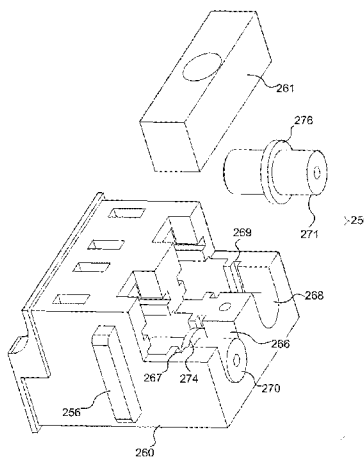
Assistant Examiner — Guy Anderson

(74) *Attorney, Agent, or Firm* — Grossman Tucker Perreault & Pfleger, PLLC; Norman S. Kinsella

(57) **ABSTRACT**

A multi-channel optical transceiver includes a multi-channel transmitter optical subassembly (TOSA), a multi-channel receiver optical subassembly (ROSA), and a dual fiber type direct link adapter directly linked to the multi-channel TOSA and the multi-channel ROSA with optical fibers. The dual fiber type direct link adapter is also configured to receive pluggable optical connectors, such as LC connectors, mounted at the end of fiber-optic cables including optical fibers for carrying optical signals to and from the transceiver. The dual fiber type direct link adapter thus provides the optical input and output to the transceiver for the optical signals received by the ROSA and transmitted by the TOSA. The multi-channel 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).

9 Claims, 6 Drawing Sheets

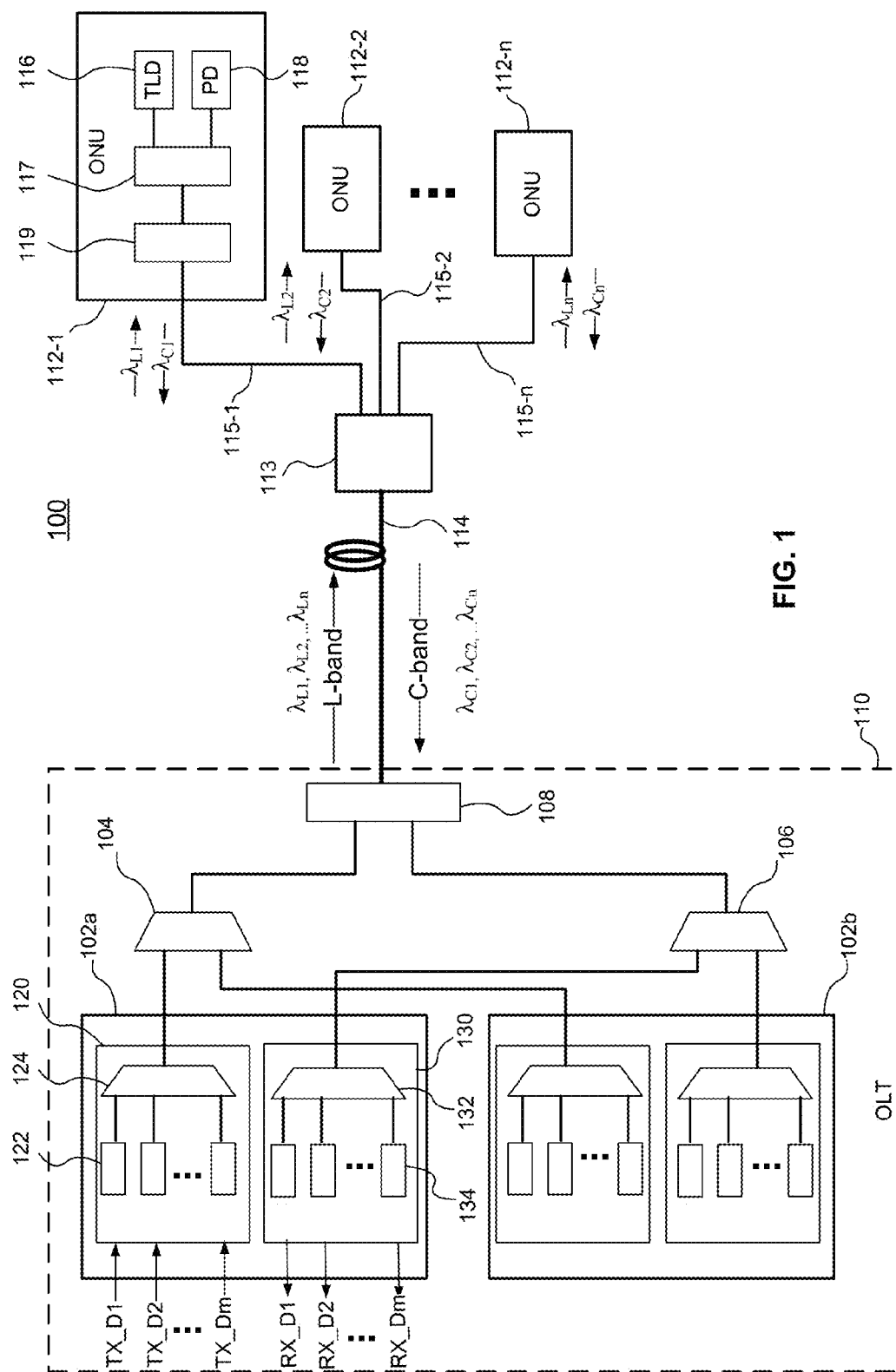


US 9,448,367 B2

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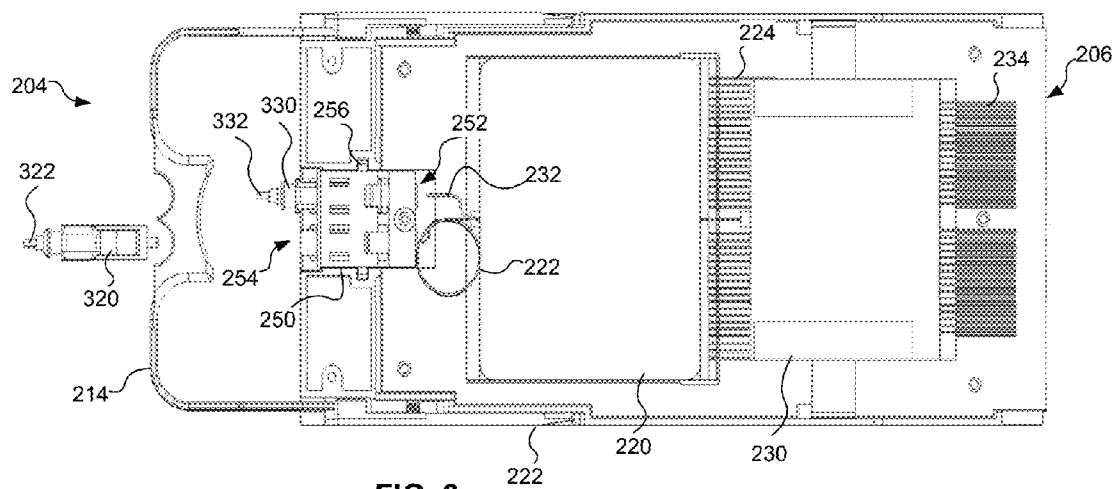
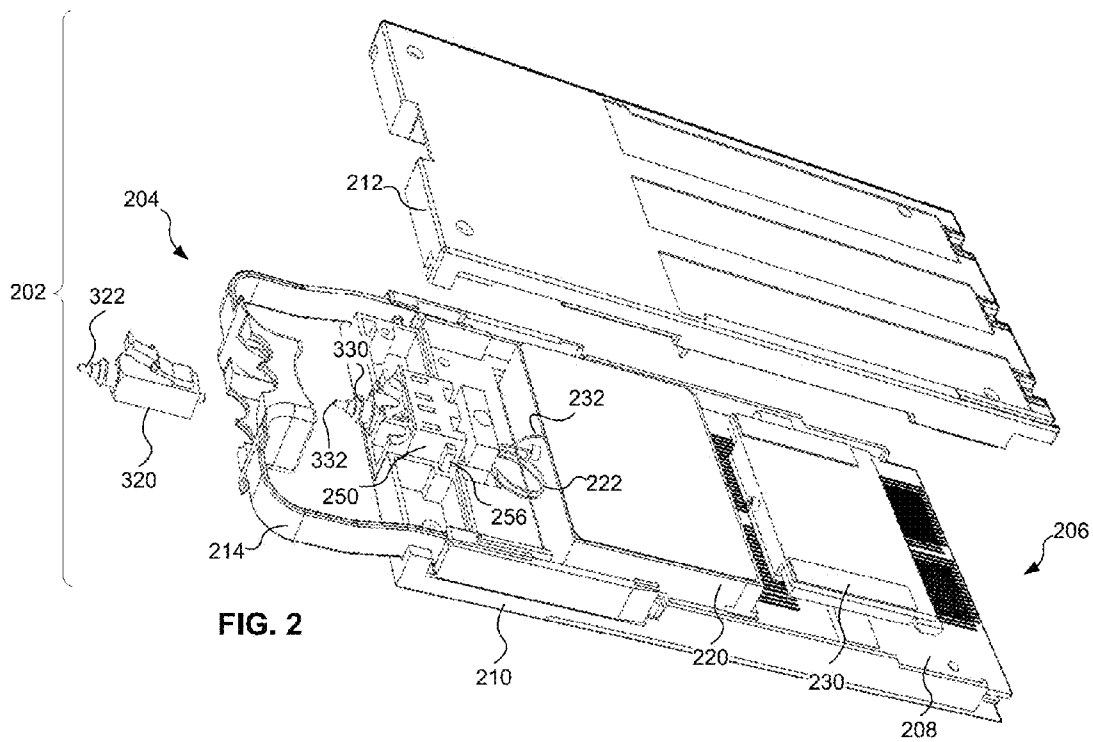


FIG. 3

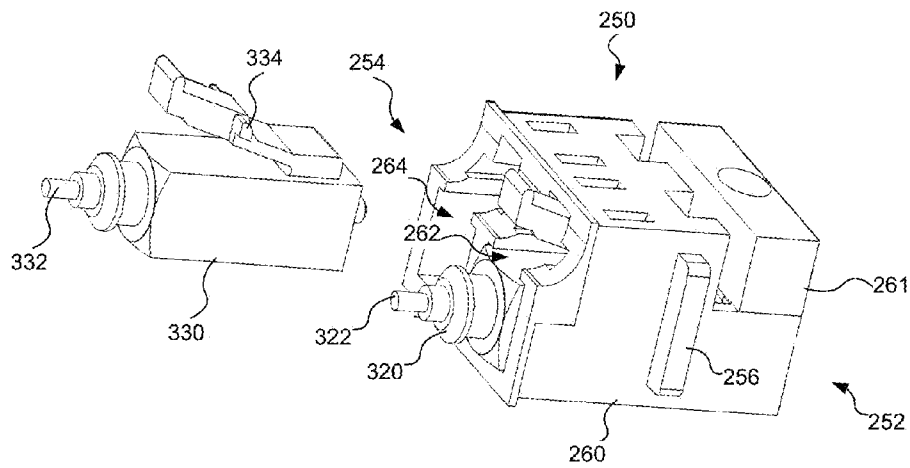


FIG. 4

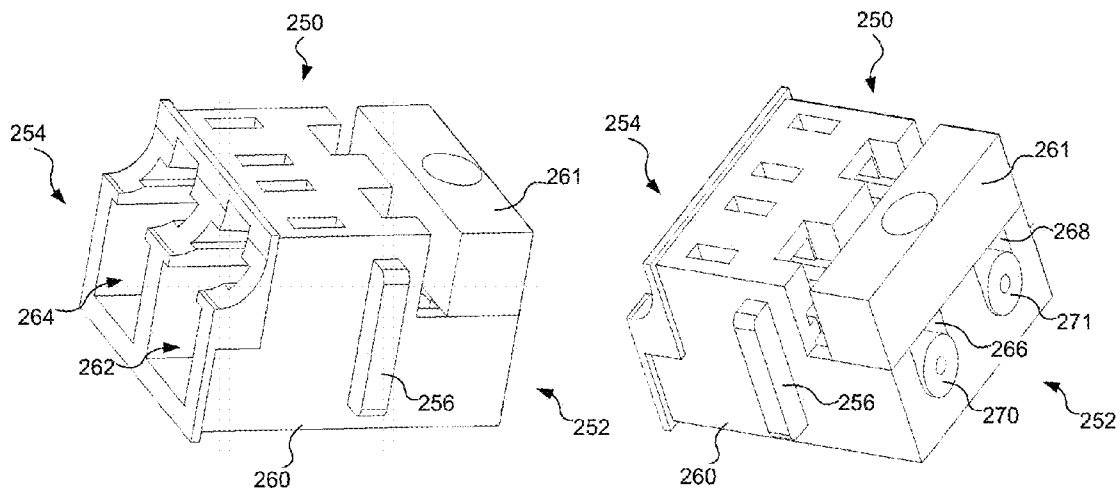


FIG. 5

FIG. 6

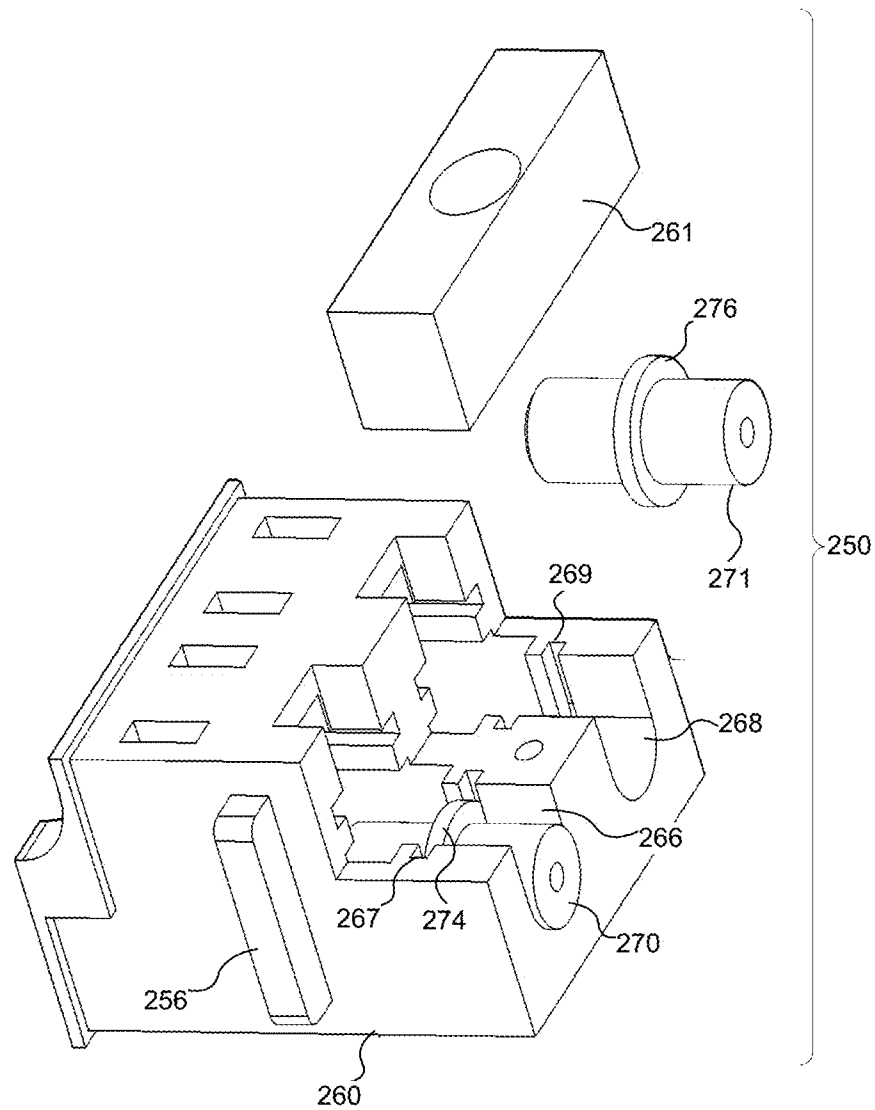


FIG. 7

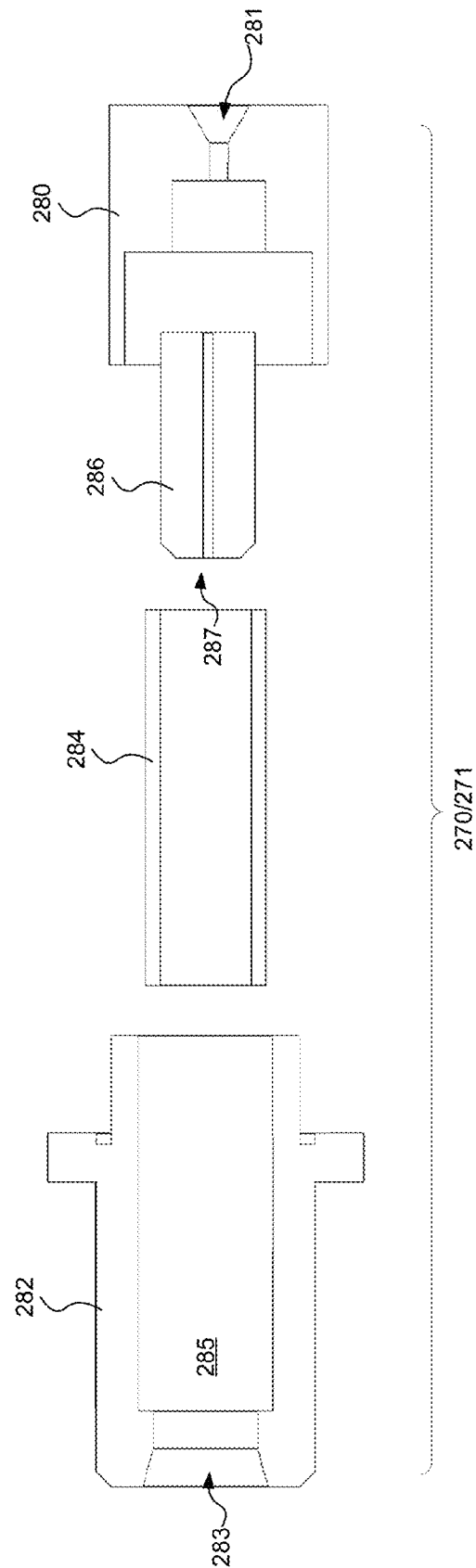


FIG. 8

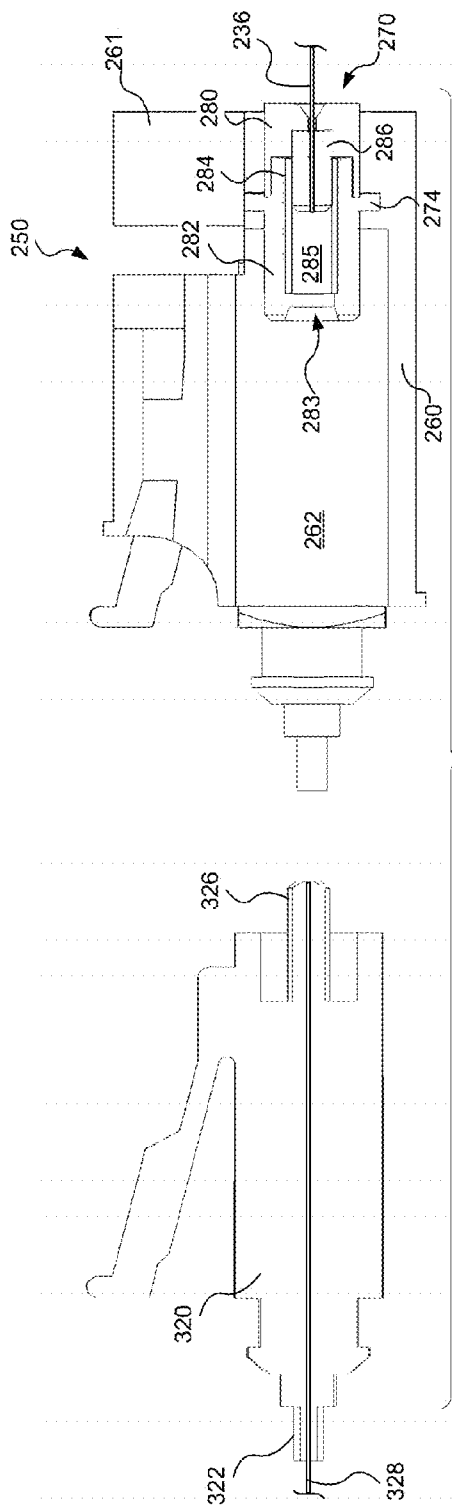


FIG. 9

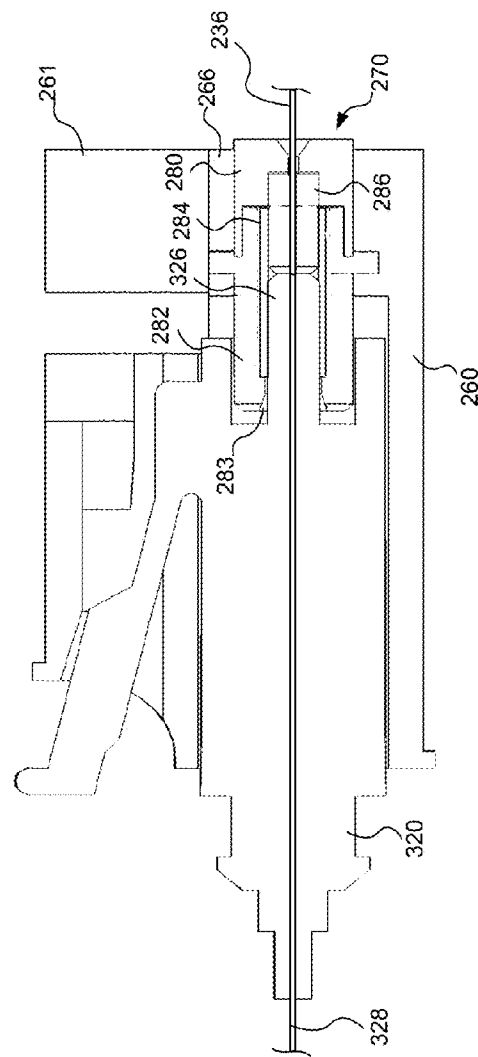


FIG. 10

US 9,448,367 B2

1

**MULTI-CHANNEL OPTICAL TRANSCEIVER
MODULE INCLUDING DUAL FIBER TYPE
DIRECT LINK ADAPTER FOR OPTICALLY
COUPLING OPTICAL SUBASSEMBLIES IN
THE TRANSCEIVER MODULE**

**CROSS-REFERENCE TO RELATED
APPLICATIONS**

The present application is a divisional of U.S. patent application Ser. No. 13/709,195 filed Dec. 10, 2012, which is fully incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to multi-channel optical transceiver modules and more particularly, to a multi-channel transceiver module including a dual fiber type direct link adapter for optically coupling optical subassemblies in the transceiver module.

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). The multi-channel TOSA and the multi-channel ROSA may be connected to external optical fibers that carry the transmitted and received optical signals. Optical connectors, such as LC connectors, may be provided at the ends of the optical fibers for connecting the optical fibers to the respective multi-channel TOSA and multi-channel ROSA. OLT transceiver modules often are designed to fit a relatively small form factor. One challenge with such OLT transceiver modules is accommodating the multi-channel TOSA and ROSA in the relatively small space available in an OLT module. In particular, certain components that may be used to provide optical connections to the TOSA and ROSA, such as conventional LC adapters, may not fit within the limited space.

2

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 dual fiber type direct link adapter for optically coupling directly to a TOSA and a ROSA, 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 a perspective view of one embodiment of the dual fiber type direct link adapter for coupling to first and second LC connectors.

FIGS. 5 and 6 are perspective views of the dual fiber type direct link adapter shown in FIG. 4 without the first and second LC connectors.

FIG. 7 is an exploded view of the dual fiber type direct link adapter shown in FIG. 4 illustrating the LC optical connecting portion.

FIG. 8 is a cross-sectional exploded view of the LC optical connecting portion of the dual fiber type direct link adapter shown in FIG. 4.

FIGS. 9 and 10 are cross-sectional views of the dual fiber type direct link adapter shown in FIG. 4 with the LC connector disconnected and connected.

DETAILED DESCRIPTION

A multi-channel optical transceiver, consistent with embodiments described herein, generally includes a multi-channel transmitter optical subassembly (TOSA), a multi-channel receiver optical subassembly (ROSA), and a dual fiber type direct link adapter directly linked to the multi-channel TOSA and the multi-channel ROSA with optical fibers. The dual fiber type direct link adapter is also configured to receive pluggable optical connectors, such as LC connectors, mounted at the end of fiber-optic cables including optical fibers for carrying optical signals to and from the transceiver. The dual fiber type direct link adapter thus provides the optical input and output to the transceiver for the optical signals received by the ROSA and transmitted by the TOSA. The multi-channel 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 by which signals carried by one system element are imparted to the “coupled” element 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.

US 9,448,367 B2

3

As used herein, “direct link” refers to optically coupling with a single optical fiber mechanically coupled between two components without using pluggable connectors at the ends of the fiber link.

Referring to FIG. 1, a WDM-PON 100 including one or more multi-channel optical transceivers 102a, 102b, 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 102a, 102b 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_{Cm}). Other wavelengths and wavelength bands are also within the scope of the system and method described herein.

4

The branching point 113 may demultiplex a downstream WDM optical signal (e.g., λ_{L1} , λ_{L2} , . . . λ_{Ln}) 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 102a, 102b may include a multi-channel transmitter optical sub-assembly (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 102a, 102b may thus include a multi-channel receiver optical sub-assembly (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_D1 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}). 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. 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 102a with a multiplexed optical signal from a multi-channel TOSA in the other multi-channel transceiver 102b to produce the downstream aggregate WDM optical signal.

US 9,448,367 B2

5

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 (R λ_{D1} to R λ_{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 102a, 102b. The OLT 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 102a, 102b 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 102a, 102b 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 102a, 102b 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 102a, 102b 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 102a, 102b, 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 102a, 102b together cover 32 channels. Thus, the multiplexer 104 may combine 16 channels from one transceiver 102a with 16 channels from the other transceiver 102b, 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.

Referring to FIGS. 2 and 3, one embodiment of a multi-channel optical transceiver module 202 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 may thus be designed to have a relatively small form factor with minimal space within the transceiver module 202. 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 a 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 320, 330, such as LC connectors, which terminate fiber optic cables 322, 332.

6

When the optical connectors 320, 330 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 322, 332, which carry the optical signals to and from the transceiver.

The dual fiber type direct link adapter 250 has a direct link end 252 mechanically coupled to the optical fibers 222, 232 and a pluggable connector end 254 configured to receive the pluggable optical connectors 320, 330. The direct link end 252 of the dual fiber type direct link adapter 250 is located inside the transceiver housing 210 and the pluggable connector end 254 faces outside of the transceiver housing 210. The illustrated embodiment of the dual fiber type direct link adapter 250 also includes one or more flanges 256 or other structures that engage the transceiver housing 210 and secure the adapter 250 within the housing 210.

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 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. To fit within this transceiver housing 210, the dual fiber type direct link adapter 250 may have a length from the direct link end 252 to the pluggable connector end 254 of less than about 30 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, and the direct link adapter 250 has a length of about 28 mm. A pull tab 214 may be coupled to the transceiver housing 210 to facilitate handling of the transceiver 202.

Referring to FIGS. 4-7, the dual fiber type direct link adapter 250 is described in greater detail. In the illustrated embodiment, the dual fiber type direct link adapter 250 includes an adapter body portion 260 defining first and second connector receiving regions 262, 264 at the pluggable connector end 254 and defining first and second slots 266, 268 at the direct link end 252. The first and second connector receiving regions 262, 264 are configured to receive the respective pluggable optical connectors 320, 330, such as LC connectors. The first and second slots 266, 268 are configured to receive respective direct link connector assemblies 270, 272, which are mechanically coupled to optical fibers (not shown) directly linking the TOSA and ROSA (not shown). An adapter cover portion 261 covers the slots 266, 268 and retains the direct link connector assemblies 266, 268. The direct link connector assemblies 270, 272 also include flange portions 274, 276 (shown in FIG. 7) that extend into receiving grooves 267, 269 in the respective slots 266, 268 to prevent axial movement and hold the direct link connector assemblies in the slots.

In one embodiment, the dual fiber type direct link adapter 250 is configured to mechanically and optically connect to an LC type optical connector. In other embodiments, the dual fiber type direct link adapter 250 may be configured to connect with other types of pluggable optical connectors.

US 9,448,367 B2

7

The optical connectors **320**, **330** may be mechanically engaged with the dual fiber type direct link adapter **250** when plugged to maintain the optical coupling. The connector **330** includes, for example, a latch **334** that engages a corresponding portion within the adapter body portion **260**.

One end of each of the direct link connector assemblies **270**, **272** is mechanically coupled to the optical fibers to provide the direct link to the TOSA and ROSA, as described above. The other end of each of the direct link connector assemblies **270**, **272** defines a connector receptacle that extends into the respective connector receiving region **262**, **264** defined by the adapter body portion **260**, as described in greater detail below.

FIG. **8** shows the direct link connector assembly **270/271** in greater detail. In this illustrated embodiment, the direct link connector assembly **270** includes an outer housing formed by first and second outer housing portions **280**, **282** around a sleeve **284**, which receives a fiber ferrule **286**. A respective one of the optical fibers (not shown) may pass through an opening **281** in the first housing portion **280** and into the fiber ferrule **286**. The optical fiber may be secured to the fiber ferrule **286** such that an end face of the optical fiber is located at an optical coupling end **287** of the fiber ferrule **286**. The second housing portion **282** and the sleeve **284** define a connector receptacle **285** at the connector coupling end, which receives a fiber ferrule of a pluggable optical connector (not shown) through an opening **283**.

FIGS. **9** and **10** illustrate the connection of a pluggable optical connector **320** (e.g., an LC connector) to the dual fiber type direct link adapter **250**. As shown in FIG. **9** and described above, the direct link connector assembly **270** defines a connector receptacle **285** that extends into the connector receiving region **262**. The direct link optical fiber **236** extends into the connector assembly **270** and is secured to the fiber ferrule **286** with an end face of the optical fiber **236** exposed for optical coupling. The pluggable optical connector **320** includes a fiber ferrule **326** extending from one end. The optical fiber **328** in the fiber-optic cable **322** coupled to the optical connector **320** extends into the connector **320** and is secured to the fiber ferrule **286** with an end face of the optical fiber **328** exposed for optical coupling.

As shown in FIG. **10**, when the optical connector **320** is plugged into the dual fiber type direct link adapter **250**, the connector fiber ferrule **326** extends into the connector receptacle **285** and contacts the adapter fiber ferrule **286** such that optical coupling is established between the optical fibers **328**, **236**. In the illustrated embodiment, the pluggable optical connector **320** is an LC type optical connector and the connector assembly **270** (and connector receptacle **285**) is configured to mate with an LC type optical connector.

Accordingly, a dual fiber type direct link adapter, consistent with embodiments described herein, allows connection to a pluggable optical connector, such as an LC connector, while providing a direct optical link to both the TOSA and ROSA in a multi-channel optical transceiver. The direct link connection reduces the size of the adapter and allows a smaller transceiver module with a pluggable optical input and output.

Consistent with an embodiment, a multi-channel transceiver module includes a transceiver housing, a multi-channel transmitter optical subassembly (TOSA) located in the transceiver housing and configured to transmit a wavelength division multiplexed (WDM) optical signal on multiple channel wavelengths, and a multi-channel receiver optical subassembly (ROSA) located in the transceiver housing and configured to receive a wavelength division multiplexed (WDM) optical signal on multiple channel

8

wavelengths. A dual fiber type direct link adapter is located inside the transceiver housing and at one side of the transceiver housing. The dual fiber type direct link adapter has a direct link end located in the transceiver housing and a pluggable connector end facing outside of the transceiver housing. The direct link end of the dual fiber type direct link adapter is coupled to the TOSA with a first optical fiber and coupled to the ROSA with a second optical fiber to provide a direct link between the dual fiber type direct link adapter and the TOSA and the ROSA. The pluggable connector end is configured to receive first and second pluggable optical connectors for optically coupling the TOSA and the ROSA to external optical fibers.

Consistent with another embodiment, a dual fiber type direct link LC adapter includes an adapter body portion defining first and second LC connector receiving regions at a pluggable connector end and defining first and second slots at a direct link end. The dual fiber type direct link LC adapter includes also includes first and second direct link connector assemblies configured to be received in the first and second slots, respectively. Each of the direct link connector assemblies defines an LC connector receptacle at one end. The LC connector receptacle extends into a respective one of the LC connector receiving regions and is configured to receive a portion of an LC connector for optical coupling. Each of the direct link connector assemblies is configured to be mechanically coupled to an optical fiber at another end. The dual fiber type direct link LC adapter further includes an adapter cover portion configured to cover the first and second slots for retaining the direct link connector assemblies in the respective slots.

Consistent with a further embodiment, an optical line terminal comprises at least first and second multi-channel transceivers. Each of the multi-channel transceivers includes a transceiver housing, a multi-channel transmitter optical subassembly (TOSA) located in the transceiver housing and configured to transmit a wavelength division multiplexed (WDM) optical signal on multiple channel wavelengths, and a multi-channel receiver optical subassembly (ROSA) located in the transceiver housing and configured to receive a wavelength division multiplexed (WDM) optical signal on multiple channel wavelengths. A dual fiber type direct link adapter is located inside the transceiver housing and at one side of the transceiver housing. The dual fiber type direct link adapter has a direct link end located in the transceiver housing and a pluggable connector end facing outside of the transceiver housing. The direct link end of the dual fiber type direct link adapter is coupled to the TOSA with a first optical fiber and coupled to the ROSA with a second optical fiber to provide a direct link between the dual fiber type direct link adapter and the TOSA and the ROSA. The pluggable connector end is configured to receive first and second pluggable optical connectors for optically coupling the TOSA and the ROSA to external optical fibers.

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.

US 9,448,367 B2

9

What is claimed is:

1. A dual fiber type direct link LC adapter comprising:
an adapter body portion defining first and second LC
connector receiving regions at a pluggable connector
end and defining first and second slots at a direct link

first and second direct link connector assemblies config-
ured to be received in the first and second slots,
respectively, each of the direct link connector assem-
blies defining an LC connector receptacle at one end,
wherein the LC connector receptacle extends into a
respective one of the LC connector receiving regions
and is configured to receive a portion of an LC con-
nector for optical coupling, and wherein each of the
direct link connector assemblies is configured to be
mechanically coupled to an optical fiber at another end;
and

an adapter cover portion configured to cover the first and
second slots for retaining the direct link connector
assemblies in the respective slots.

2. The dual fiber type direct link LC adapter of claim 1,
wherein each of the direct link connector assemblies include
a fiber ferrule for receiving the optical fiber and a sleeve
around the fiber ferrule for defining at least a portion of the
LC connector receptacle.

3. The dual fiber type direct link LC adapter of claim 1
wherein a length of the dual fiber type direct link adapter
from the direct link end to the pluggable connector end is
less than 30 mm.

10

4. The dual fiber type direct link LC adapter of claim 2
wherein each of the direct link connector assemblies further
comprises an outer housing around the fiber ferrule and the
sleeve, the outer housing defining at least a portion of the
connector receptacle and including a flange portion for
securing the direct link connector assembly.

5. The dual fiber type direct link LC adapter of claim 1
wherein the first and second slots are open on one side to
receive the first and second direct link connector assemblies,
respectively, in a direction orthogonal to longitudinal axes of
the slots.

6. The dual fiber type direct link LC adapter of claim 5
wherein the first and second slots include grooves, respec-
tively, for engaging the direct link connector assemblies to
prevent axial movement.

7. The dual fiber type direct link LC adapter of claim 1
wherein the first and second slots include grooves, respec-
tively, for engaging the direct link connector assemblies to
prevent axial movement.

8. The dual fiber type direct link LC adapter of claim 7
wherein the first and second direct link connector assemblies
further comprises flange portions configured to extend into
the grooves of the first and second slots, respectively.

9. The dual fiber type direct link LC adapter of claim 6
wherein the first and second direct link connector assemblies
further comprises flange portions configured to extend into
the grooves of the first and second slots, respectively.

* * * * *

Exhibit D



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(12) **United States Patent**
Luo et al.

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(45) **Date of Patent:** **Aug. 13, 2019**

(54) **MULTI-CHANNEL PARALLEL OPTICAL RECEIVING DEVICE**

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G02B 6/12 (2006.01)

G02B 6/32 (2006.01)

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

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(58) **Field of Classification Search**

CPC **G02B 6/12019**; **G02B 6/32**; **G02B 6/4214**; **G02B 6/4249**

See application file for complete search history.

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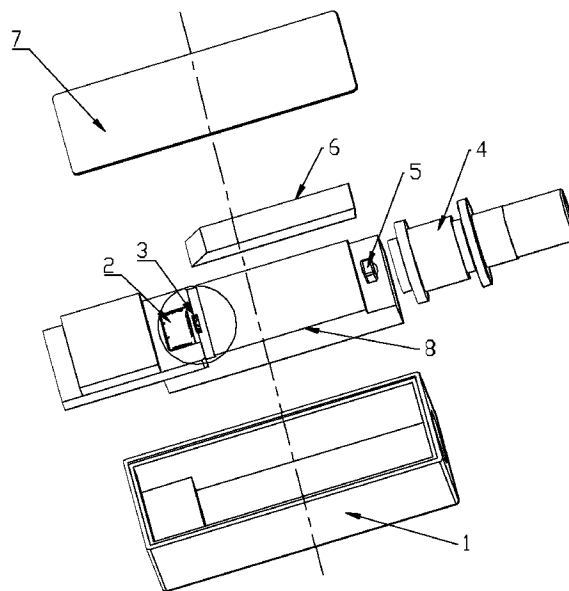
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(57) **ABSTRACT**

The present disclosure provides a multi-channel parallel optical receiving device, including a carrier, a light receiving chip, a plurality of optoelectronic diodes disposed on a top surface of an end of the carrier, an optical fiber connector disposed in another end of the carrier, and an arrayed waveguide grating disposed on the top surface of the carrier. The plurality of optoelectronic diodes is electrically connected to the light receiving chip, and an input end of the arrayed waveguide grating is connected to the optical fiber connector for receiving an optical signal from the optical fiber. The optical signals are divided into multi-channel optical signals in parallel. The top surface of an output end of the arrayed waveguide grating is at a predetermined angle, causing the multi-channel optical signals to be reflected by the top surface and to photosensitive surfaces of the optoelectronic diodes arranged in parallel.

7 Claims, 6 Drawing Sheets



US 10,379,301 B2

Page 2

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U.S. Patent

Aug. 13, 2019

Sheet 1 of 6

US 10,379,301 B2

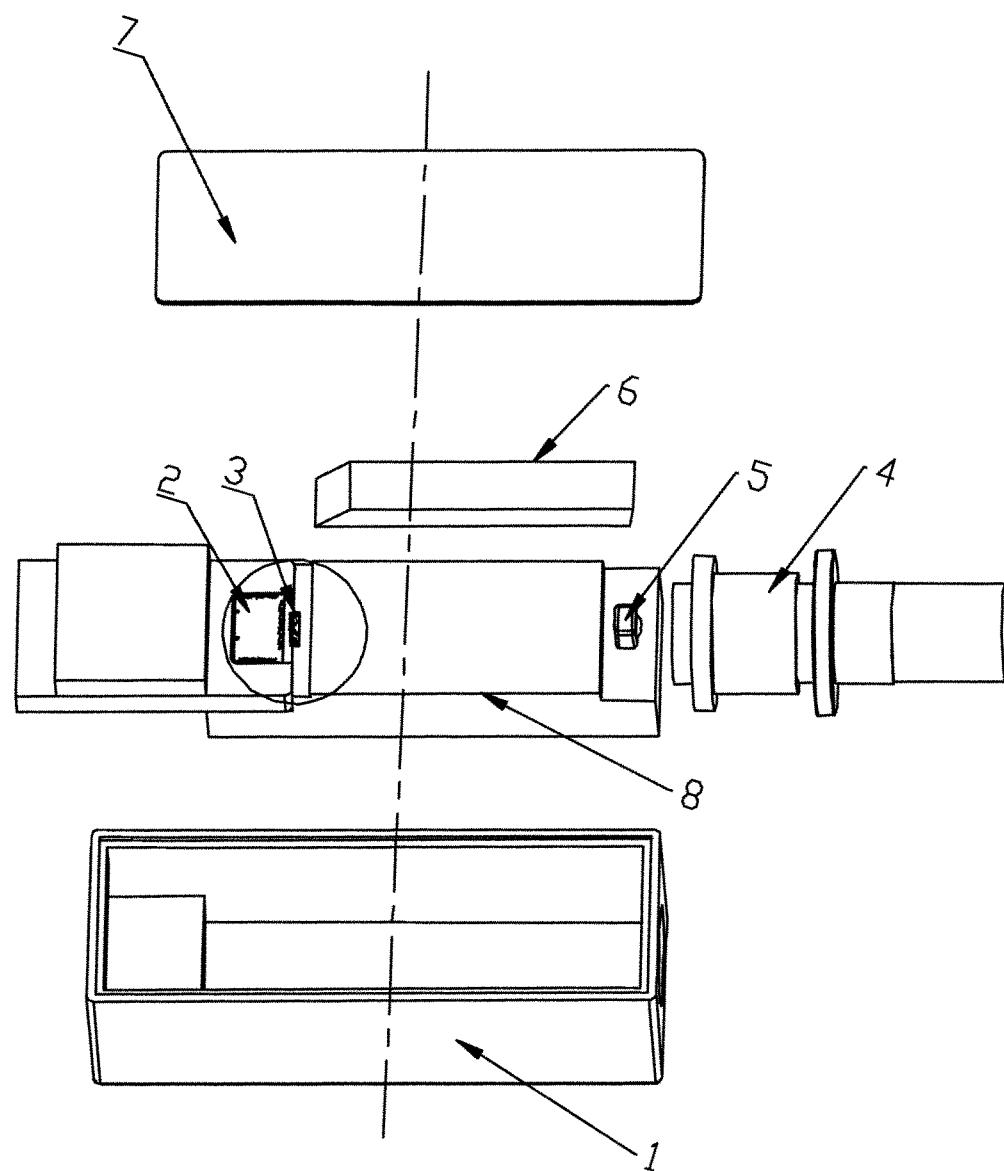


FIG. 1

U.S. Patent

Aug. 13, 2019

Sheet 2 of 6

US 10,379,301 B2

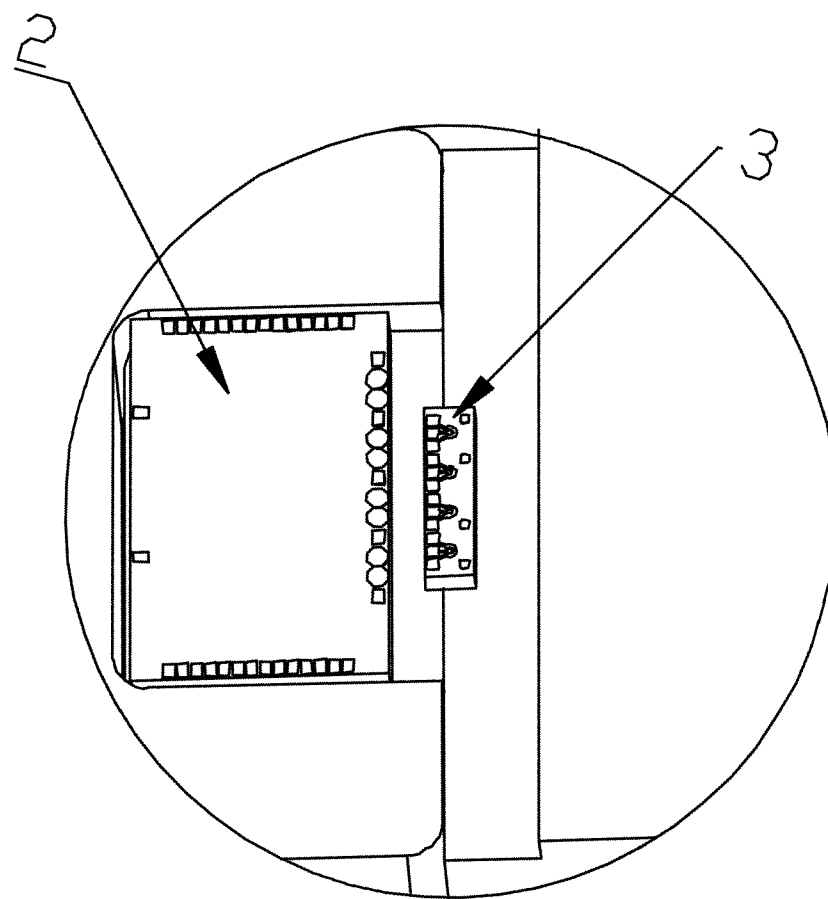


FIG. 2

U.S. Patent

Aug. 13, 2019

Sheet 3 of 6

US 10,379,301 B2

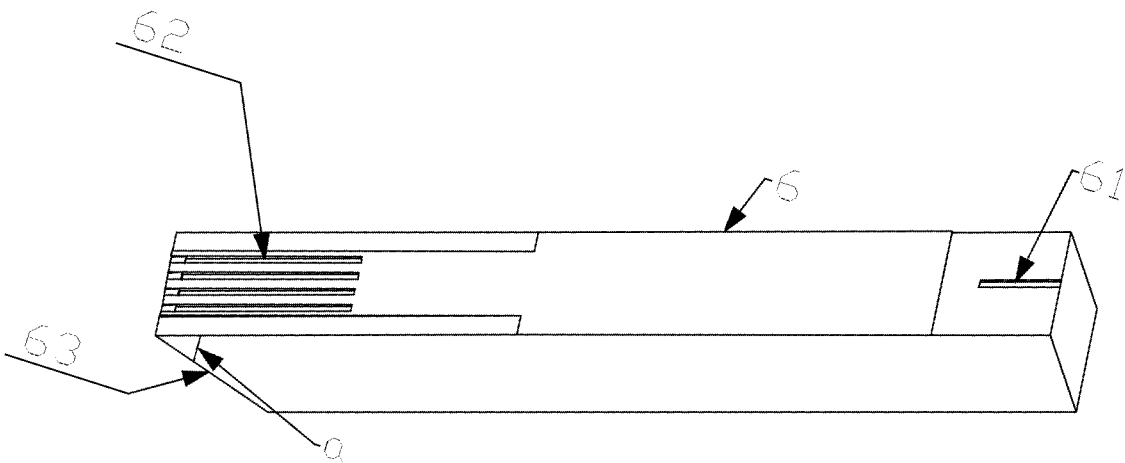


FIG. 3

U.S. Patent

Aug. 13, 2019

Sheet 4 of 6

US 10,379,301 B2

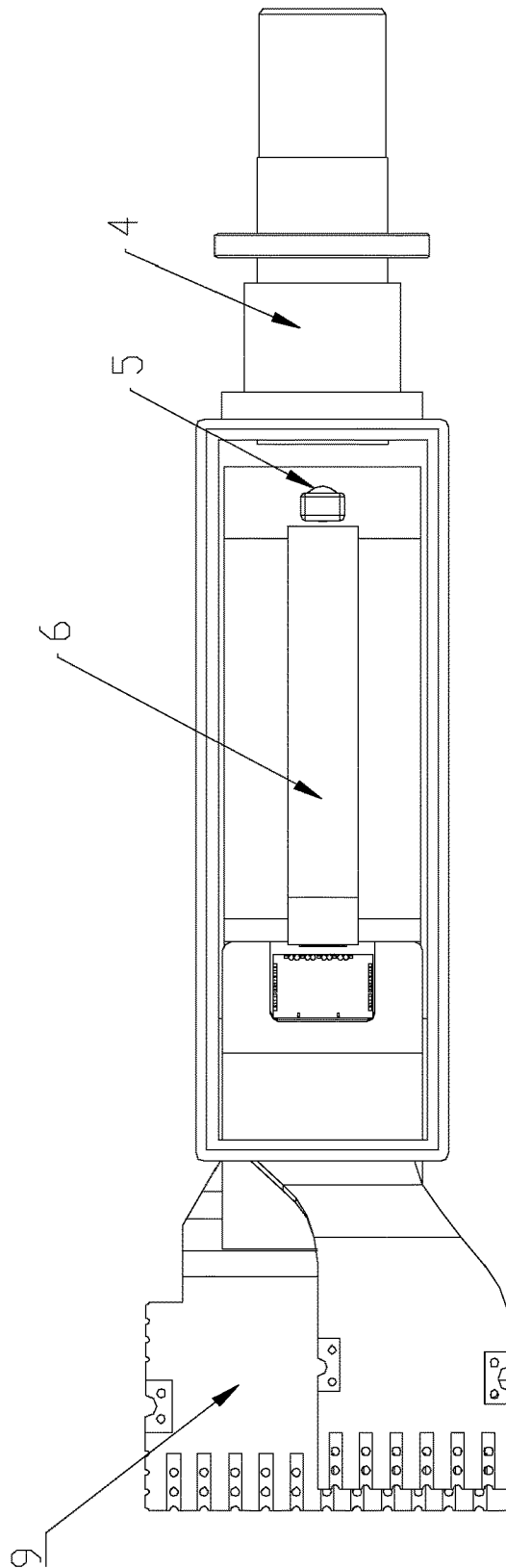


FIG. 4

U.S. Patent

Aug. 13, 2019

Sheet 5 of 6

US 10,379,301 B2

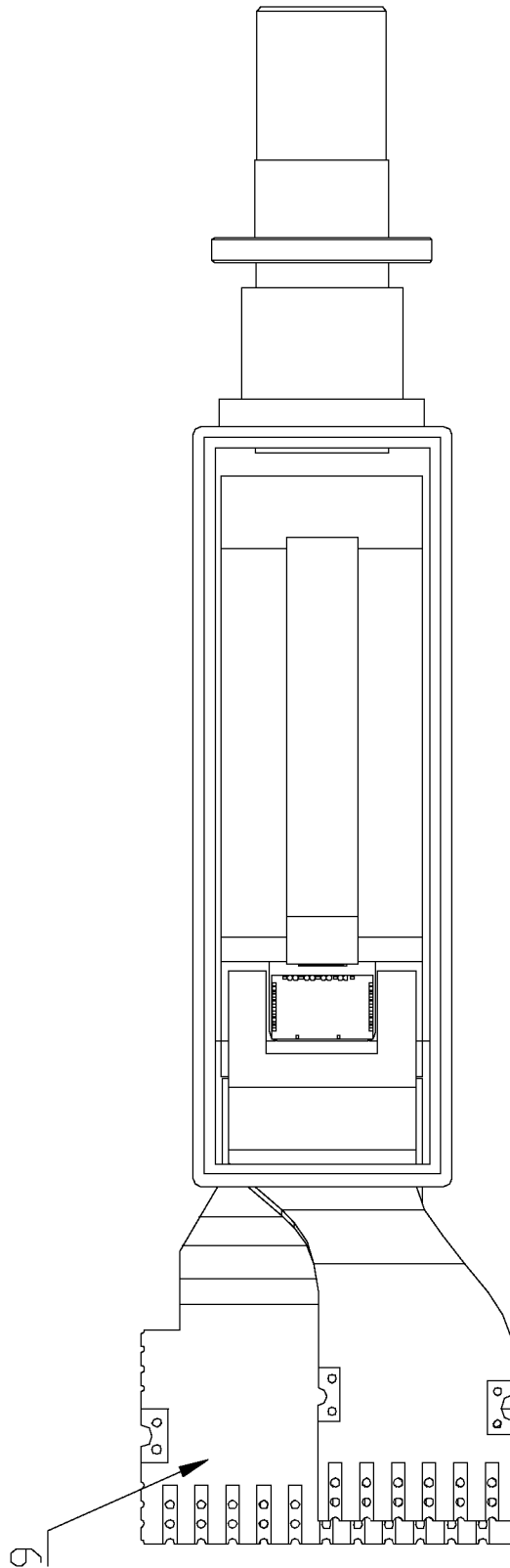


FIG. 5

U.S. Patent

Aug. 13, 2019

Sheet 6 of 6

US 10,379,301 B2

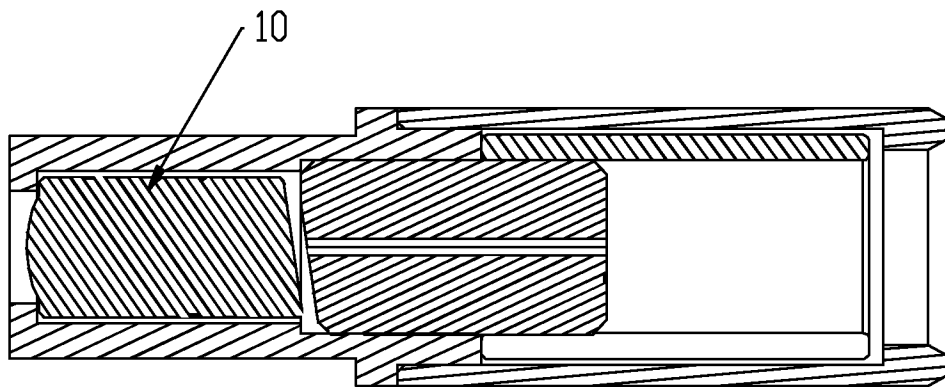


FIG. 6

US 10,379,301 B2

1

**MULTI-CHANNEL PARALLEL OPTICAL
RECEIVING DEVICE****TECHNICAL FIELD**

The present disclosure relates to fiber optical communications, and, more particularly, to multi-channel parallel optical receiving modules.

BACKGROUND

The optical receiving module refers to a device used in the field of the fiber optical communication for receiving an optical signal from an optical fiber and converting the received optical signal into an electrical signal. With the corresponding market continuing to grow, the demands of product cost and performance become stricter and stricter. In the current optical communication of the data center, transmitting speed of a single channel of product and the number of the channels must increase in order to improve the overall performance of the datacenter whose limited physical space puts restraint on density of the products. Hence, in many circumstances, multi-channel paralleling lights need to be enabled in the optical module. The data transmission of the optical modules needs to be implemented by connecting the optical modules, and the optical modules are connected by a jumper, resulting in higher cost.

SUMMARY

The present disclosure overcomes the currently existing technical drawback. The present disclosure provides a multi-channel parallel optical receiving module capable of achieving multi-channel receiving and transmitting. Further, the disclosed module is reliable and could be manufactured with reduced cost.

The present disclosure provides a multi-channel parallel optical receiving module including a carrier and a light receiving chip. A plurality of optoelectronic diodes may be disposed in array on a top surface of an end of the carrier, and the optoelectronic diodes may be electrically connected to the light receiving chip. An optical fiber connector may be disposed in another end of the carrier. An arrayed waveguide grating may be further disposed on the top surface of the carrier, and an input end of the arrayed waveguide grating may be connected to the optical fiber connector for receiving an optical signal from the optical fiber. The optical signals may be divided into multi-channel optical signals in parallel by the arrayed waveguide grating based on their wavelengths. The top surface of an output end of the arrayed waveguide grating may be at a predetermined angle so that the multi-channel optical signals may be reflected by the top surface to photosensitive surfaces of the plurality of optoelectronic diodes arranged in array.

With the aforementioned structure, the present disclosure has following features. In the present disclosure, the top surface of the arrayed waveguide grating may be designed to allow for the optical signals emitting from the arrayed waveguide grating to be reflected by the top surface to the photosensitive surfaces of the optoelectronic diodes. Based on such design, after the position of the optoelectronic diodes is determined, only a placement groove or a guiding structure for the arrayed waveguide grating is needed on the carrier to guide the arrayed waveguide grating to be in the position aligning with the optoelectronic diodes. Accordingly, the arrayed waveguide grating may be installed without too much difficulty, and the coupling between the

2

arrayed waveguide grating and the optoelectronic diodes may be no longer necessary. Further, the optoelectronic diodes and the light receiving chip may be disposed on the same surface, simplifying the design of the structure and reducing the length of the bonding wire to enhance the integrity of the entire structure and lower the manufacturing cost of the same.

In some embodiments, the plurality of optoelectronic diodes may be disposed on the same circuit board. With this structure, the position of the optoelectronic diodes may become definitive to simplify and streamline the manufacturing process.

In some embodiments, the amount of the optoelectronic diodes may be equal to the amount of the optical paths divided by the arrayed waveguide grating.

In some embodiments, the predetermined angle of the top surface of an output end of the arrayed waveguide grating may be 41 to 46 degrees.

In some embodiments, the predetermined angle of the top surface of the output end of the arrayed waveguide grating may be 42 degrees.

In some embodiments, a first lens, for coupling the optical fiber, may be disposed between the input end of the arrayed waveguide grating and the optical fiber connector. With this structure, the first lens may be disposed between the optical fiber connector and the arrayed waveguide grating for a coupling process to be finalized.

In some embodiments, the input end of the arrayed waveguide grating may be inserted directly into the optical fiber connector, and a graded index lens may be disposed in an end where the optical fiber connector and the arrayed waveguide grating may connect. With this structure, the number of the coupling is reduced, which in turn may improve the integrity of the product.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure will become more understood from the detailed description given herein below and the accompanying drawings which are given by way of illustration only and thus are not limitative of the present disclosure and wherein:

FIG. 1 shows an exploded view of a structure of the present disclosure;

FIG. 2 shows an enlarged view of a structure in FIG. 1;

FIG. 3 shows perspective view of a structure of an arrayed waveguide grating;

FIG. 4 shows a perspective view of a structure according to a first embodiment of the present disclosure;

FIG. 5 shows a perspective view of a structure according to a second embodiment of the present disclosure; and

FIG. 6 shows a sectional view of an optical fiber connector according to a second embodiment of the present disclosure.

DETAILED DESCRIPTION

In the following detailed description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the disclosed embodiments. It will be apparent, however, that one or more embodiments may be practiced without these specific details. In other instances, well-known structures and devices are schematically shown in order to simplify the drawings.

As shown in FIG. 1 to FIG. 6, the present disclosure provides a multi-channel parallel optical receiving device

US 10,379,301 B2

3

which includes a carrier 8 and a light receiving chip 2. A plurality of optoelectronic diodes 3 may be disposed on a top surface of an end of the carrier 8, and the plurality of optoelectronic diodes 3 may be electrically connected to the light receiving chip 2. The light receiving chip 2 of this embodiment may be a trans-impedance amplifier (TIA) chip, and the optoelectronic diodes 3 and the trans-impedance amplifier (TIA) chip may be connected by bonding wires. An optical fiber connector 4 may be disposed at another end of the carrier 8, and an arrayed waveguide grating 6 may be further disposed on the top surface of the carrier 8. An input end 61 of the arrayed waveguide grating 6 may be connected to the optical fiber connector 4 for receiving an optical signal from the optical fiber. The optical signals may be divided into multi-channel optical signals in parallel by the arrayed waveguide grating 6 based on their wavelengths. The top surface 63 of an output end 62 of the arrayed waveguide grating 6 may be designed to be at a predetermined angle, allowing for the multi-channel optical signals to be reflected by the top surface 63 to the photosensitive surfaces of the plurality of optoelectronic diodes 3 arranged in array.

The optical receiving module of this embodiment may further include a bottom shell 1 and top cap 7, defining a space in which the aforementioned structure may be placed so that the aforementioned structure may be protected. Some other shell bodies may be used in the present disclosure to serve the protection purpose. The light receiving chip 2 may be connected to a flexible circuit board 9 by the bonding wires, and the flexible circuit board 9 may be used to connect to other devices of the optical device. The arrayed waveguide grating 6 may include an input end 61 and an output end 62, and the optical signal may be input from the input end. Since a wavelength division multiplexing technology may be used in the optical fiber of the present disclosure, the signals with different wavelengths may be divided into the multi-channel optical signals and output from the output end. The arrayed waveguide grating is a well-known technology, in which the plurality of optical filters capable of filtering the optical signals in different wavelengths is used, so that each of the channels may transmit the optical signal having the specific wavelength range, and the optical signals from the optical fiber may be divided before being outputted. The top surface 63 may be an inclined plane, enabling the reflection of the optical signal upon the top surface 63. The reflected optical signal may be transmitted to the photosensitive surface of the plurality of optoelectronic diodes 3 on the carrier 8 since the top surface 63 may tilt at a predetermined angle. Generally speaking, the optical paths from the output end 62 of the arrayed waveguide grating 6 may correspond to the optoelectronic diodes 3. This embodiment here shows four channels as an example, as the amount of the channels could be based on the actual demand.

With the aforementioned structure, the present disclosure has following features. In the present disclosure, the top surface 63 of the arrayed waveguide grating 6 may be designed to be with a predetermined angle. Therefore, the optical signals emitting from the arrayed waveguide grating 6 may be reflected by the top surface 63 to the photosensitive surfaces of the plurality of optoelectronic diodes. Based on such design, after the position of the optoelectronic diodes is determined, only a placement groove or a guiding structure for the arrayed waveguide grating 6 may be needed on the carrier 8 to guide the arrayed waveguide grating 6 to be in the position aligning with the optoelectronic diodes. Accordingly, the arrayed waveguide grating may be installed without much difficulty, and the coupling between

4

the arrayed waveguide grating 6 and the optoelectronic diodes may be no longer necessary. Further, the optoelectronic diodes and the light receiving chip 2 may be disposed on the same surface, reducing length of the bonding wire to improve the integrity and lower the manufacturing cost.

The plurality of optoelectronic diodes may be disposed on the same circuit board. The position of the optoelectronic diodes may become definitive so as to simplify and streamline the manufacturing process. The optoelectronic diodes may be disposed onto the carrier 8 simultaneously, minimizing the iteration of disposing the optoelectronic diodes.

The amount of the optoelectronic diodes may be equal to the amount of the optical paths divided by the arrayed waveguide grating 6.

The predetermined angle of the top surface 63 of an output end 62 of the arrayed waveguide grating 6 may be 41 to 46 degrees.

The predetermined angle of the top surface 63 of the output end 62 of the arrayed waveguide grating 6 may be 42 degrees.

FIG. 4 is an embodiment of the present disclosure in which first lens 5, for coupling the optical fiber, may be disposed between the input end 61 of the arrayed waveguide grating 6 and the optical fiber connector 4. In this embodiment, the first lens 5 disposed on the carrier 8 may be located on the optical path of the optical fiber connector 4 and the arrayed waveguide grating 6, for the optical coupling to be realized.

FIG. 5 to FIG. 6 show a second embodiment of the present disclosure in which the input end 61 of the arrayed waveguide grating 6 may be inserted directly into the optical fiber connector 4, and a graded index lens 10 may be disposed on an end where the optical fiber connector 4 and the arrayed waveguide grating 6 may connect. With this structure, the lens does not need to be coupled on the carrier 8, reducing the number of the optical coupling and increasing the integrity of the entire product.

The foregoing description, for the purpose of explanation, has been described with reference to specific embodiments; however, the embodiments were chosen and described in order to best explain the principles of the disclosure and its practical applications, to thereby enable others skilled in the art to best utilize the disclosure and various embodiments with various modifications as are suited to the particular use contemplated. The embodiments depicted above and the appended drawings are exemplary and are not intended to be exhaustive or to limit the scope of the disclosure to the precise forms disclosed. Modifications and variations are possible in view of the above teachings.

What is claimed is:

1. A multi-channel parallel optical receiving device, comprising:

- a carrier;
- a light receiving chip disposed on a top surface of an end of the carrier;
- a plurality of optoelectronic diodes disposed on the top surface of the end of the carrier, and the plurality of optoelectronic diodes electrically connected to the light receiving chip via bonding wire, wherein the optoelectronic diodes and the light receiving chip are disposed directly on the same top surface of the end of the carrier;
- an optical fiber connector disposed in an end of the carrier;
- an arrayed waveguide grating further disposed on a top surface of the carrier that defines a midpoint of the carrier, the arrayed waveguide grating having a first

US 10,379,301 B2

5

end, a middle, and a second end disposed opposite the first end, and an input end of the arrayed waveguide grating connected to the optical fiber connector for receiving an optical signal from the optical fiber, wherein the top surface of the carrier underlies the middle of the arrayed waveguide grating; and wherein the optical signal is divided into multi-channel optical signals in parallel by the arrayed waveguide grating based on their wavelengths, a top surface defined by an output end of the arrayed waveguide grating is at a predetermined angle, causing the multi-channel optical signals reflected by the top surface defined by the output end of the arrayed waveguide grating to be reflected to a photosensitive surface of the plurality of optoelectronic diodes arranged in parallel, wherein the predetermined angle of the top surface defined by the output end of the arrayed waveguide grating is in a range of 41 to 46 degrees such that the top surface provides the reflection.

2. The multi-channel parallel optical receiving device according to claim 1, wherein the top surface of the end of the carrier is defined at least in part by a circuit board, and wherein the plurality of optoelectronic diodes and the light receiving chip are directly disposed on the circuit board.

3. The multi-channel parallel optical receiving device according to claim 1, wherein the amount of the optoelectronic diodes is equal to the amount of optical paths divided by the arrayed waveguide grating.

4. The multi-channel parallel optical receiving device according to claim 1, wherein the predetermined angle of the top surface of the output end of the arrayed waveguide grating is 42 degrees.

5. The multi-channel parallel optical receiving device according to claim 1, wherein a first lens, for coupling the optical fiber, is disposed between the input end of the arrayed waveguide grating and the optical fiber connector.

6. The multi-channel parallel optical receiving device according to claim 1, wherein the input end of the arrayed waveguide grating is inserted directly into the optical fiber

6

connector and a graded index lens is disposed in an end where the optical fiber connector and the arrayed waveguide grating connect.

7. A multi-channel parallel optical receiving device, comprising:

a carrier;

a light receiving chip disposed on a top surface of an end of the carrier;

a plurality of optoelectronic diodes disposed on the top surface of the end of the carrier, and the plurality of optoelectronic diodes electrically connected to the light receiving chip via wire bonding, wherein the plurality of optoelectronic diodes and the light receiving chip are directly disposed on the same top surface of the end of the carrier;

an optical fiber connector disposed in an end of the carrier;

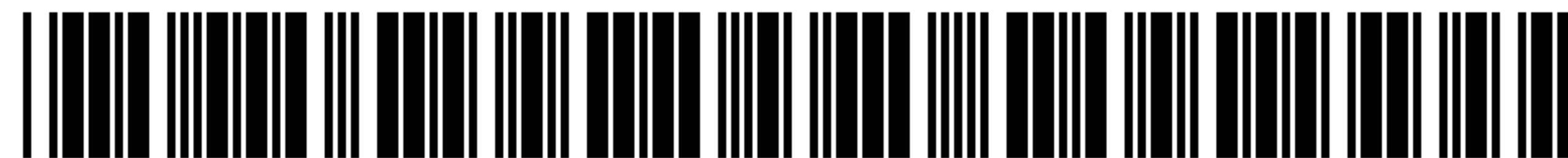
an arrayed waveguide grating further disposed on a top surface of the carrier that defines a midpoint of the carrier, the arrayed waveguide grating having a first end, a middle, and a second end disposed opposite the first end, and an input end of the arrayed waveguide grating connected to the optical fiber connector for receiving an optical signal from the optical fiber;

wherein the top surface of the carrier that defines the midpoint of the carrier underlies the middle of the arrayed waveguide grating; and

wherein the optical signal is divided into multi-channel optical signals in parallel by the arrayed waveguide grating based on their wavelengths, a top surface defined by an output end of the arrayed waveguide grating is at a predetermined angle of 42 degrees, causing the multi-channel optical signals reflected by the top surface defined by the output end of the arrayed waveguide grating to be reflected to a photosensitive surface of the plurality of optoelectronic diodes arranged in parallel.

* * * * *

Exhibit E



US010313024B1

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Ho et al.

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(45) **Date of Patent: Jun. 4, 2019**

(54) **TRANSMITTER OPTICAL SUBASSEMBLY
WITH TRACE ROUTING TO PROVIDE
ELECTRICAL ISOLATION BETWEEN
POWER AND RF TRACES**

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H04B 10/80 (2013.01)
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H01S 5/40 (2006.01)
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CPC **H04B 10/80** (2013.01); **H01S 5/0222**
(2013.01); **H01S 5/02284** (2013.01); **H01S**
5/02415 (2013.01); **H01S 5/042** (2013.01);
H01S 5/4087 (2013.01); **H04B 10/50**
(2013.01); **H04J 14/02** (2013.01)

(58) **Field of Classification Search**

USPC 398/135, 164, 79
See application file for complete search history.

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Primary Examiner — David C Payne

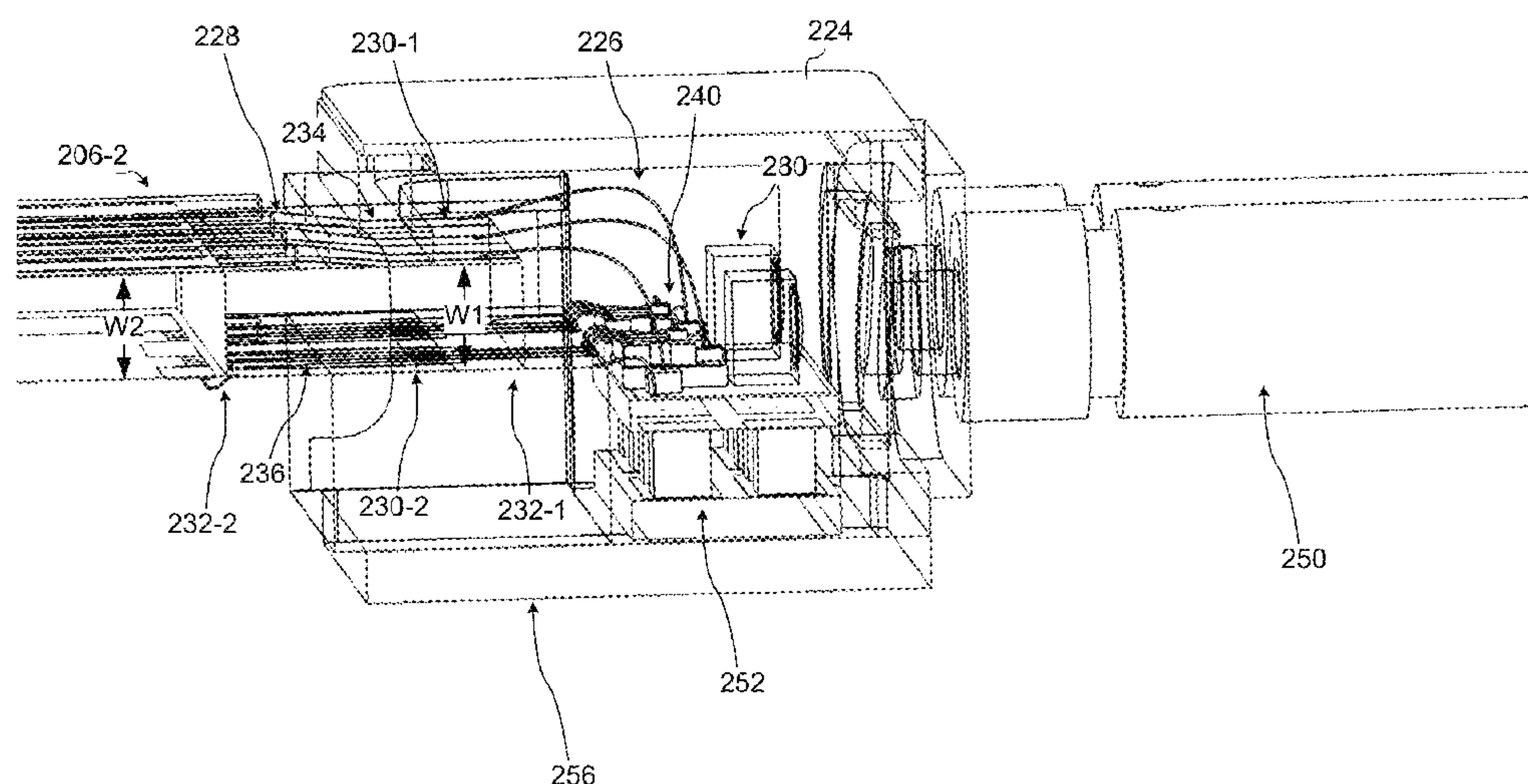
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(57) **ABSTRACT**

The present disclosure is generally directed to a transmitter optical subassembly (TOSA) having a hermetically-sealed housing with a feedthrough device that electrically isolates RF and power traces. In more detail, a TOSA consistent with the present disclosure includes a substrate with driving circuitry disposed thereon. A first end of the substrate may electrically couple to transmit connecting circuitry and a second end may couple to a hermetically-sealed housing. The hermetically-sealed housing can include one or more laser packages for emitting associated channel wavelengths in addition to monitor photodiodes (PDs), and temperature control devices such as TECs. The hermetic-sealed housing includes a first end with a feedthrough device that provides traces to electrically couple to the circuitry of the substrate. The hermetic-sealed housing further includes an optical coupling port, e.g., a LC connector, for coupling to an external fiber, for example.

17 Claims, 4 Drawing Sheets



US 10,313,024 B1

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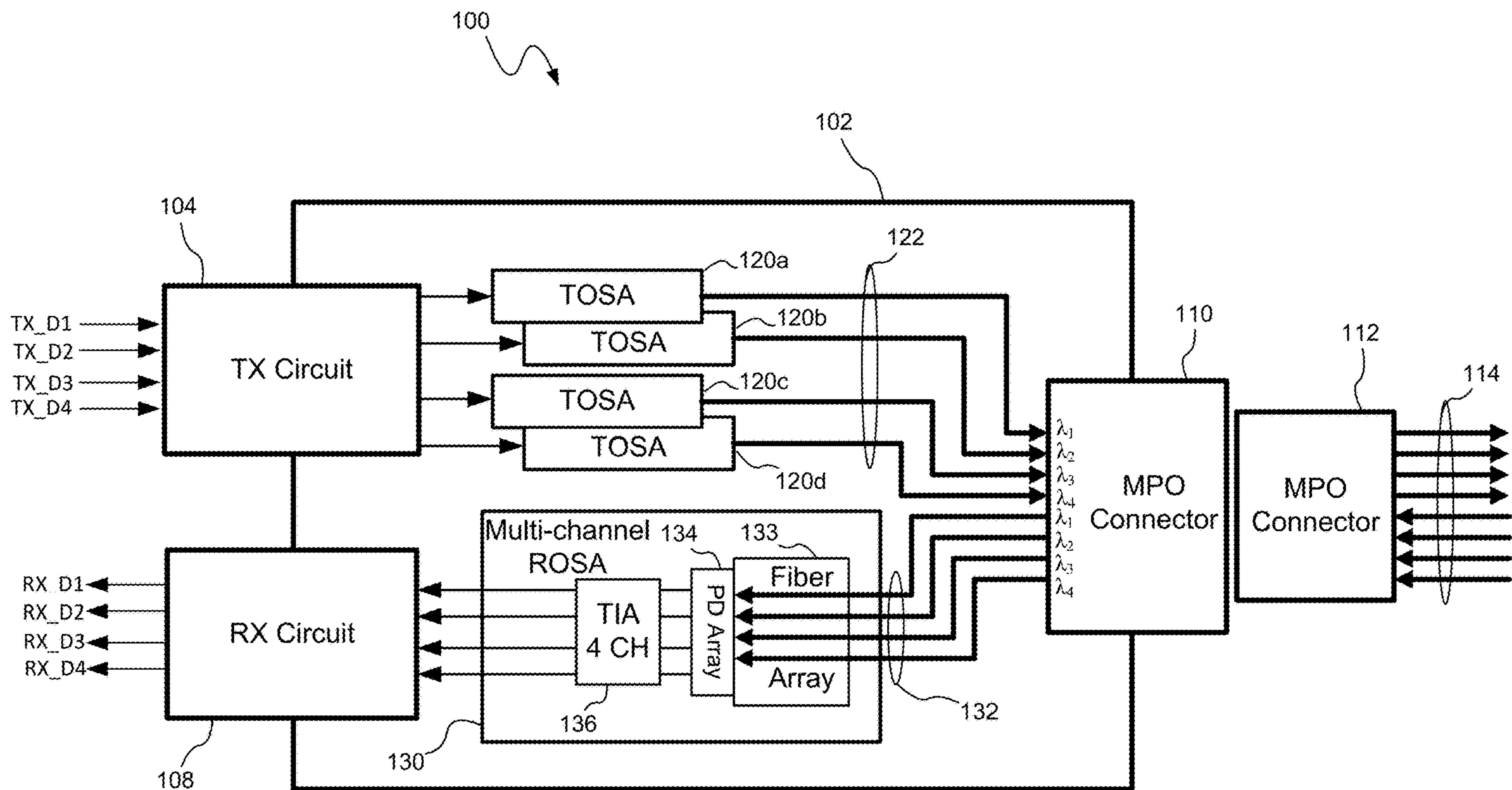


FIG. 1A

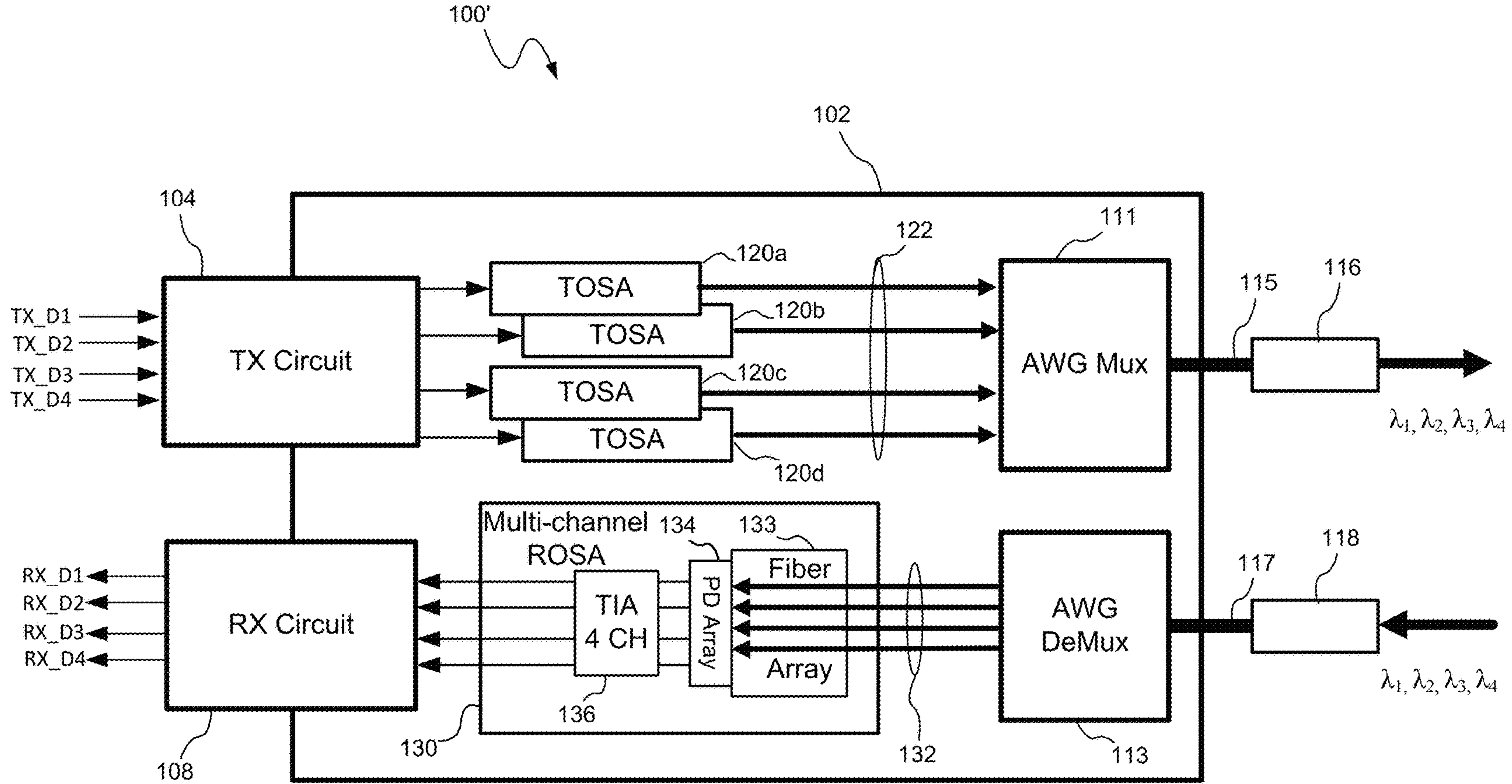


FIG. 1B

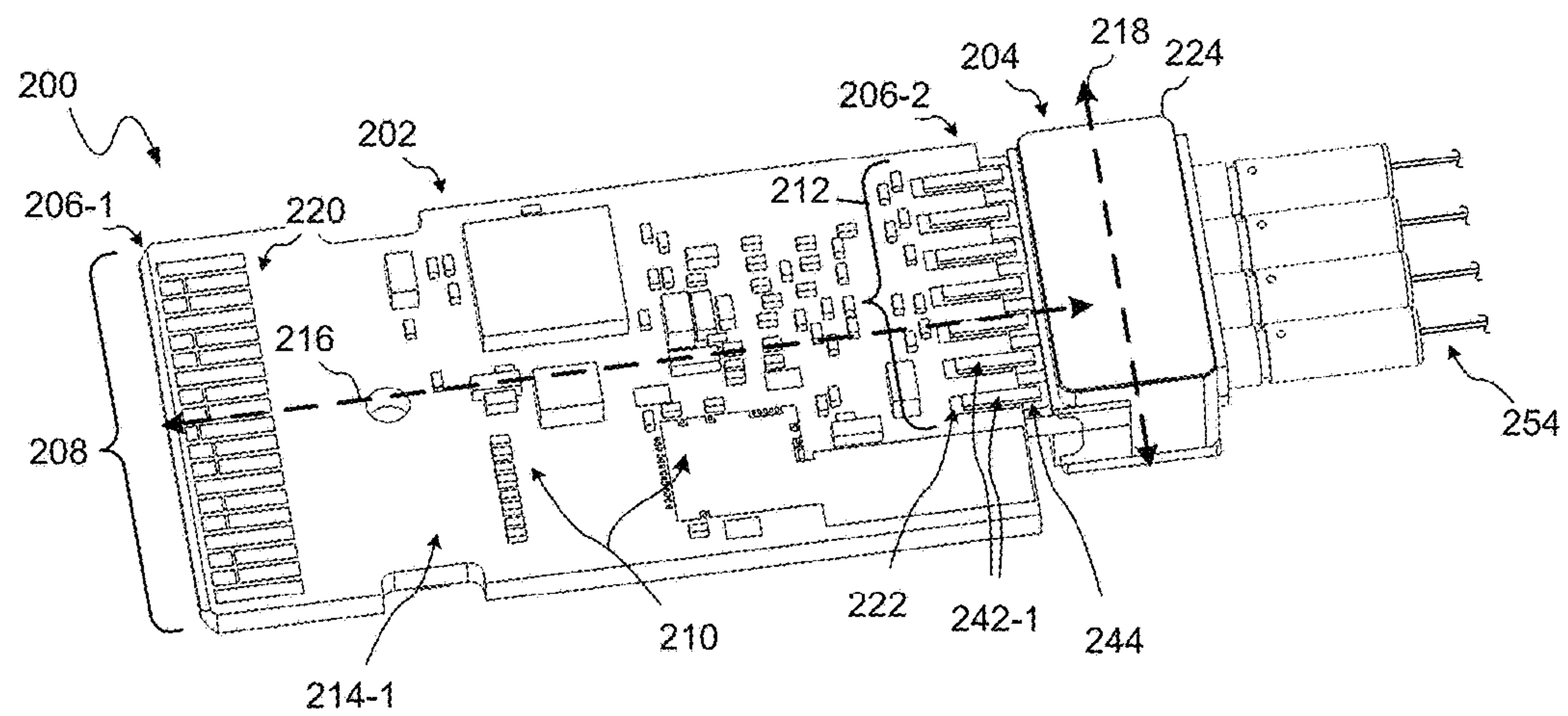


FIG. 2A

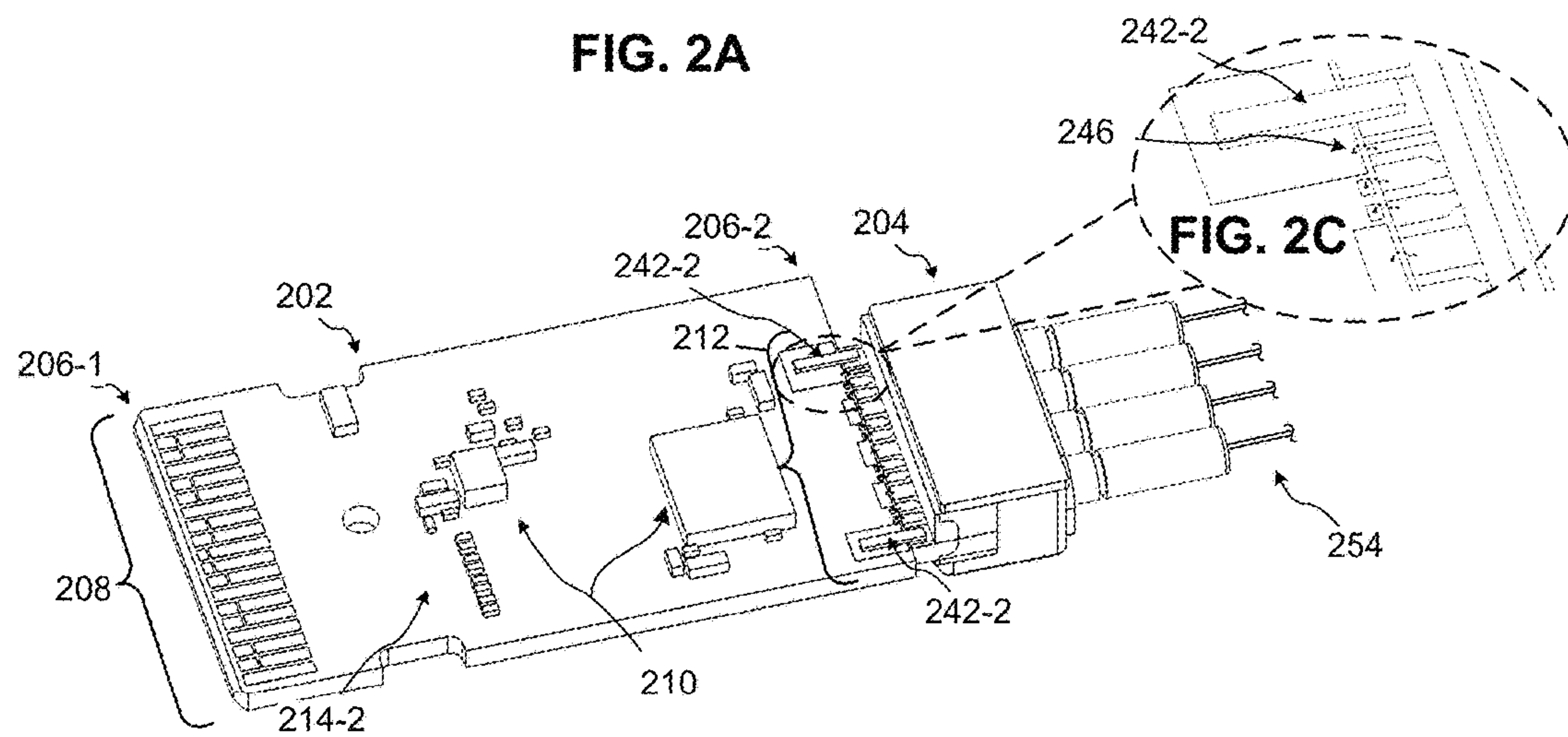


FIG. 2B

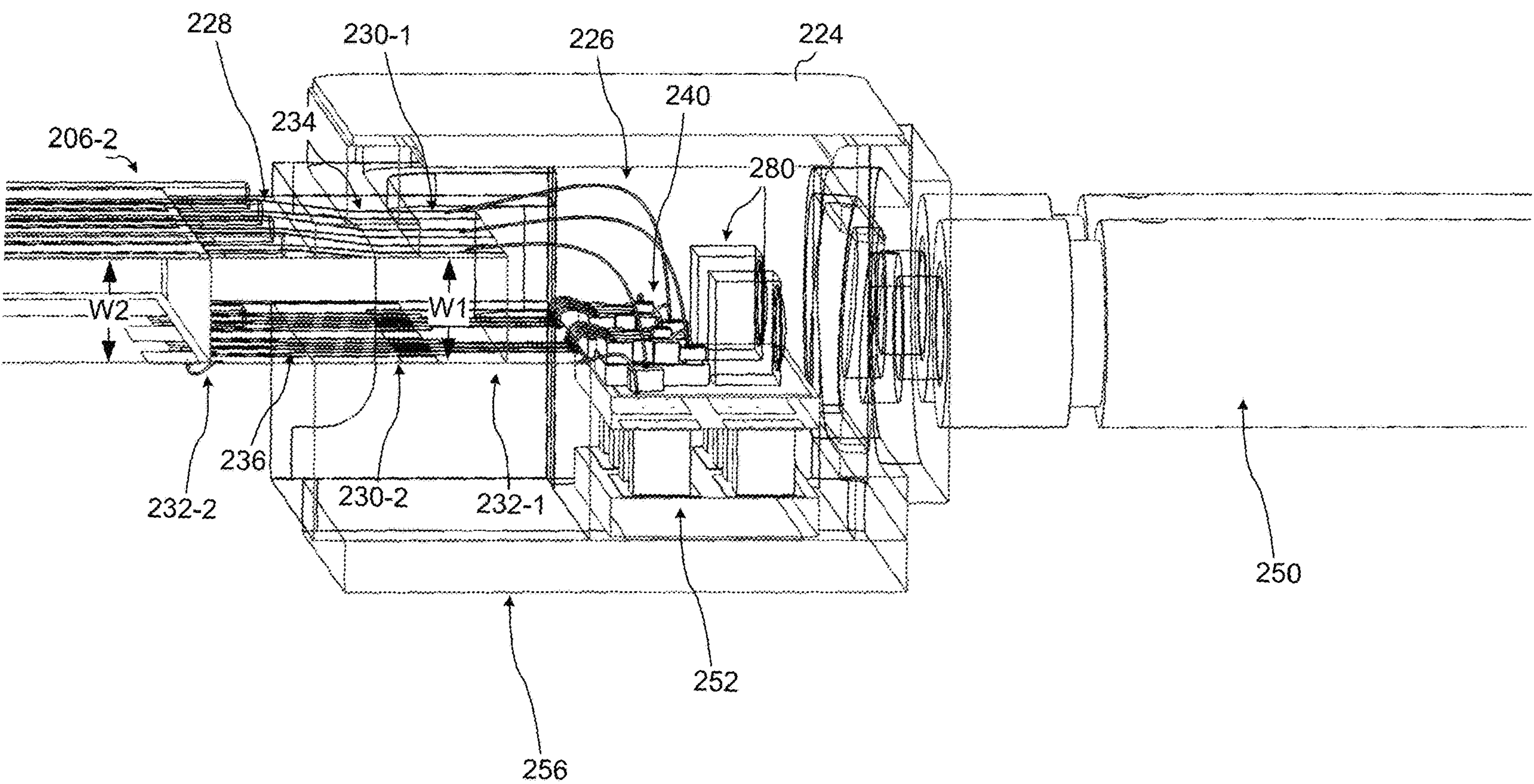


FIG. 3

1

**TRANSMITTER OPTICAL SUBASSEMBLY
WITH TRACE ROUTING TO PROVIDE
ELECTRICAL ISOLATION BETWEEN
POWER AND RF TRACES**

TECHNICAL FIELD

The present disclosure relates to optical communications and more particularly, to a transmitter optical subassembly (TOSA) with a hermetically-sealed light engine housing that electrically isolates DC and RF traces to ensure nominal performance.

BACKGROUND INFORMATION

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 thermal management, insertion loss, and manufacturing yield.

Optical transceiver modules generally include one or more transmitter optical subassemblies (TOSAs) for transmitting optical signals. In general, TOSAs include one or more lasers to emit one or more channel wavelengths and associated circuitry for driving the lasers. Some optical applications, such as long-distance communication, may require TOSAs to include hermetically-sealed housings with arrayed waveguide gratings, laser packages and associated circuitry disposed therein to reduce loss and ensure optical performance. However, the inclusion of hermetically-sealed components increases manufacturing complexity, cost, and raises non-trivial challenges.

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:

FIGS. 1A and 1B are block diagrams of multi-channel optical transceivers, consistent with embodiments of the present disclosure.

FIG. 2A is a perspective view of a first side of an transmitter optical subassembly (TOSA) module consistent with embodiments of the present disclosure.

FIG. 2B is a perspective view of a second side of the TOSA module of FIG. 2A consistent with embodiments of the present disclosure.

FIG. 2C shows an enlarged region of the second side of the TOSA module shown in FIG. 2B in accordance with an embodiment of the present disclosure.

FIG. 3 shows a cross-sectional view of a hermetically-sealed housing consistent with an embodiment of the present disclosure.

DETAILED DESCRIPTION

As discussed above, some TOSAs can reach optical transmission distances of up to 10 km or more. Such TOSAs may be suitable for use in C form-factor pluggable (CFP), CFP2, CFP4 and quad small form-factor pluggable (QSFP) applications. In general, such TOSAs include a hermetic-sealed package (or housing) with an LC receptacle (or other

2

suitable port) for optical coupling. The hermetic-sealed package can house laser packages, e.g., electro-absorption modulator integrated lasers (EMLs), power monitors photodiodes (PDs), an optical multiplexer such as an arrayed waveguide grating for multiplexing multiple channel wavelengths, and electrical interconnects such as flexible printed circuit boards. To supply power such as direct current (DC) and RF signaling to drive the lasers, feedthrough devices may be utilized. The feedthrough device may include patterns/traces disposed thereon to propagate signals from external circuitry to components within the hermetic-sealed package. Multiple feedthrough devices may be utilized in some instances to provide both RF and DC signals. However, the available space to route traces shrinks as TOSA packages continue to scale, which can lead to electrical interference between DC and RF signals that may degrade performance.

Thus, the present disclosure is generally directed to a TOSA having a hermetically-sealed housing with a feedthrough device that electrically isolates RF traces from power-related traces (e.g., DC traces, ground traces) by disposing power and RF traces on opposite sides. This configuration of power and RF traces may also be referred to as an opposing arrangement. In more detail, a TOSA consistent with the present disclosure includes a substrate with driving circuitry disposed thereon. A first end of the substrate may electrically couple to transmit connecting circuitry and a second end may couple to a hermetically-sealed housing. Thus, the first end may be referred to as an electrical coupling end and the second end may be referred to as a light engine interface end. The hermetically-sealed housing can include one or more laser packages for emitting channel wavelengths in addition to monitor photodiodes (PDs), and temperature control devices such as TECs. The hermetically-sealed housing includes a first end with a feedthrough device that provides traces to electrically couple to the circuitry of the substrate. The hermetically-sealed housing further includes an optical coupling port, e.g., a LC connector, for coupling to an external fiber, for example. A first side of the feedthrough device may include traces configured to propagate power signals, e.g., DC signals, from circuitry of the substrate to components within the hermetically-sealed housing. On the other hand, a second side of the feedthrough device, opposite the first side, may include traces configured to propagate RF signals from circuitry of the substrate to components within the hermetically-sealed housing.

Therefore, the RF and power signal traces of the feedthrough device may be electrically isolated from each other based on the distance therebetween, e.g., provided by the width of the feedthrough device, and/or the material properties of the feedthrough device. For example, the feedthrough device may comprise ceramic or other suitable material that may provide electrical shielding. Likewise, the power and RF traces may be similarly disposed and routed on either side of the substrate to minimize or otherwise reduce electrical interference. In addition, a first type of interconnect device such as DC bus bars or other similarly rigid device may be utilized to electrically couple traces of the substrate to the corresponding power traces (including ground traces) of the feedthrough substrate. A plurality of the first type of interconnect devices may be both used to provide power and to brace the hermetically-sealed housing to the substrate. A second type of interconnect device, different from the first type, such as wire bonding may be utilized to electrically couple the substrate to the RF traces of the feedthrough device. Wire bonding, although particu-

3

larly well suited for high-speed RF transmission, can be relatively fragile and the increased rigidity of the interface between the substrate and the hermetic-sealed housing provided by the first type of interconnect device may advantageously provide bracing to limit stress that could break or otherwise compromise the wire bonds.

As used herein, the terms hermetic-sealed and hermetically-sealed may be used interchangeably and refer to a housing that releases a maximum of about 5×10^{-8} cc/sec of filler gas. The filler gas may comprise an inert gas such as nitrogen, helium, argon, krypton, xenon, or various mixtures thereof, including a nitrogen-helium mix, a neon-helium mix, a krypton-helium mix, or a xenon-helium mix.

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. This disclosure is equally applicable to coarse wavelength division multiplexing (CWDM). In one specific example embodiment, the channel wavelengths are implemented in accordance with local area network (LAN) wavelength division multiplexing (WDM), which may also be referred to as LWDM. 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.

The term substantially, as generally referred to herein, refers to a degree of precision within acceptable tolerance that accounts for and reflects minor real-world variation due to material composition, material defects, and/or limitations/peculiarities in manufacturing processes. Such variation may therefore be said to achieve largely, but not necessarily wholly, the stated characteristic. To provide one non-limiting numerical example to quantify "substantially," minor variation may cause a deviation of up to and including $\pm 5\%$ from a particular stated quality/characteristic unless otherwise provided by the present disclosure.

Referring to the Figures, FIG. 1A, an optical transceiver 100, consistent with embodiments of the present disclosure, is shown and described. In this embodiment, the optical transceiver 100 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 Gbps per channel. 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. Other channel wavelengths are within the scope of this disclosure including those associated with local area network (LAN) wavelength division multiplexing (WDM). The optical transceiver 100 may also be capable of transmission distances of 2 km to at least about 10 km. The optical transceiver 100 may be used, for example, in internet data center applications or fiber to the home (FTTH) applications.

This embodiment of the optical transceiver 100 includes multiple transmitter optical subassemblies (TOSAs) 120a-d for transmitting optical signals on different channel wavelengths and a multi-channel receiver optical subassembly (ROSA) 130 for receiving optical signals on different channel wavelengths. The TOSAs 120a-d and the multi-channel ROSA 130 are located in a transceiver housing 102.

A transmit connecting circuit 104 and a receive connecting circuit 108 provide electrical connections to the TOSAs

4

120a-d and the multi-channel ROSA 130, respectively, within the housing 102. The transmit connecting circuit 104 is electrically connected to the electronic components (e.g., the laser, monitor photodiode, etc.) in each of the TOSAs 120a-d and the receive connecting circuit 108 is electrically connected to the electronic components (e.g., the photodiodes, the TIA, etc.) in the multi-channel ROSA 130. The transmit connecting circuit 104 and the receive connecting circuit 108 may be flexible printed circuits (FPCs) including at least conductive paths to provide electrical connections and may also include additional circuitry.

Each of the TOSAs 120a-d may be implemented as the TOSA 200 as discussed in greater detail below. Each TOSA may be electrically coupled to conductive paths on the transmit connecting circuit 104 and be configured to receive driving signals (e.g., TX_D1 to TX_D4) and launch channel wavelengths on to fibers of the transmit optical fibers 122.

A multi-fiber push on (MPO) connector 110 provides optical connections to the TOSAs 120a-d and the multi-channel ROSA 130 within the housing 102. The MPO connector 110 is optically coupled to the TOSAs 120a-d and the multi-channel ROSA 130 via transmit optical fibers 122 and receive optical fibers 132, respectively. The MPO connector 110 is configured to be coupled to a mating MPO connector 112 such that the optical fibers 122, 132 in the optical transceiver 100 are optically coupled to external optical fibers 114.

Continuing on, this embodiment of the multi-channel ROSA 130 shown in FIG. 1A includes a photodetector array 134 including, for example, photodiodes optically coupled to a fiber array 133 formed by the ends of the receive optical fibers 132. The multi-channel ROSA 130 also includes a multi-channel transimpedance amplifier 136 electrically connected to the photodetector array 134. The photodetector array 134 and the transimpedance amplifier 136 detect and convert optical signals received from the fiber array 133 into electrical data signals (RX_D1 to RX_D4) that are output via the receive connecting circuit 108. Other embodiments of a ROSA may also be used in the transceiver 100 for receiving and detecting one or more optical signals.

This embodiment of the optical transceiver 100 does not include an optical multiplexer or demultiplexer. The optical signals may be multiplexed and demultiplexed external to the optical transceiver 100.

Referring to FIG. 1B, another embodiment of an optical transceiver 100' includes the same light engine (e.g., TOSAs 120a-d and ROSA 130) described above together with an optical multiplexer 111 and an optical demultiplexer 113. The optical multiplexer 111 and the optical demultiplexer 113 both may include arrayed waveguide gratings (AWGs). The optical multiplexer 111 is optically coupled to the transmit optical fibers 122 and the optical demultiplexer 113 is optically coupled to the receive optical fibers 132. The optical multiplexer 111 multiplexes the optical signals being transmitted over transmit optical fibers 122 to provide a multiplexed optical signal on an output optical fiber 115. The optical demultiplexer 113 demultiplexes a multiplexed optical signal received on an input optical fiber 117 to provide received optical signals on receive optical fibers 132. The output optical fiber 115 and the input optical fiber 117 are coupled to an output optical connector 116 and an input optical connector 118, respectively.

This embodiment of the optical transceiver 100' includes 4 channels and may be configured for coarse wavelength division multiplexing (CWDM), although other numbers of channels are possible. This embodiment of the optical transceiver 100' may also be capable of transmission rates of at

US 10,313,024 B1

5

least about 25 Gbps per channel and transmission distances of 2 km to at least about 10 km and may be used in internet data center applications or fiber to the home (FTTH) applications.

Referring now to FIGS. 2A-2B, an example transmitter optical subassembly (TOSA) module **200** is shown consistent with an embodiment of the present disclosure. As shown, the TOSA **200** includes a substrate **202** and a hermetically-sealed light engine **204** coupled to an end of the substrate **202**. In more detail, the substrate **202** includes a first end **206-1** that extends to a second end **206-2** along a longitudinal axis **216**. The substrate may comprise a printed circuit board (PCB) formed of silicon or any other material capable of coupling/mounting to electrical components. The substrate **202** includes at least two mounting surfaces for mounting of components, such as mounting surfaces **214-1** and **214-2**, which are disposed opposite each other in an opposing arrangement/configuration.

The substrate **202** includes a transmit circuit (TX) interface region **208** proximate the first end **206-1**, a light engine interface region **212** proximate the second end **206-2** of the substrate, and a light engine driving circuit **210** disposed therebetween. The TX interface region **208** may include a plurality of terminals/pads **220** for electrically coupling to a transmit connecting circuit, e.g., transmit connecting circuit **104**. The TX interface region **208** may therefore receive signals, e.g., power and other signals such as RF, from an associated transmit connecting circuit when coupled thereto. The light engine interface region **212** also includes terminals/pads **222** for electrically coupling to the hermetically-sealed light engine **204**.

The light engine driving circuit **210** may include power conversion circuitry and other chips/devices suitable for driving a light engine such as the hermetically-sealed light engine **204**. The light engine driving circuit **210** may be disposed on one or more of the mounting surfaces of the substrate **202**. For instance, as shown in FIGS. 2A and 2B, the light driving circuit is disposed on both the first and second mounting surfaces **214-1**, **214-2**. This dual-sided arrangement allows for separation of RF and DC traces which may advantageously minimize or otherwise reduce electrical interference with each other. However, this disclosure is not necessarily limited in this regard and the light driving circuit may be disposed on only one side of the substrate **202** depending on a desired configuration. The light engine driving circuit **210** may electrically couple to the TX interface region **208**, and more specifically to the plurality of terminals/pads, via traces. Likewise, the light engine driving circuit **210** may electrically couple to the pads/terminals of the light engine interface region **212** via traces, which are described in greater detail below.

The hermetically-sealed light engine **204** includes a hermetically-sealed housing **224** or housing **224** defined by a plurality of sidewalls. The housing **224** may include a longitudinal axis **218** that extends substantially transverse relative to the longitudinal axis **216** of the substrate **202**. The housing **224** may comprise, for example, metal, plastic, ceramic, or any other suitable material. The housing **224** may be formed from multiple pieces, or a single piece, of material.

The housing **224** may further define a laser cavity **226** (FIG. 3) which may be filled with an inert gas to form an inert atmosphere. In one embodiment, the inert atmosphere sealed within the hermetically-sealed container comprises nitrogen, and preferably, 1 atmosphere (ATM) of nitrogen. The inert atmosphere may also be formed from nitrogen, helium, argon, krypton, xenon, or various mixtures thereof,

6

including a nitrogen-helium mix, a neon-helium mix, a krypton-helium mix, or a xenon-helium mix. The inert gas or gas mix included within the hermetically-sealed container may be selected for a particular refractive index or other optical property. Gases may also be selected based on their ability to promote thermal insulation. For instance, Helium is known to promote heat transfer may be utilized alone or in addition to others of the aforementioned gases. In any event, the terms hermetic-sealed and hermetically-sealed may be used interchangeably and refers to a housing that releases a maximum of about 5×10^{-8} cc/sec of filler gas.

As shown, the housing **224** may abut (e.g., directly couple to) the second end **206-2** of the substrate **202** and extend therefrom. This may also be referred to as an end-to-end connection between the housing **224** and the substrate **202**. The housing **224** may be securely attached to the substrate via an adhesive or other suitable device such as screws, rivets, friction-fit, tongue-and-groove or any combination thereof. However, the housing **224** may not necessarily directly couple to the second end **206-2** of the substrate **202** and the housing **224** may indirectly couple to the second end **206-2** of the substrate **202** via an intermediate device/structure.

Alternatively, or in addition to adhesive or other attachment devices, the housing **224** may be securely attached to the substrate **202** based on electrical interconnect devices (or simply interconnects) soldered or otherwise coupled between the substrate **202** and the housing **224** such as shown in FIGS. 2A and 2B. For example, a first type of interconnects referred to collectively as **242** and individually as **242-1** and **242-2** may be coupled to the substrate **202** by way of respective pads **222**. The first type of interconnect devices **242** may be substantially similar in dimension and type, although other embodiments are within the scope of this disclosure. For instance, each of the interconnect devices **242** may have substantially similar dimensions and may each comprise copper, aluminum, steel or any other suitably conductive metal or metal alloy. In other cases, the interconnect devices **242-1** may comprise a different metal material than that of the interconnect devices **242-2** and have different dimensions. In one specific example embodiment, the interconnect devices **242** comprise DC bus bar interconnects.

As shown, the interconnects **242-1** may be coupled to the first surface **214-1** of the substrate **202** and the interconnects **242-2** may be disposed opposite the interconnects **242-1** on the second surface **214-2** of the substrate **202**. This opposing configuration/arrangement of interconnects may increase structural stability of the interface between the housing **224** and the substrate **202** versus only coupling interconnects on only one side of the substrate **202**. In this embodiment, each of the first interconnect devices **242-1** may be disposed in a coextensive manner with corresponding ones of the second interconnect devices **242-2**, although in other cases the interconnect devices may be disposed in a staggered manner and may not necessarily be coextensive. In some cases the interconnects **242** may only be coupled on one side to provide electrical communication between the substrate **202** and the housing **224** and this disclosure should not be construed as limiting in this regard.

In any event, the interconnect devices **242** may be suitably rigid, and thus prevent or otherwise mitigate rotational movement of the housing **224** relative to the substrate **202**. A substantial portion, e.g., greater than 50%, of the bottom surface of each of the interconnect devices **242** may couple to the pads **222** of the substrate **202**. This may allow the interconnect devices **242** to have a relatively large amount of

surface area in contact with the substrate **202** to allow for additional soldering. The additional soldering may further increase structural support and securely hold the housing **224** in position relative to the substrate **202**. Thus, in some cases, the ratio of surface area of each of the interconnects **242** coupled to the substrate **202** relative to the housing **224** may be 2:1, 3:1, 4:1, 6:1, or any ratio therebetween.

In an embodiment, each of the interconnect devices **242** may form a substantially continuous electrical conductor when electrically coupled, e.g., when soldered or otherwise electrically coupled, to associated pads **222** of the substrate **202** and the pads **244** of the housing **224**. The continuous electrical conductor may be straight, e.g., without bends. Although the interconnects **242-2** may be configured to carry a DC signal, the associated pads of the substrate **202** and the housing **224** may not necessarily be electrically coupled to the light engine driving circuit **210** and the laser packages **240**, which may also be referred to as laser transmitter arrangements or simply laser arrangements (See FIG. 3). Instead, the interconnects **242-2** may be electrically isolated and may simply be present to provide structural support (e.g., to prevent rotational movement) between the substrate **202** and the housing **224** and/or a ground connection. Alternatively, one or more of the interconnects **242-2** may be electrically isolated while others may be utilized to provide a DC signal between the substrate **202** and the hermetically-sealed light engine **204**.

Continuing on, a second type of interconnect **246** may electrically couple the substrate **202** to the hermetically-sealed light engine **204** to provide RF signaling. The second type of interconnect **246** may comprise wire bonding, as shown, although other types of interconnect devices may be utilized. As shown, the embodiment of FIGS. 2B and 2C include a plurality of the second type of interconnect **246**. Wire bonding may be particularly well suited for transmission of high-frequency RF signals. However, wire bonding can be easily damaged based on, for instance, movement between the substrate **202** and the housing **224**. In an embodiment, the first interconnect devices **242** may introduce rigidity and a secure connection between the substrate **202** and the housing **224** to prevent or otherwise mitigate the potential for such damage.

FIG. 3 shows a cross-sectional view of the housing **224** consistent with an embodiment of the present disclosure. The housing **224** depicted in FIG. 3 includes transparent sections for clarity and for ease of explanation. As shown, the housing **224** includes a plurality of sidewalls that define cavity **226**. The cavity **226** includes laser packages **240** disposed therein. The laser packages **240** may be configured to launch associated channel wavelengths into a fiber, e.g., one of fibers **254** (See FIG. 2B), or other waveguide disposed in connector/receptacle **250**. Note, the fibers **254** may be implemented as the transmit optical fiber **122** of FIGS. 1A and 1B. Focusing lenses, e.g., focus lens **280**, may be disposed within the cavity **226** and aligned with associated laser packages to launch light emitted from the same into a fiber or waveguide of receptacle **250**. The cavity **226** may also include temperature control devices **252** in thermal communication with the laser packages **240**. The temperature control devices **252** may comprise TECs or other suitable devices. The temperature control devices **252** may also be in thermal communication with the bottom sidewall **256** to allow for transfer of heat. Therefore, the temperature control devices **252** may advantageously disperse heat through a metal housing (or other housing) that the housing **224** may be disposed in.

The cavity **226** may be at least partially formed by a feedthrough device **228**, which may also be referred to as a passthrough device **228**. The feedthrough device **228** may comprise, for example, a suitably rigid non-metal material such as inorganic material such as a crystalline oxide, nitride or carbide material, which may be commonly referred to as ceramic. Some elements, such as carbon or silicon, may also be considered ceramics, and are also within the scope of this disclosure. A first portion **232-1** of the feedthrough device **228** may at least partially extend into the cavity and a second portion **232-2** may extend from the cavity **226**.

The feedthrough device **228** may be defined by at least a first mounting surface **230-1** and a second mounting surface **230-2** disposed opposite the first surface **230-1** in an opposing arrangement/configuration. Each of the first and second mounting surfaces **230-1** and **230-2** may include traces disposed/patterned thereon, and may also be referred to herein as simply first and second surfaces **230-1**, **230-2**. For example, the first surface **230-1** may include power traces **234** (or DC traces **234**) disposed thereon that are configured for transmission of DC signals. On the other hand, the second surface **230-2** may include traces **236** (or RF traces **236**) disposed thereon that are configured for transmission of RF signals. The feedthrough device **228** may include a width (or thickness) of **W1**, with **W1** being between 0.1 mm to 2 mm, although other dimensions are within the scope of this disclosure. The width **W1** may be configured to allow the feedthrough device **228** to prevent or otherwise reduce electrical interference between the DC and RF signals carried by the traces **234** and **236**, respectively. The width **W1** of the feedthrough device **228** may be equal to the width **W2** of the substrate **202**. However, the widths **W1** and **W2** may not necessarily be equal and width **W2** may be greater or less than the width **W1**. As further shown, the first and second mounting surfaces **214-1**, **214-2** of the substrate **202** may extend in parallel, and may be substantially coplanar, with the first and second surfaces **230-1**, **230-2** of the feedthrough device **228** when the substrate **202** and the feedthrough device **228**, are coupled together.

Continuing on, a first end of the DC traces **234** may be electrically coupled to the substrate **202**, and more particularly, the light engine driving circuit **210** via respective interconnect devices, such as the first type of interconnect devices **242-1**. The second end of the DC traces **234** on the first surface **230-1** of the feedthrough device **228** may then be wire bonded, such as shown, or otherwise electrically coupled to the laser transmitter arrangements **240** via a suitable approach. Each laser transmitter arrangement **240** may comprise, for instance, a laser diode and a monitor photodiode and may be configured to emit an associated channel wavelength. Likewise, a first end of the RF traces **234** electrically couple to the light engine driving circuit **210** via respective interconnect devices, e.g., the second type of interconnect devices **242-2**, and a second end electrically couples to the laser transmitter arrangements **240** via wire bonding or other suitable approach.

In an accordance with an aspect of the present disclosure a transmitter optical subassembly (TOSA) module is disclosed. The TOSA module comprising a hermetically-sealed light engine with a housing that defines a hermetic-sealed cavity and at least one laser package for emitting an associated channel wavelength disposed within the hermetic-sealed cavity, a substrate defined by first and second surfaces disposed opposite each other, the substrate including an electrical coupling region for electrically coupling with a transmit connecting circuit and a light engine interface region for electrically coupling with the hermetically-sealed

US 10,313,024 B1

9

light engine, a light engine driving circuit disposed on the substrate to provide a radio frequency (RF) signal and a power signal to drive the hermetically-sealed light engine to output one or more channel wavelengths, and wherein the substrate includes at least a first trace disposed on the first surface to provide the power signal and at least a second trace disposed on the second surface to provide the RF signal, the first and second traces being disposed in an opposing arrangement to provide electrical isolation to reduce electrical interference between the power signal and the RF signal.

In accordance with another aspect of the present disclosure an optical transceiver. The optical transceiver comprising a housing, a transmitter optical subassembly (TOSA) module disposed in the housing, the TOSA module comprising a hermetically-sealed light engine with a housing that defines a hermetic-sealed cavity and at least one laser package disposed within the hermetic-sealed cavity, a substrate defined by first and second surfaces disposed opposite each other, the substrate including an electrical coupling region for electrically coupling with a transmit connecting circuit and a light engine interface region for electrically coupling with the hermetically-sealed light engine, a light engine driving circuit disposed on the substrate to provide a radio frequency (RF) signal and a power signal to drive the hermetically-sealed light engine to output one or more channel wavelengths, and wherein the substrate includes at least a first trace disposed on the first surface to provide the power signal, and at least a second trace disposed on the second surface to provide the RF signal, the first and second traces being disposed in an opposing arrangement to provide electrical isolation to reduce electrical interference between the power signal and the RF signal, a receive optical subassembly (ROSA) module disposed in the housing.

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 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.

What is claimed is:

1. A transmitter optical subassembly (TOSA) module comprising:

- a hermetically-sealed light engine with a housing that defines a hermetic-sealed cavity and at least one laser package for emitting an associated channel wavelength disposed within the hermetic-sealed cavity;
- a substrate defined by first and second surfaces disposed opposite each other, the substrate including an electrical coupling region for electrically coupling with a transmit connecting circuit and a light engine interface region for electrically coupling with the hermetically-sealed light engine;
- a light engine driving circuit disposed on the substrate to provide a radio frequency (RF) signal and a power signal to drive the hermetically-sealed light engine to output one or more channel wavelengths;
- wherein the substrate includes at least a first trace disposed on the first surface to provide the power signal and at least a second trace disposed on the second surface to provide the RF signal, the first and second traces being disposed in an opposing arrangement to

10

provide electrical isolation to reduce electrical interference between the power signal and the RF signal
a feedthrough device to electrically couple the at least one laser package to the light engine driving circuit; and
wherein the feedthrough device is defined by at least a first surface disposed opposite a second surface, and wherein the first and second surfaces extend substantially parallel with the first and second surfaces of the substrate.

2. The TOSA module of claim 1, further comprising at least a first interconnect device of a first type electrically coupled to the first trace and a corresponding trace of the hermetically-sealed light engine housing to provide the power signal, and at least a second interconnect device of a second type electrically coupled to the second trace and a corresponding trace of the hermetically-sealed light engine housing to provide the RF signal, the first and second types of interconnect devices being different.

3. The TOSA module of claim 2, wherein the first type of interconnect device is a DC bus bar interconnect.

4. The TOSA module of claim 2, wherein the second type of interconnect device is a wire bond.

5. The TOSA module of claim 1, further comprising at least one ground trace disposed on the second surface adjacent the second trace.

6. The TOSA module of claim 5, further comprising a DC bus bar interconnect device electrically coupled to the at least one ground trace and a wire bond electrically coupled to the second trace.

7. The TOSA module of claim 1, wherein the electrical isolation is provided at least in part by a width of the substrate and/or material properties of a material that forms the substrate.

8. The TOSA module of claim 1, further comprising a plurality of electrical interconnects that brace the substrate to the housing of the hermetically-sealed light engine.

9. The TOSA module of claim 1, wherein the feedthrough device is configured to directly couple to the substrate with an end-to-end connection.

10. The TOSA module of claim 1, wherein the first and second surfaces of the feedthrough device are substantially coplanar with the first and second surfaces of the substrate when the feedthrough device and substrate are coupled together.

11. The TOSA module of claim 1, further comprising at least one trace for receiving the power signal from the light engine driving circuit disposed on the first surface of the feedthrough and at least one trace for receiving the RF signal from the light engine driving circuit disposed on the second surface.

12. An optical transceiver comprising:

- a housing;
- a transmitter optical subassembly (TOSA) module disposed in the housing, the TOSA module comprising:
 - a hermetically-sealed light engine with a housing that defines a hermetic-sealed cavity and at least one laser package disposed within the hermetic-sealed cavity;
 - a substrate defined by first and second surfaces disposed opposite each other, the substrate including an electrical coupling region for electrically coupling with a transmit connecting circuit and a light engine interface region for electrically coupling with the hermetically-sealed light engine;
 - a light engine driving circuit disposed on the substrate to provide a radio frequency (RF) signal and a power signal to drive the hermetically-sealed light engine to output one or more channel wavelengths; and

US 10,313,024 B1

11

wherein the substrate includes at least a first trace disposed on the first surface to provide the power signal, and at least a second trace disposed on the second surface to provide the RF signal, the first and second traces being disposed in an opposing arrangement to provide electrical isolation to reduce electrical interference between the power signal and the RF signal;

at least a first interconnect device of a first type electrically coupled to the first trace and a corresponding trace of the hermetically-sealed light engine to provide the power signal, and at least a second interconnect device of a second type electrically coupled to the second trace and a corresponding trace of the hermetically-sealed light engine to provide the RF signal, the first and second types of interconnect devices being different;

a receive optical subassembly (ROSA) module disposed in the housing.

13. The optical transceiver of claim **12**, wherein the first type of interconnect device comprises a DC bus bar disposed on the first and second surfaces of the substrate.

14. The optical transceiver of claim **12**, wherein the second type of interconnect device is a wire bonds.

15. A transmitter optical subassembly (TOSA) module comprising:

a hermetically-sealed light engine with a housing that defines a hermetic-sealed cavity and at least one laser package for emitting an associated channel wavelength disposed within the hermetic-sealed cavity;

12

a substrate defined by first and second surfaces disposed opposite each other, the substrate including an electrical coupling region for electrically coupling with a transmit connecting circuit and a light engine interface region for electrically coupling with the hermetically-sealed light engine;

a light engine driving circuit disposed on the substrate to provide a radio frequency (RF) signal and a power signal to drive the hermetically-sealed light engine to output one or more channel wavelengths;

wherein the substrate includes at least a first trace disposed on the first surface to provide the power signal and at least a second trace disposed on the second surface to provide the RF signal, the first and second traces being disposed in an opposing arrangement to provide electrical isolation to reduce electrical interference between the power signal and the RF signal; and

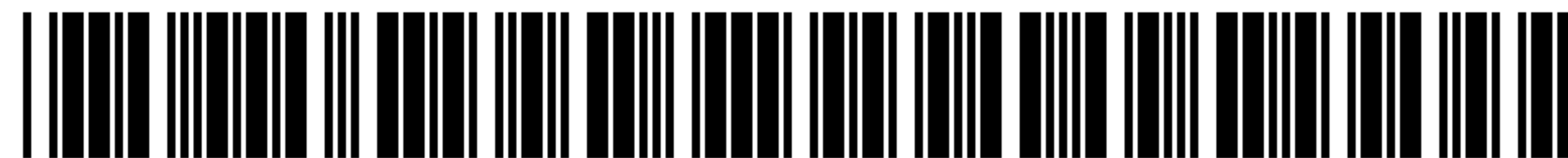
at least a first interconnect device of a first type electrically coupled to the first trace and a corresponding trace of the hermetically-sealed light engine housing to provide the power signal, and at least a second interconnect device of a second type electrically coupled to the second trace and a corresponding trace of the hermetically-sealed light engine housing to provide the RF signal, the first and second types of interconnect devices being different.

16. The TOSA module of claim **15**, wherein the first type of interconnect device is a DC bus bar interconnect.

17. The TOSA module of claim **15**, wherein the second type of interconnect device is a wire bond.

* * * * *

Exhibit F



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(12) **United States Patent**
Lin et al.

(10) **Patent No.: US 10,788,690 B2**
(45) **Date of Patent: Sep. 29, 2020**

(54) **OPTICAL ISOLATOR ARRAY FOR USE IN AN OPTICAL SUBASSEMBLY MODULE**

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(73) Assignee: **Applied Optoelectronics, Inc.**, Sugar Land, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 105 days.

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(22) Filed: **Jan. 25, 2019**

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(51) **Int. Cl.**
G02F 1/01 (2006.01)
G02F 1/09 (2006.01)

(52) **U.S. Cl.**
CPC **G02F 1/093** (2013.01)

(58) **Field of Classification Search**
CPC G02F 1/093; G02F 1/0136; G02B 5/3083; G02B 6/2746; G02B 27/283
USPC 359/484.03
See application file for complete search history.

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Primary Examiner — William R Alexander

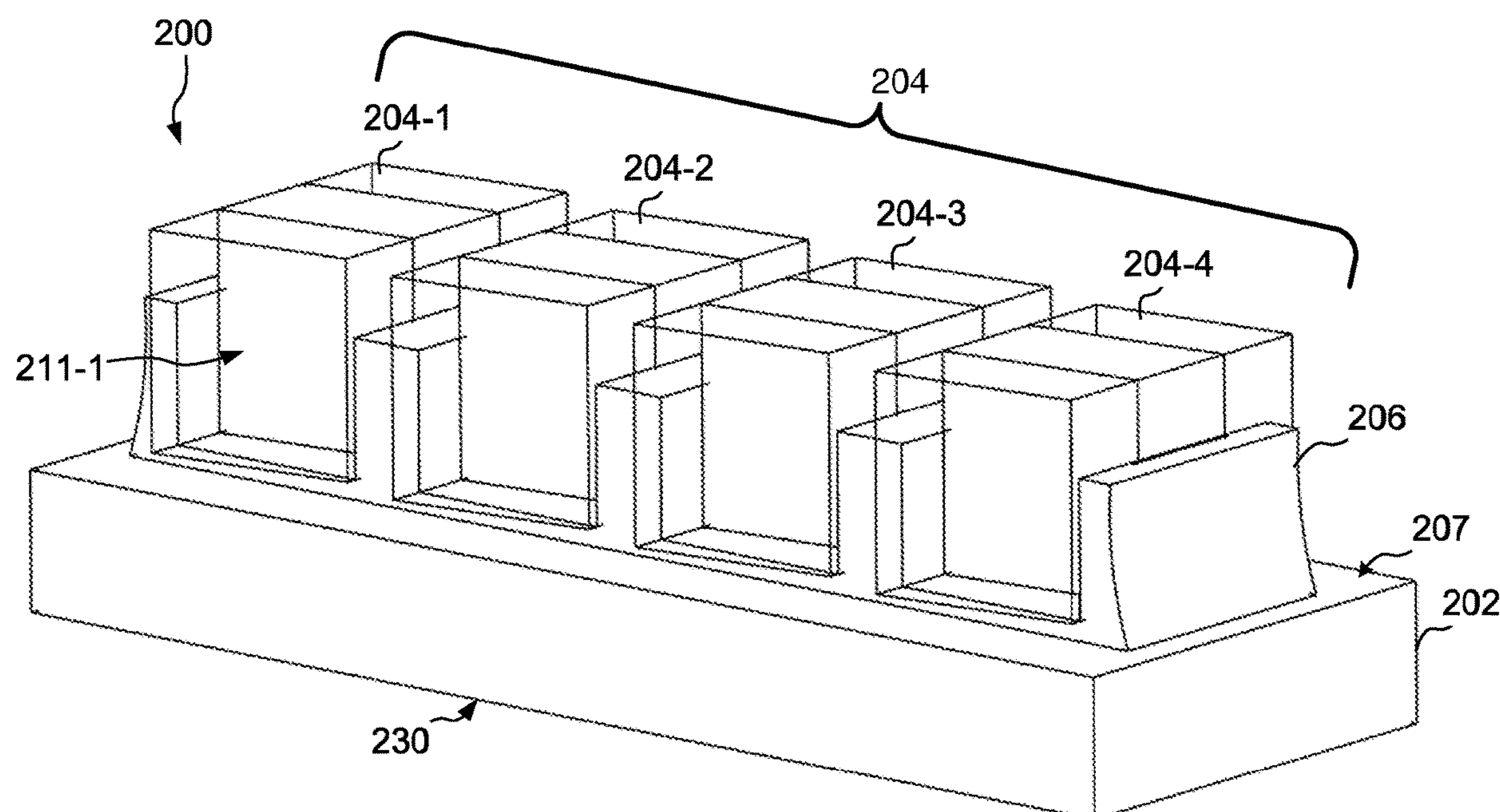
Assistant Examiner — Henry A Duong

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(57) **ABSTRACT**

This present disclosure is generally directed to an optical isolator array with a magnetic base that allows for mounting and alignment of N number of optical isolators modules within an optical subassembly module. In an embodiment, the magnetic base provides at least one mounting surface for coupling to N number of optical isolators, with N being equal to an optical channel count for the optical subassembly (e.g., 4-channels, 8-channels, and so on). The magnetic base includes an overall width that allows for a desired number of optical isolators to get mounted thereon. Each optical isolator can be uniformly disposed along the same axis on the magnetic base and at a distance D from adjacent optical isolators. An adhesive such as ultraviolet-curing (UV-curing) optical adhesives may be used to secure each optical isolator at a predefined position and increase overall structural integrity.

19 Claims, 6 Drawing Sheets



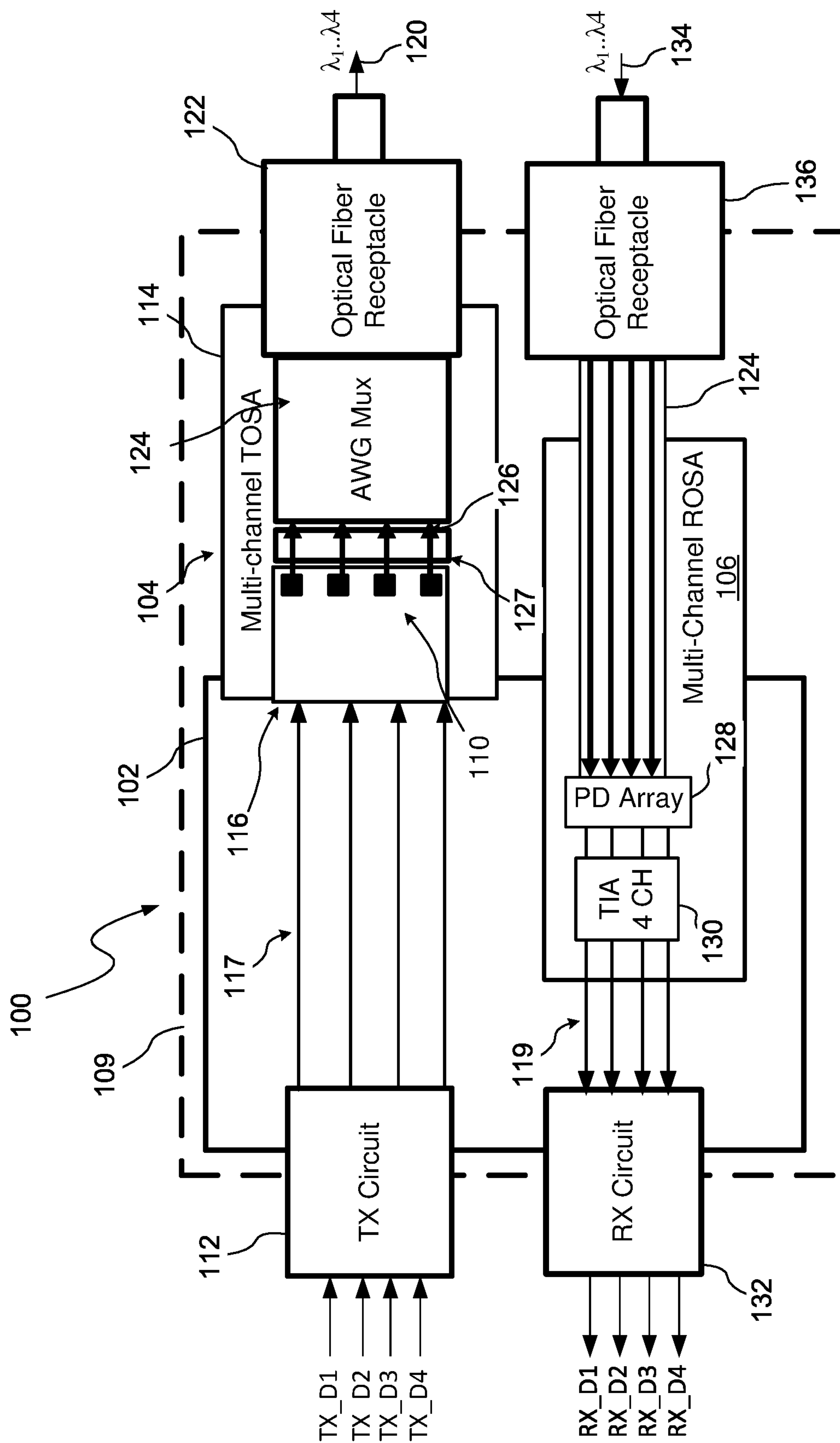


FIG. 1

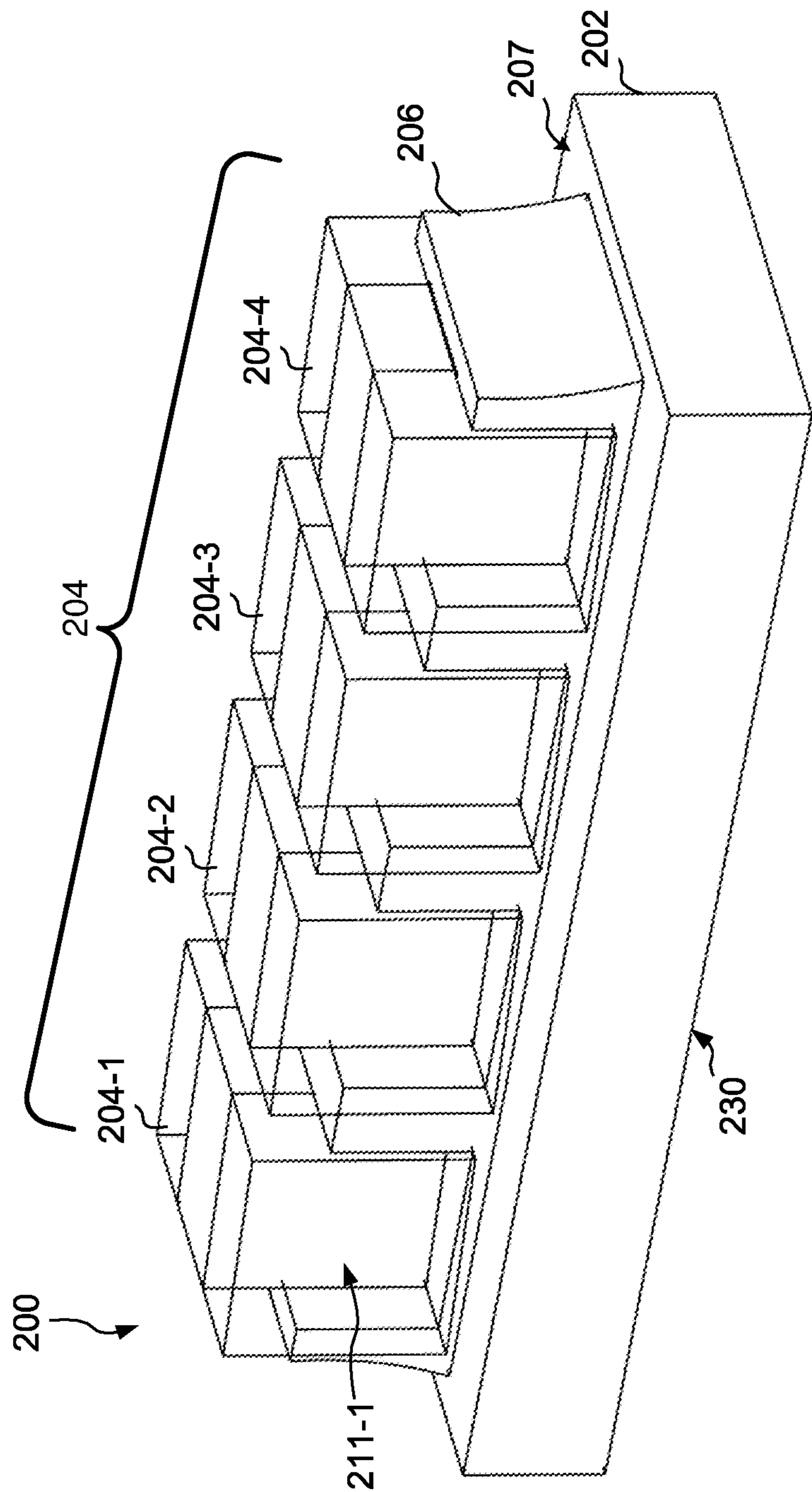


FIG. 2

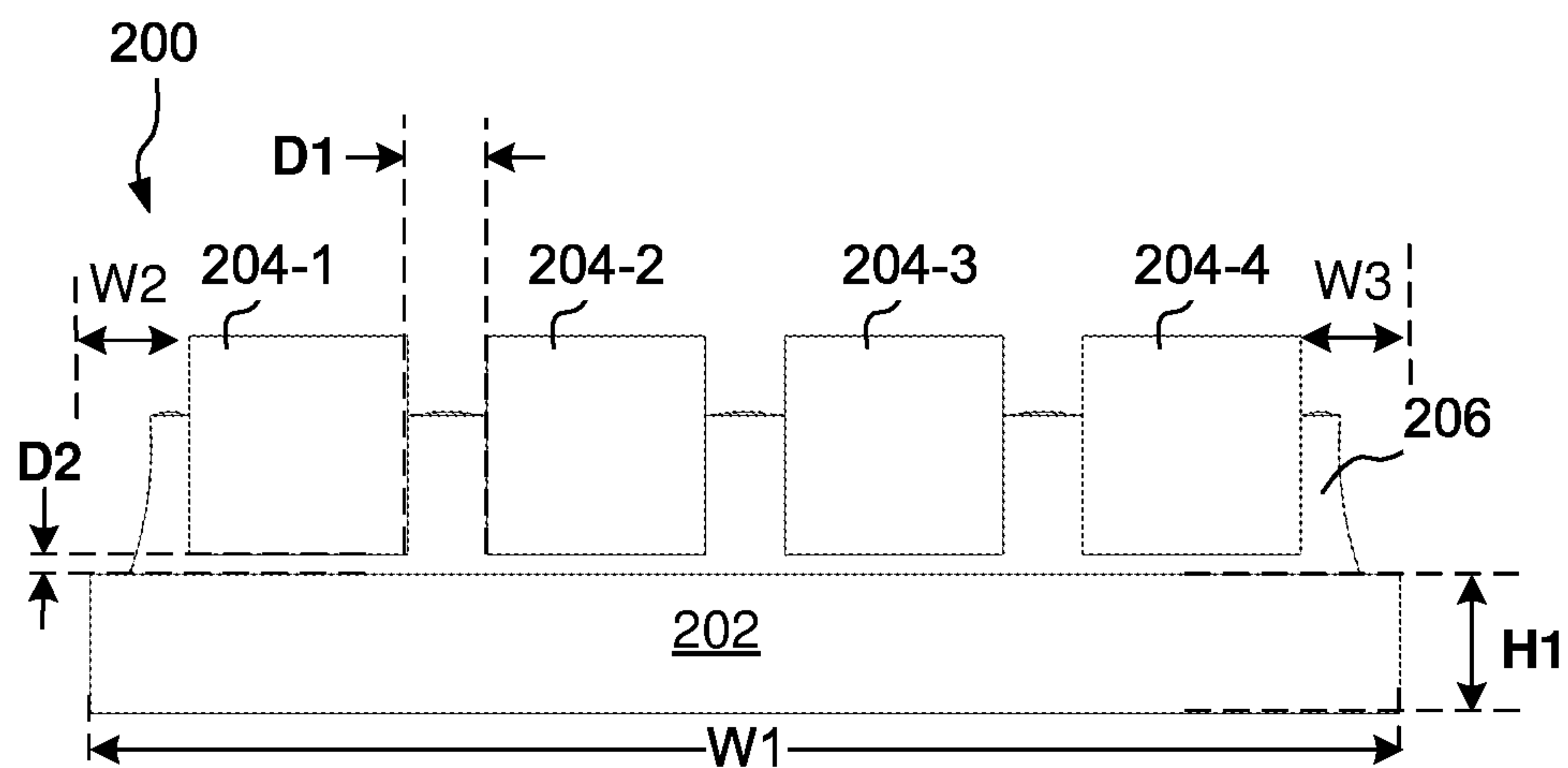


FIG. 3

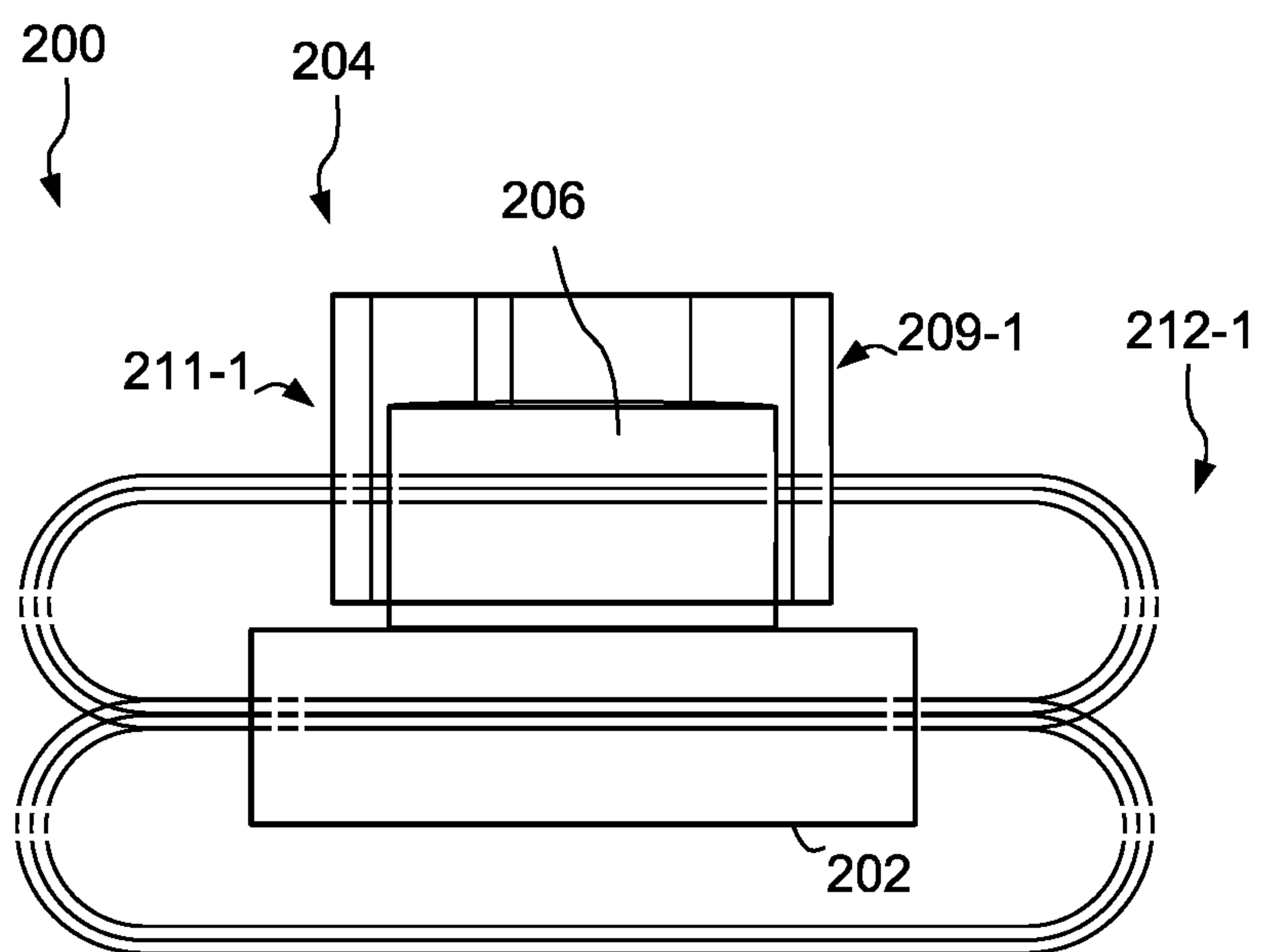


FIG. 4

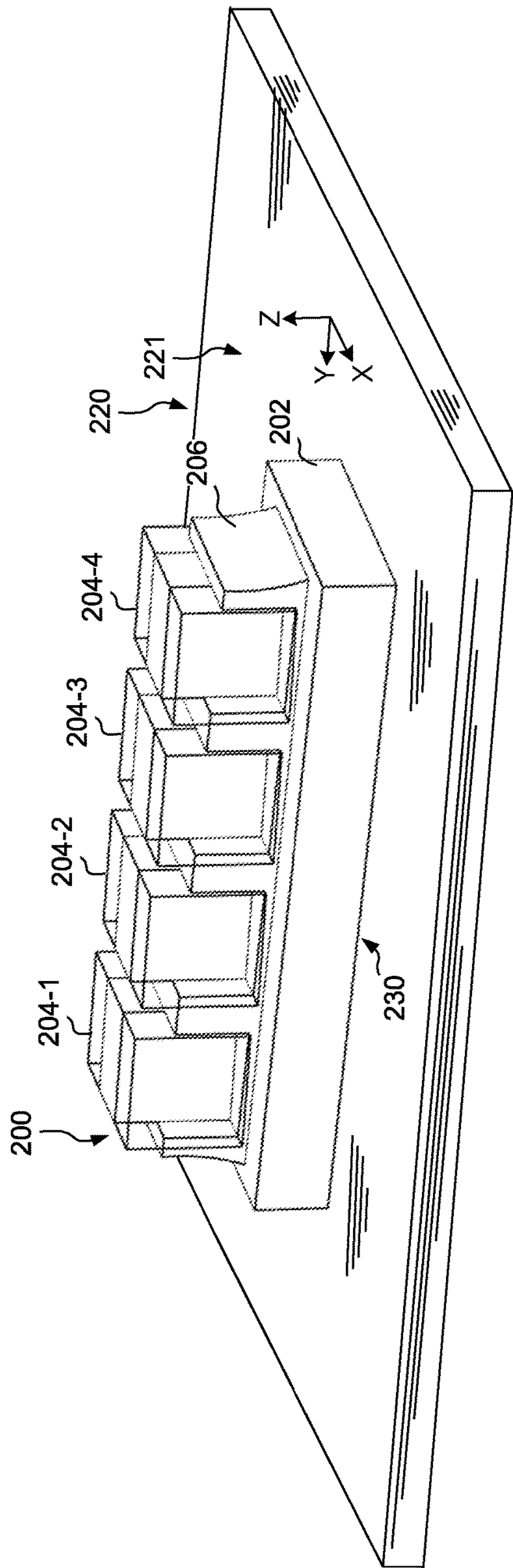


FIG. 5

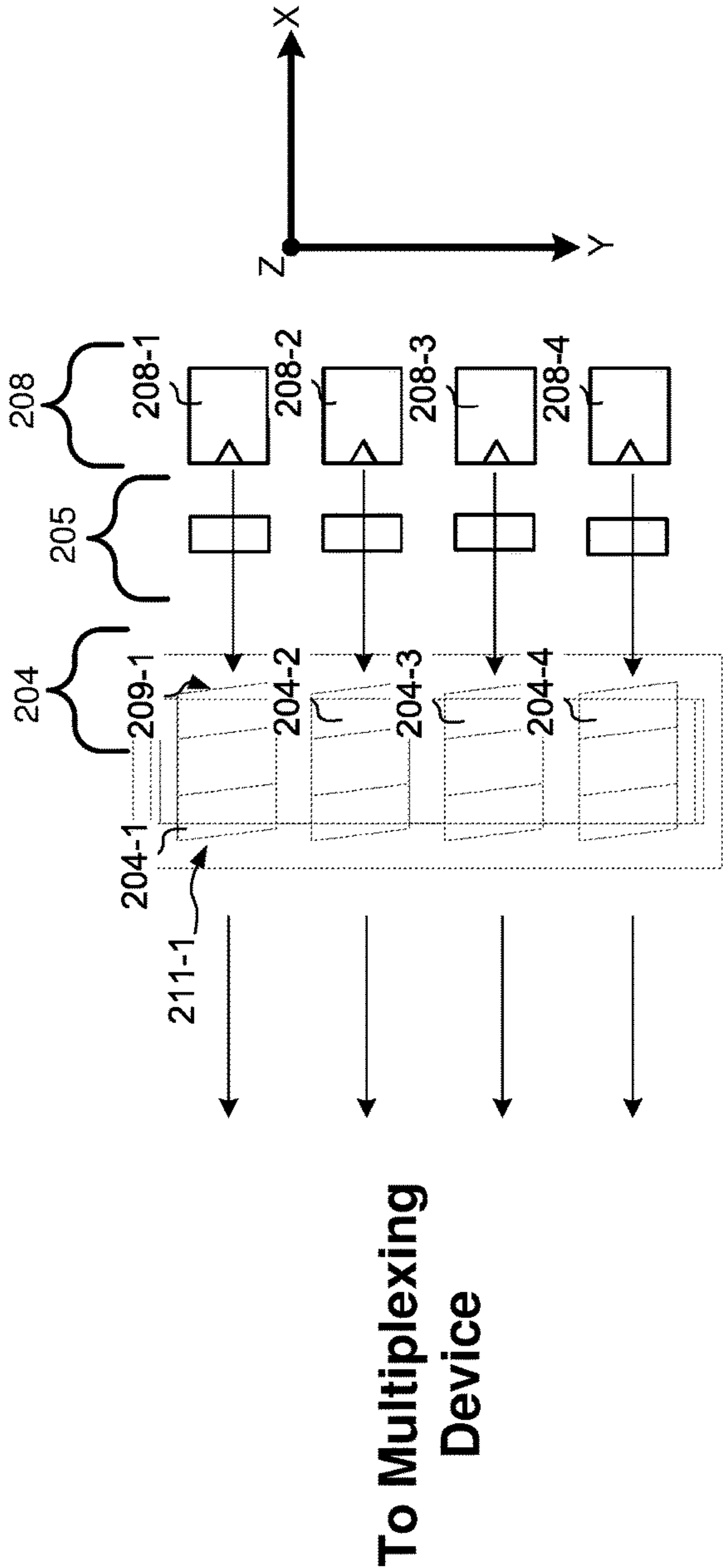


FIG. 6

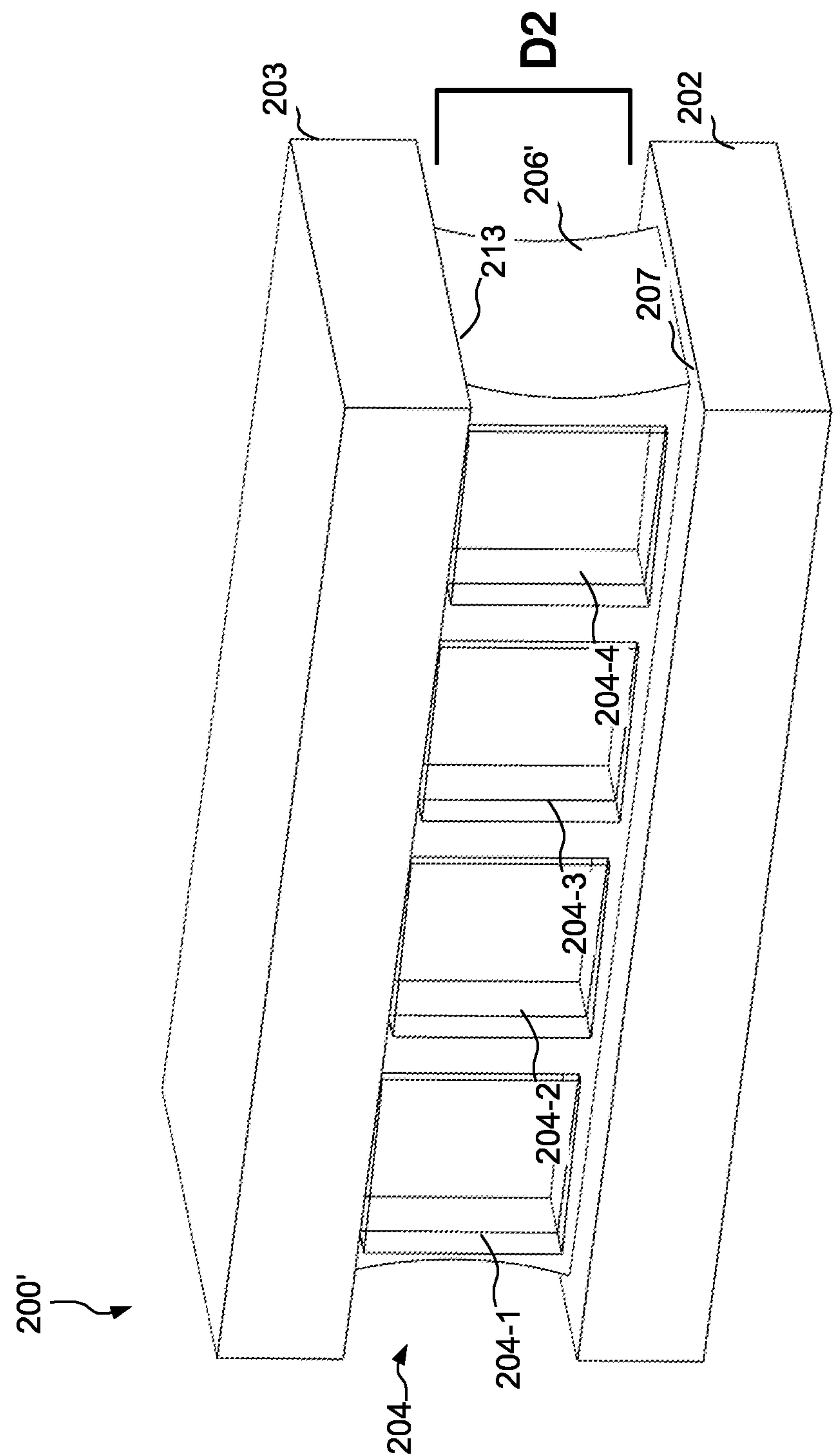


FIG. 7

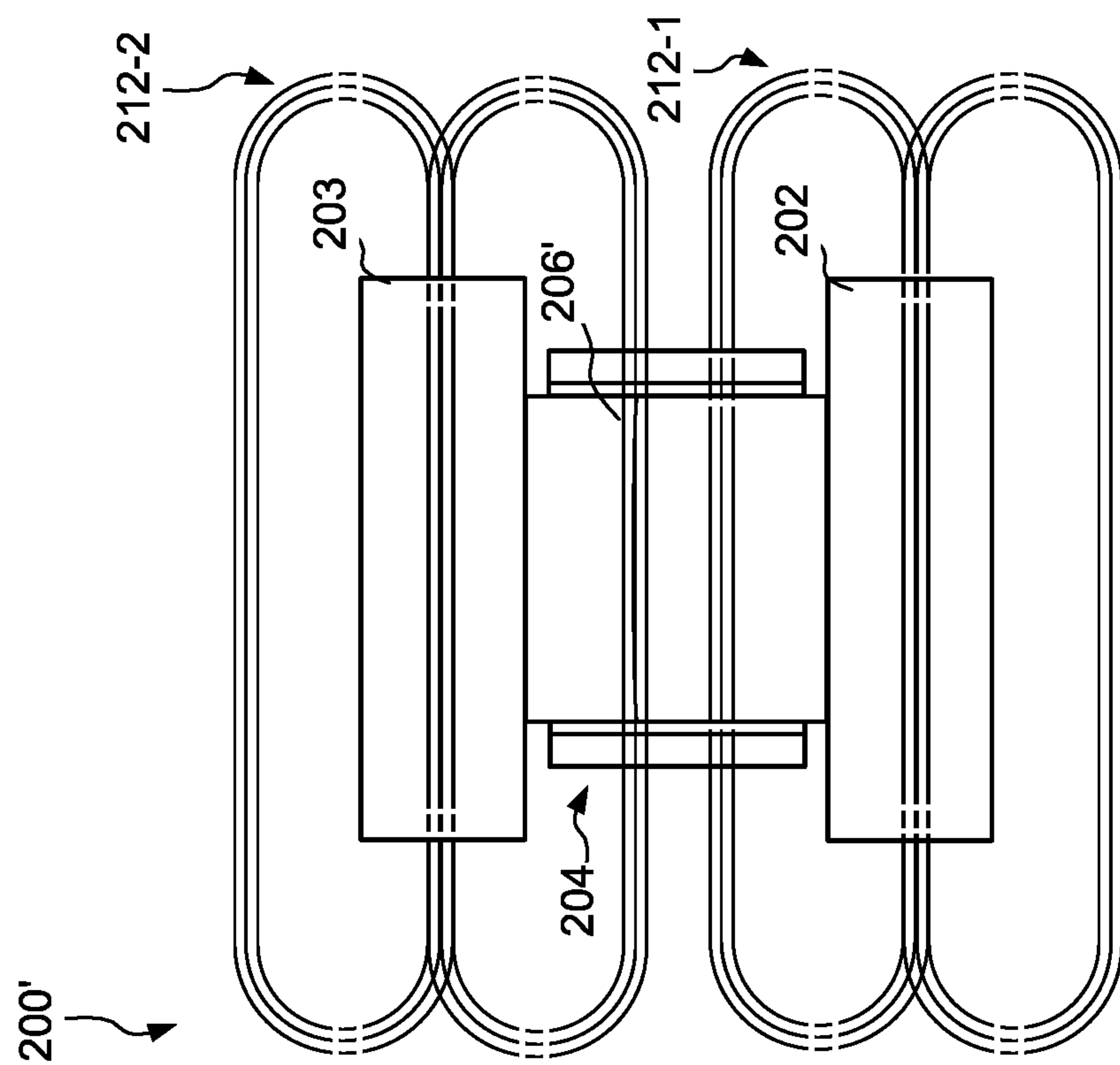


FIG. 8

1

**OPTICAL ISOLATOR ARRAY FOR USE IN
AN OPTICAL SUBASSEMBLY MODULE**

TECHNICAL FIELD

The present disclosure relates to optical communications, and more particularly, to an optical isolator array for use in a multi-channel optical subassembly module, the optical isolator array having a magnetic base with a relatively compact and modular profile that supports N number of optical isolators for use in an optical subassembly module.

BACKGROUND INFORMATION

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 transmit/receive speeds in increasingly space-constrained optical transceiver modules has presented significant challenges. Moreover, optical transceiver modules include a wide-range of package profiles with large variations in channel density and housing dimensions, for instance, that can make reusability of components difficult across multiple types of profiles, if not impossible.

For example, some approaches to transmitter optical subassemblies (TOSAs) include having a plurality of laser arrangements including, for example, a laser diode driver (LDD), laser diode, focus lens and multiplexer device, and a multiplexing device for combining channel wavelengths from each of the plurality of laser arrangements in a single housing. Each component of the TOSA must be securely attached and optically aligned with other associated optical components, which presents significant challenges for part designs (e.g., sub-mounts, lenses, mirror holders, and so on) that can be reused between package types, particularly as TOSAs continue to scale. In addition, manufacture of such TOSAs routinely require multiple test, correction, and re-test stages, which can ultimately increase per-unit manufacture time, complexity, and reduce yield.

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 shows a block diagram of a multi-channel optical transceiver in accordance with an embodiment of the present disclosure.

FIG. 2 shows a perspective view of an optical isolator array for use in the optical transceiver of FIG. 1, in accordance with an embodiment of the present disclosure.

FIG. 3 shows a front view of the optical isolator array of FIG. 2, in accordance with an embodiment of the present disclosure.

FIG. 4 shows a side view of the optical isolator array of FIG. 2, in accordance with an embodiment of the present disclosure.

FIG. 5 shows a perspective view of the optical isolator array of FIG. 2 coupled to an optical subassembly substrate, in accordance with an embodiment of the present disclosure.

FIG. 6 shows a top-down view of the optical isolator array of FIG. 2 and associated optical components, in accordance with an embodiment of the present disclosure.

2

FIG. 7 shows another example optical isolator array suitable for use in the optical transceiver of FIG. 1, in accordance with an embodiment of the present disclosure.

FIG. 8 shows a side view of the example optical isolator array of FIG. 7, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

This present disclosure is generally directed to an optical isolator array with a magnetic base (or plate) that allows for mounting and alignment of N number of optical isolator chips, referred to herein as simply optical isolators, within an optical subassembly module. In an embodiment, the magnetic base provides at least one mounting surface for supporting and coupling to N number of optical isolators, with N being equal to an optical channel count for the optical subassembly (e.g., 4-channels, 8-channels, and so on). The magnetic base includes an overall width that allows for a desired number of optical isolators to get mounted thereon. Each optical isolator can be disposed along the same axis on the magnetic base and at a uniform distance from adjacent optical isolators. The optical isolators can extend substantially parallel relative to each other when coupled to the magnetic base. Further, each optical isolator provides a light-receiving surface at a first end to receive channel wavelengths from a corresponding laser diode, and a light-emitting surface at a second end, opposite the first end, to pass the received channel wavelengths along a direction of propagation. The polarity and orientation of the magnetic base within the optical subassembly module establishes the direction of propagation through each optical isolator. The magnetic base introduces a magnetic field with a magnetic field strength sufficient to ensure nominal power along the desired direction of propagation. Accordingly, each optical isolator coupled to the magnetic base can pass channel wavelengths along the same direction. In an embodiment, this includes optical isolators passing channel wavelengths along a corresponding light path that extends parallel relative to each other. An adhesive such as ultraviolet-curing (UV-curing) optical adhesives may be used to secure each optical isolator at a predefined position on the magnetic base and provide additional structural support. Other types of adhesives and fixation approaches may be utilized and are within the scope of this disclosure.

In another embodiment of the present disclosure, an optical isolator array is disclosed that includes first and second magnetic bases or plates disposed opposite each other and a plurality of optical isolators sandwiched/disposed therebetween. The optical isolators may be coupled via, for instance, adhesive or other suitable approach to the first and second magnetic bases. The first and second magnetic bases introduce a first and second magnetic field, respectively, and can determine a direction of propagation for the optical isolators based on the same. The magnetic field strength of the first and second magnetic bases may be substantially equal, or different depending on a desired configuration. The addition of a second magnet, and by extension, a second magnetic field, results in greater isolation performance relative to that of a single magnetic field.

Continuing on, each of the first and second magnetic bases may be configured identically, and thus, either magnetic base can be utilized to couple the optical isolator array to the surface of a substrate, e.g., the sidewall of a transmitter optical subassembly (TOSA). In this embodiment, at least one layer of adhesive may extend between the first and second magnetic bases to securely hold the optical isolators

3

in a predetermined position between the first and second magnetic bases and can increase the overall structural integrity of the optical isolator array.

Numerous advantages will be apparent over other approaches that utilize discrete/separate optical isolators coupled to a substrate. For example, an optical isolator array consistent with the present disclosure can be easily be shortened or lengthened to accommodate different optical subassembly housing/packaging requirements and/or when less or more optical channels are desired. The total number of optical isolators may vary according to desired channel counts, and such modifications are achievable without substantial redesign of the optical isolator array. Alternatively, or in addition, the distance/pitch between adjacent optical isolator chips may be varied to accommodate a wide-range of package designs.

In addition, an optical isolator array consistent with the present disclosure may be separately manufactured and optionally tested apart from other optical subassembly components, and then subsequently coupled into an associated housing, e.g., a TOSA housing, as a single unit. This advantageously ensures that each of the optical isolators are optically aligned with associated active and/or passive optical components, e.g., multiplexers, laser diodes, and so on, by virtue of the optical isolator array being coupled to the optical subassembly at a predefined position. The orientation of each optical isolator can be uniformly adjusted in tandem at a fine-grain level (e.g., by less than 10 microns) by simply shifting the physical position of the magnetic base relative to associated optical components, thus minimizing or otherwise reducing the overall number adjustments to achieve nominal power. This can significantly reduce manufacturing complexity, error, and the number of fix-and-repeat testing iterations that normally characterizes optical subassembly manufacturing.

While the present disclosure includes examples and scenarios directed specifically to optical isolator arrays being used in a transmitter optical subassembly (TOSA) arrangement, this disclosure is not limited in this regard. For example, an optical isolator consistent with the present disclosure may be utilized to align and mount optical isolators in receiver optical subassembly (ROSA) arrangements.

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. This disclosure is equally applicable to coarse wavelength division multiplexing (CWDM). In one specific example embodiment, the channel wavelengths are implemented in accordance with local area network (LAN) wavelength division multiplexing (WDM), which may also be referred to as LWDM.

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. On the other hand, the term “direct optical coupling” refers to an optical coupling via an optical path between two elements that does not include such intermediate components or devices, e.g., a mirror, waveguide, and so on, or bends/turns along the optical path between two elements.

4

The term substantially, as generally referred to herein, refers to a degree of precision within acceptable tolerance that accounts for and reflects minor real-world variation due to material composition, material defects, and/or limitations/peculiarities in manufacturing processes. Such variation may therefore be said to achieve largely, but not necessarily wholly, the stated/nominal characteristic. To provide one non-limiting numerical example to quantify “substantially,” such a modifier is intended to include minor variation that can cause a deviation of up to and including $\pm 5\%$ from a particular stated quality/characteristic unless otherwise provided by the present disclosure.

Referring to the Figures, FIG. 1, an optical transceiver **100**, consistent with embodiments of the present disclosure, is shown and described. In this embodiment, the optical transceiver **100** includes a multi-channel transmitter optical subassembly (TOSA) arrangement **104** and a multi-channel receiver optical subassembly (ROSA) arrangement **106** coupled to a substrate **102**, which may also be referred to as an optical module substrate. The substrate **102** may comprise, for example, a printed circuit board (PCB) or PCB assembly (PCBA). The substrate **102** may be configured to be “pluggable” for insertion into an optical transceiver cage **109**.

In the embodiment shown, the optical transceiver **100** transmits and receives four (4) channels using four different channel wavelengths ($\lambda_1, \lambda_2, \lambda_3, \lambda_4$) via the multi-channel TOSA arrangement **104** and the multi-channel ROSA arrangement **106**, respectively, and may be capable of transmission rates of at least about 25 Gbps per channel. In one example, the channel wavelengths $\lambda_1, \lambda_2, \lambda_3, \lambda_4$ may be 1270 nm, 1290 nm, 1310 nm, and 1330 nm, respectively. Other channel wavelengths are within the scope of this disclosure including those associated with local area network (LAN) wavelength division multiplexing (WDM). The optical transceiver **100** may also be capable of transmission distances of 2 km to at least about 10 km. The optical transceiver **100** may be used, for example, in Internet data center applications or fiber to the home (FTTH) applications. Although the following examples and embodiments show and describe a 4-channel optical transceiver, this disclosure is not limited in this regard. For example, the present disclosure is equally applicable to 2, 6, or 8-channel configurations.

In more detail, the multi-channel TOSA arrangement **104** includes a TOSA housing **114** with a plurality of sidewalls that define a cavity (not shown). The cavity includes a plurality of laser arrangements **110**, an optical isolator array **127**, and a multiplexing device **124** disposed therein. The optical isolator array **127** may be implemented as the optical isolator array **200** of FIGS. 2-6 or the optical isolator array **200'** of FIGS. 7-8, which will be discussed in greater detail below. In any event, each laser arrangement of the plurality of laser arrangements **110** can be configured to transmit optical signals having different associated channel wavelengths. Each laser arrangement may include passive and/or active optical components such as a laser diode (LD), monitor photodiode (MPD), laser diode driver (LDD), and so on. Additional components comprising each laser arrangement include filters, optical isolators, filtering capacitors, and so on.

To drive the plurality of laser arrangements **110**, the optical transceiver **100** includes a transmit connecting circuit **112** to provide electrical connections to the plurality of laser arrangements **110** within the housing **114**. The transmit connecting circuit **112** may be configured to receive driving signals (e.g., TX_D1 to TX_D4) from, for example, circuitry

US 10,788,690 B2

5

within the optical transceiver cage **109**. The housing **114** may be optionally hermetically sealed to prevent ingress of foreign material, e.g., dust and debris. Therefore, a plurality of transmit (TX) traces **117** (or electrically conductive paths) may be patterned on at least one surface of the substrate **102** and are electrically coupled with a feedthrough device **116** of the TOSA housing **114** to bring the transmit connecting circuit **112** into electrical communication with the plurality of laser arrangements **110**, and thus, electrically interconnect the transmit connecting circuit **112** with the multi-channel TOSA arrangement **104**. The feedthrough device **116** may comprise, for instance, ceramic, metal, or any other suitable material.

In operation, the multi-channel TOSA arrangement **104** may then receive driving signals (e.g., TX_D1 to TX_D4), and in response thereto, generates and launches multiplexed channel wavelengths on to an output waveguide **120** such as a transmit optical fiber. The generated multiplexed channel wavelengths may be combined based on a demultiplexing device **124** such as an arrayed waveguide grating (AWG) that is configured to receive emitted channel wavelengths **126** from the plurality of laser assemblies **110** and output a signal carrying the multiplexed channel wavelengths on to the output waveguide **120** by way of optical fiber receptacle **122**.

Continuing on, the multi-channel ROSA arrangement **106** includes a demultiplexing device **124**, e.g., an arrayed waveguide grating (AWG), a photodiode (PD) array **128**, and an amplification circuitry **130**, e.g., a transimpedance amplifier (TIA). An input port of the demultiplexing device **124** may be optically coupled with a receive waveguide **134**, e.g., an optical fiber, by way of an optical fiber receptacle **136**. An output port of the demultiplexing device **124** may be configured to output separated channel wavelengths on to the PD array **128**. The PD array **128** may then output proportional electrical signals to the TIA **130**, which then may be amplified and otherwise conditioned. The PD array **128** and the transimpedance amplifier **130** detect and convert optical signals received from the fiber array **133** into electrical data signals (RX_D1 to RX_D4) that are output via the receive connecting circuit **132**. In operation, the PD array **128** may then output electrical signals carrying a representation of the received channel wavelengths to a receive connecting circuit **132** by way of conductive traces **119** (which may be referred to as conductive paths).

Referring to FIGS. 2-6, an example optical isolator array **200** is shown consistent with an embodiment of the present disclosure. As shown, the optical isolator array **200** includes a magnetic base **202** (or magnetic plate) and a plurality of optical isolators shown collectively as **204** and individually as **204-1** to **204-4**. The magnetic base **202** may be formed from a metal or metal alloy such as iron, nickel, cobalt, or any combination thereof. In an embodiment the magnetic base **202** may be configured as a permanent magnet device, although other types of magnets are within the scope of this disclosure as such electromagnet devices.

A plurality of sidewalls define the magnetic base **202** and provide at least a first mounting surface **207**. The first mounting surface **207** can be substantially planar, as shown, although in other embodiments the first mounting surface **207** may not necessarily be flat. The first mounting surface **207** supports the plurality of optical isolators **204**. The overall width **W1** (See FIG. 3) of the magnetic base **202** may be a function of the desired number of optical isolators. For instance, in the embodiment shown in FIG. 3 the overall width **W1** may measure about 100 microns with each of the plurality of optical isolators **204** having a corresponding

6

with of about 20 microns. In this example, 100 microns may be chosen for the overall width **W1** to allow for a portion of the overall width **W1**, namely widths **W2** and **W3**, to provide adhesive overflow regions, with **W2** and **W3** each measuring equally at about 10 microns. This advantageously provides sufficient mounting space for the four optical isolators as well as surface area to allow each end of the at least one layer of adhesive **206** to flow and cure without overflowing beyond the sides of the magnetic base **202**. Thus, the following equation may be used to determine the overall width **W1** of the magnetic base **202**:

$$W1 = N * Wn + Wn \quad \text{Equation (1)}$$

with **W1** being the overall length, **N** being the desired number of optical isolators, and **Wn** being the width of an optical isolator.

On the other hand, the overall height **H1** of the magnetic base **202** may be chosen to ensure, for instance, that each optical isolator of the plurality of optical isolators **204** is aligned vertically with an associated laser arrangement along a **Z** axis, which will be discussed in greater detail below with regard to FIG. 7.

Each of the plurality of optical isolators **204** can comprise polarization-insensitive Faraday Isolators that include multiple segments/portions including a rotator portion sandwiched/disposed between first and second polarization sections. The first and second polarization sections polarizers can comprise birefringent wedges, e.g. made of rutile (TiO2). This configuration is particularly well suited for space constrained housing. Each of the plurality of optical isolators **204** may include segments formed from different materials to target desired channel wavelengths.

The plurality of optical isolators may be secured at a predefined position on the first mounting surface **207** via at least one layer of adhesive **206**. As shown, the at least one layer of adhesive **206** may be disposed in a manner that at least partially surrounds each optical isolator of the plurality of optical isolators **204**. The at least one layer of adhesive **206** may flow during a depositing process along a direction that is substantially transverse relative to the first mounting surface **207** based on capillary action caused by proximity of each of the plurality of optical isolators **204**, or may simply cure as shown based on being disposed between each optical isolator of the plurality of optical isolators **204**. In either case, the at least one layer of adhesive **206** can be used as, in a general sense, a submount to hold and/or support each of the plurality of optical isolators at a predefined position relative to the magnetic base **202**.

To this end, a method for forming the optical isolator array **200** may include first disposing the at least one layer of adhesive **206** on to the mounting surface **207** of the base followed by disposing each of the plurality of optical isolators **204** at their predefined positions. Notably, the use of adhesives to hold each optical isolator **204-1** to **204-4** in place advantageously allows for relatively simple, fine-grain adjustments to the pitch/distance between optical isolators. As further shown in FIG. 3, each of the plurality of optical isolators **204** may be disposed at predefined positions that include a uniform distance of **D1** between adjacent optical isolators. The at least one layer of adhesive **206** may vertically displace each of the plurality of optical isolators **204** by a distance **D2**. Distance **D2** may be uniform across the plurality of optical isolators **204**, although variations may be introduced by design and/or by function of how the at least one layer of adhesive **206** cures. Each of the optical isolators may be further disposed parallel with each other in a linear array.

With specific reference to FIG. 4, the magnetic base **202** introduces a first magnetic field **212-1**. As shown, the flux lines of the first magnetic field **212-1** intersect with each of the optical isolators in the plurality of optical isolators **204** mounted to the magnetic base **202**. In operation, the polarity of the first magnetic field **212-2** therefore determines the direction of propagation for light which is incident to the plurality of optical isolators **204**.

Turning to FIG. 5, the optical isolator array **200** is shown mounted to a substrate **220**. In particular, the magnetic base **202** of the optical isolator array **200** is coupled to the mounting surface **221** provided by the substrate **220** by way of a substrate mating surface **230**. The substrate mating surface **230** may be substantially planar and correspond with the mounting surface **221** of a substrate **220**.

The substrate **220** may comprise, for example, a printed circuit board (PCB), a sidewall of a housing (e.g., made of metal or other suitably rigid material) or any other suitable material. The optical isolator array **200** may be at least partially assembled separately from other components in an optical subassembly and later coupled during manufacturing processes as effectively, a single piece. Accordingly, each of the plurality of optical isolators **204** may be disposed at a predetermined orientation and position on the magnetic base **202** to ensure that each will be aligned within nominal tolerances along and X and Y axis. Optical alignment of the optical isolator array **200**, and more particularly each of the optical isolators mounted thereon, with associated passive and/or active optical components, e.g., a laser diode, may therefore be achieved by simply coupling the optical isolator **200** at a predefined location on the mounting surface **221** of the substrate **220**. The overall height **H1** (See FIG. 3) may then displace the plurality of optical isolators **200** along the Z axis such that each optical isolator is optically aligned within nominal tolerances of associated active and/or passive components.

For example, and as shown in the highly simplified embodiment of FIG. 6, each of the optical isolators **204-1** to **204-4** may be optically aligned with a corresponding collimating lens of a plurality of collimating lenses **205** and corresponding laser diode **208-1** to **208-4** of the plurality of laser diodes **208** based at least in part on the dimensions of the magnetic base **202**. This advantageously allows for the mounting surface **221** of the substrate **220** to act as a stop for the substrate mating surface **230** and provide a positive indication that each of the optical isolators is at a desired position along the Z axis simply by having the substrate mating surface **230** of the magnetic base **202** flush with the mounting surface **221** of the substrate **220**. Likewise, alignment for each of the plurality of optical isolators **204** along the X and Y axis requires simply ensuring the magnetic base **202** is positioned at a predetermined X and Y position relative to the associated optical components.

Each of the laser diodes **208-1** to **208-4** may be configured to emit a different channel wavelength. Following the laser diodes **208**, each of the optical isolators **204-1** to **204-4** include a light-receiving surface (e.g., light-receiving surface **209-1**) for receiving channel wavelengths from a corresponding laser diode of the laser diodes **208-1** to **208-4**, and a light-emitting surface (e.g., light-emitting surface **211-1**) disposed opposite the light-receiving surface for passing the received channel wavelengths to the multiplexing device, e.g., the multiplexing device **124** (FIG. 1). Each light-receiving and light-emitting surface may be angled, e.g., at about 8 degrees, relative to a corresponding light path, such as shown.

Thus, after coupling of the optical isolator array **200** on the substrate **220**, an optical path may then extend from each an emission surface of each of the laser diodes **208-1** to **208-4**, through an associated collimating lens of the plurality of collimating lenses **205** and then through the an associated optical isolator of the plurality of optical isolators **204**. Each of the light paths may extend substantially parallel to each other, although other embodiments are within the scope of this disclosure.

FIG. 7 shows another example optical isolator array **200'** in accordance with an embodiment of the present disclosure. As shown, the optical isolator array **200'** is substantially similar to the optical isolator array **200** discussed above with regard to FIGS. 2-6, the description of which is equally applicable to the embodiment of FIG. 7 but will not be repeated for brevity. However, the example optical isolator array **200'** includes a second magnetic base **203**. The second magnetic base **203** may be disposed on an upper surface of the optical isolators **204-1** to **204-4**, or alternatively supported by the at least one layer of adhesive **206'** disposed between the optical isolators **204** and the second magnetic base **203**.

Therefore, the plurality optical isolators **204** and the at least one layer of adhesive **206'** can be sandwiched/disposed between the first and second magnetic bases **202**, **203**. The first and second magnetic bases may extend substantially parallel relative to each other and may have identical dimensions, although other embodiments are within the scope of this disclosure. As shown, the at least one layer of adhesive **206'** may extend a distance **D2** from the mounting surface **207** of the first magnetic base **202** up to a mounting surface **213** of the second magnetic base **203**. To this end, the at least one layer of adhesive **206'** securely attaches the first and second magnetic bases **202**, **203** to each other, and more importantly, securely fixes the optical isolators **204-1** to **204-4** therebetween.

As shown in FIG. 8, the first and second magnetic base **202**, **203** introduce first and second magnetic fields **212-1**, **212-2**, respectively. The first and second magnetic fields **212-1**, **212-2** may at least partially overlap, or not, depending on a desired configuration. In either case, the polarity of the first and second magnetic fields **212-1**, **212-2** may be utilized to establish a direction of propagation for wavelengths incident to the plurality of optical isolators **204**.

In accordance with an aspect of the present disclosure an optical isolator array for use in an optical subassembly module is disclosed. The optical isolator array comprising a first magnetic base defining at least one mounting surface, a plurality of optical isolators mounted to the at least one mounting surface, each of the plurality of optical isolators disposed substantially in parallel relative to each other, and at least one layer of adhesive disposed on the at least one mounting surface to couple the plurality of optical isolators to the first magnetic base and to hold each optical isolator of the plurality of optical isolators at a predefined position relative to each other.

In accordance with another aspect of the present disclosure an optical transceiver is disclosed. The optical transceiver comprising a transceiver housing, at least one optical transmitter subassembly (TOSA) arrangement disposed in the transceiver housing, the at least one TOSA arrangement comprising a substrate defined by at least one mounting surface, a plurality of laser diodes mounted to the at least one mounting surface of the substrate, each laser diode of the plurality of laser diodes to emit a different associated channel wavelength along a corresponding light path of a plurality of light paths, and an optical isolator array mounted to

US 10,788,690 B2

9

the at least one mounting surface adjacent the plurality of laser diodes such that the plurality of light paths intersect with the optical isolator array, the optical isolator array comprising a at least a first magnetic base and a plurality of optical isolators coupled thereto, and wherein each optical isolator is optically aligned with a corresponding laser diode of the plurality of laser diodes via a corresponding light path, an optical receiver subassembly (ROSA) disposed in the transceiver housing.

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.

What is claimed is:

1. An optical isolator array for use in an optical subassembly module, the optical isolator array comprising:

a first magnetic base defining at least one mounting surface;

a plurality of optical isolators mounted to the at least one mounting surface, each of the plurality of optical isolators disposed substantially in parallel relative to each other; and

at least one layer of adhesive disposed on the at least one mounting surface to couple the plurality of optical isolators to the first magnetic base and to hold each optical isolator of the plurality of optical isolators at a predefined position relative to each other.

2. The optical isolator array of claim 1, wherein the magnetic base is formed from a permanent magnet.

3. The optical isolator array of claim 1, wherein the magnetic base introduces a first magnetic field that intersects with the plurality of optical isolators to establish a direction of propagation.

4. The optical isolator array of claim 1, wherein each optical isolator of the plurality of optical isolators comprises a Faraday Isolator.

5. The optical isolator array of claim 1, wherein each optical isolator of the plurality of optical isolators includes an angled light-receiving surface to receive channel wavelengths from an associated laser diode.

6. The optical isolator array of claim 1, wherein the plurality of optical isolators is disposed uniformly across the at least one mounting surface.

7. The optical isolator array of claim 1, wherein the at least one layer of adhesive is disposed between adjacent optical isolators of the plurality of optical isolators.

8. The optical isolator array of claim 1, wherein the magnetic base includes a substrate mating surface, and whereby the substrate mating surface is substantially flat to correspond with a mounting surface of a substrate and to mount thereto.

9. The optical isolator array of claim 1, further comprising a second magnetic base, the second magnetic base being coupled to the plurality of optical isolators via the at least one layer of adhesive.

10

10. The optical isolator array of claim 9, wherein the second magnetic base introduces a second magnetic field, the second magnetic field intersecting with the plurality of optical isolators.

11. An optical transceiver, the optical transceiver comprising:

a transceiver housing;

at least one optical transmitter subassembly (TOSA) arrangement disposed in the transceiver housing, the at least one TOSA arrangement comprising:

a substrate defined by at least one mounting surface;

a plurality of laser diodes mounted to the at least one mounting surface of the substrate, each laser diode of the plurality of laser diodes to emit a different associated channel wavelength along a corresponding light path of a plurality of light paths; and

an optical isolator array mounted to the at least one mounting surface adjacent the plurality of laser diodes such that the plurality of light paths intersect with the optical isolator array, the optical isolator array comprising a at least a first magnetic base and a plurality of optical isolators coupled thereto, and wherein each optical isolator is optically aligned with a corresponding laser diode of the plurality of laser diodes via a corresponding light path;

an optical receiver subassembly (ROSA) disposed in the transceiver housing.

12. The optical transceiver of claim 11, wherein the first magnetic base of the optical isolator array is formed from a permanent magnet.

13. The optical transceiver of claim 11, wherein the first magnetic base introduces a first magnetic field that intersects with the plurality of optical isolators to establish a direction of propagation.

14. The optical transceiver of claim 11, wherein each optical isolator of the plurality of optical isolators includes an angled light-receiving surface to receive channel wavelengths from a corresponding laser diode of the plurality of laser diodes.

15. The optical transceiver of claim 11, wherein the plurality of optical isolators is disposed uniformly across the at least one mounting surface.

16. The optical transceiver of claim 11, wherein at least one layer of adhesive is disposed between adjacent optical isolators of the plurality of optical isolators.

17. The optical transceiver of claim 11, wherein the first magnetic base includes a substrate mating surface, and whereby the substrate mating surface is substantially flat to correspond with the mounting surface of a substrate to mount thereto.

18. The optical transceiver of claim 11, further comprising a second magnetic base, the second magnetic base being coupled to the plurality of optical isolators and the first magnetic base via at least one layer of adhesive.

19. The optical transceiver of claim 18, wherein the second magnetic base introduces a second magnetic field, the second magnetic field intersecting with the plurality of optical isolators.

* * * * *

Exhibit G

Exhibit G - Representative Claim Chart for U.S. Patent No. 9,523,826

ATI 100G QSFP LR4

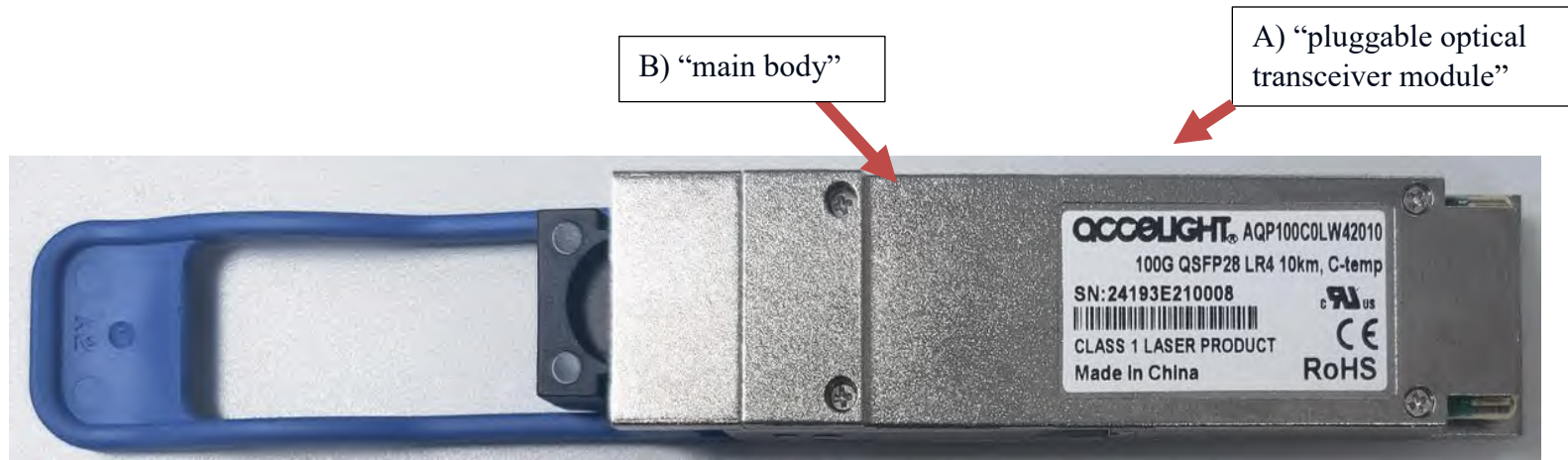


FIG. 1

Exhibit G - Representative Claim Chart for U.S. Patent No. 9,523,826

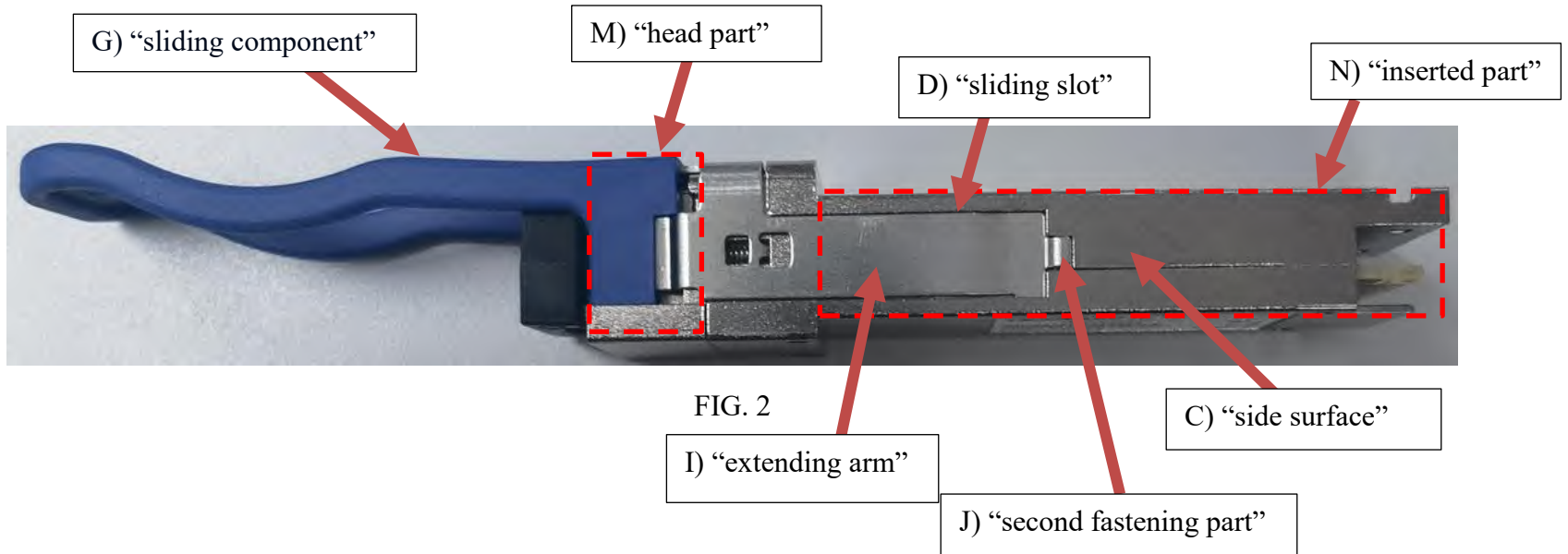


Exhibit G - Representative Claim Chart for U.S. Patent No. 9,523,826

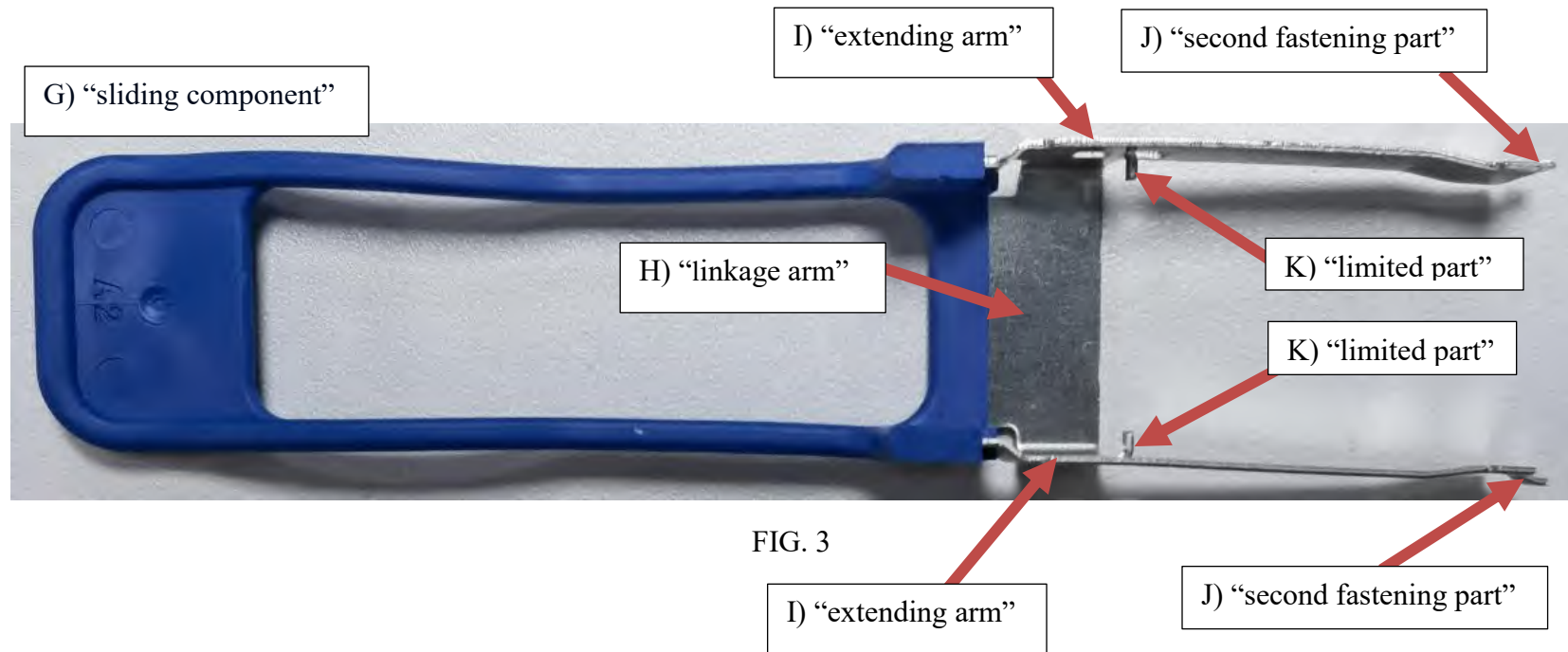


Exhibit G - Representative Claim Chart for U.S. Patent No. 9,523,826

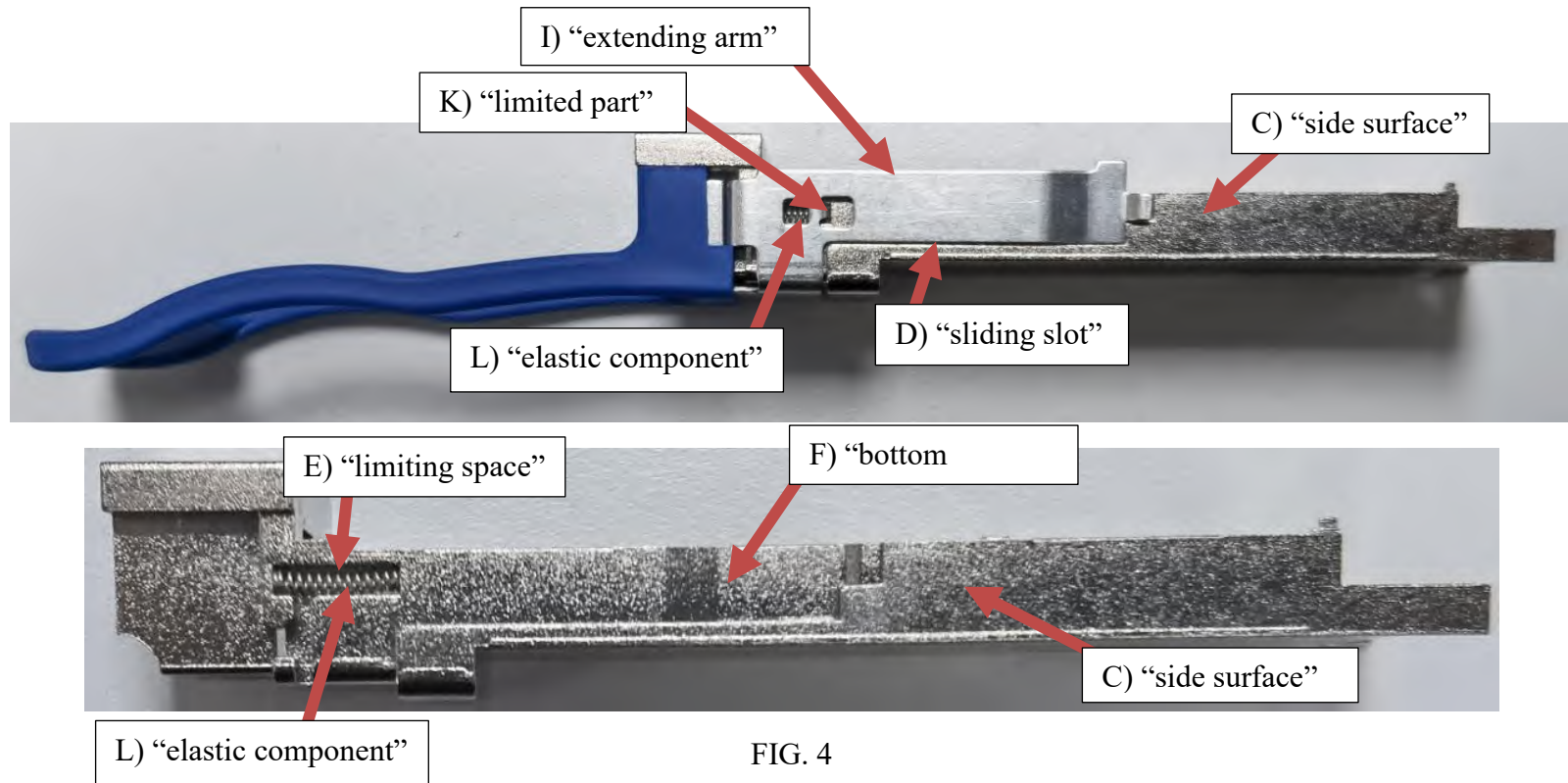


Exhibit G - Representative Claim Chart for U.S. Patent No. 9,523,826

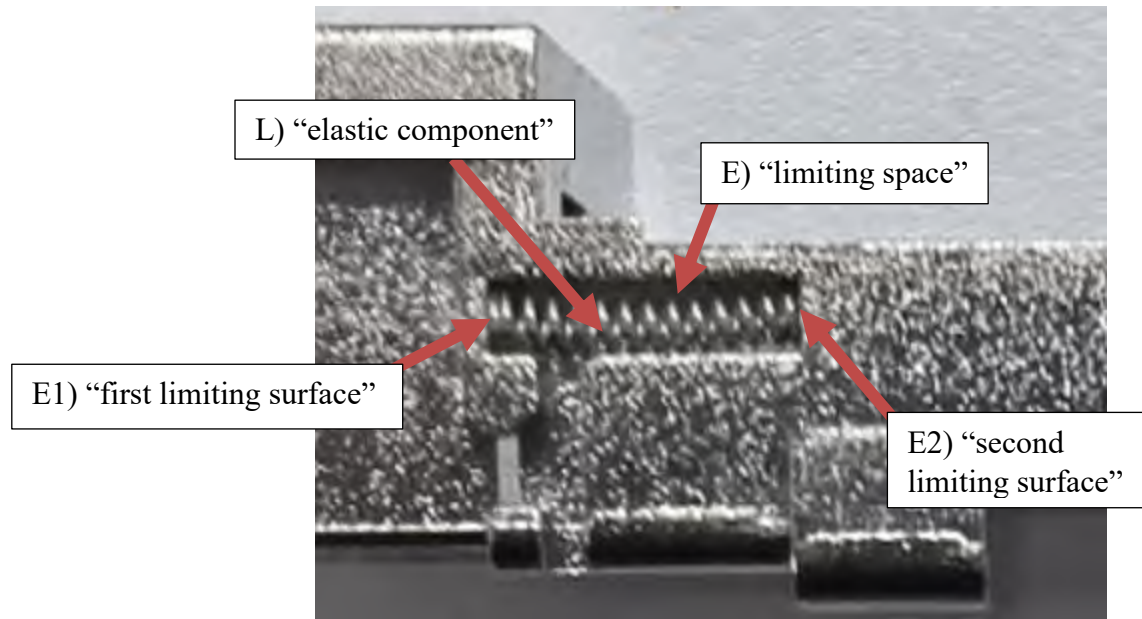


FIG. 5

Exhibit G - Representative Claim Chart for U.S. Patent No. 9,523,826**U.S. Patent No. 9,523,826**

U.S. Patent No. 9,523,826 Claim 1	ATI 100G QSFP LR4
A pluggable optical transceiver module, for being inserted into a plugging slot of a socket, the socket comprising two first fastening parts located in the plugging slot, the pluggable optical transceiver module comprising:	A pluggable optical transceiver module (A) for being inserted into a plugging slot of a socket. See FIGS. 1–5.
a main body having two side surfaces that are opposite to each other and	A main body (B) has two side surfaces (C) that are opposite to each other. See FIGS. 1, 2 and 4.
two sliding slots located at the two side surfaces, respectively,	Two sliding slots (D) are located at the two side surfaces (C), respectively. See FIG. 2 and FIG. 4.
wherein the main body is configured to be inserted into the plugging slot,	On information and belief, the main body (B) is configured to be inserted into a plugging slot. See FIGS. 1–5.
wherein the main body has at least one limiting space and two bottom surfaces forming the two sliding slots, respectively,	The main body (B) has at least one limiting space (E) and two bottom surfaces (F) forming the two sliding slots (D), respectively. See FIGS. 1, 2, 4 and 5.
the two bottom surfaces are parallel to the two side surfaces,	The two bottom surfaces (F) are parallel to the two side surfaces (C). See FIGS. 2 and 4.
the at least one limiting space is located at one of the two side surfaces;	The at least one limiting space (E) is located at one of the two side surfaces (C). See FIGS. 2, 4 and 5.
a sliding component comprising a linkage arm and two extending arms,	A sliding component (G) includes a linkage arm (H) and two extending arms (I). See FIG. 3.
wherein the two extending arms are connected to two ends of the linkage arm, respectively,	The two extending arms (I) are connected to two ends of the linkage arm (H), respectively. See FIG. 3.
each extending arm has a second fastening part,	Each extending arm (I) has a second fastening part (J). See FIGS. 2 and 3.
the main body is between the two extending arms,	The main body (B) is between the two extending arms (I). See FIGS. 1–3.
the two extending arms are slidably disposed on the two sliding slots to have a fastening position and a releasing position,	The two extending arms (I) are slidably disposed on the two sliding slots (D) to have a fastening position and a releasing position. See FIGS. 2 and 4.

Exhibit G - Representative Claim Chart for U.S. Patent No. 9,523,826

U.S. Patent No. 9,523,826 Claim 1	ATI 100G QSFP LR4
the two first fastening parts are fastened to the two second fastening parts when the two extending arms are located at the fastening position, and	On information and belief, the two first fastening parts are configured to be fastened to the two second fastening parts (J) when the two extending arms (I) are located at the fastening position. See FIGS. 2 and 3.
the two second fastening parts press the two first fastening parts, respectively, to make the two first fastening parts be farther away from each other when the two extending arms are located at the releasing position,	On information and belief, the two second fastening parts (J) press the two first fastening parts to make the two first fastening parts to be farther away from each other when the two extending arms (I) are located at the releasing position. See FIGS. 2 and 3.
wherein each extending arm has a limited part configured to move in the at least one limiting space; and	Each extending arm (I) has a limited part (K) configured to move in the at least one limiting space (E). See FIGS. 3–5.
an elastic component,	An elastic component (L). See FIGS. 4 and 5.
wherein the main body has a first limiting surface and a second limiting surface forming the limiting space,	The main body (B) has a first limiting surface (E1) and a second limiting surface (E2) forming the limiting space (E). See FIGS. 1, 4, and 5.
the first limiting surface is closer to the head part than the second limiting surface,	The first limiting surface (E1) is closer to the head part (M) than the second limiting surface (E2). See FIG. 2 and FIG. 5.
and the elastic component is located in the limiting space and between the first limiting surface and the limited part and is covered by the extending arm such that the elastic component is confined by the main body and the sliding component.	The elastic component (L) is located in the limiting space (E) and between the first limiting surface (E1) and the limited part (K) and is covered by the extending arm such that the elastic component (L) is confined by the main body (B) and the sliding component (G). See FIGS. 1, 3, 4 and 5.

U.S. Patent No. 9,523,826 Claim 7	Accellight 100G QSFP LR4
A pluggable optical transceiver module, comprising:	A pluggable optical transceiver module (A). See FIG. 1–5.
a main body having a head part and an inserted part that are connected to each other,	A main body (B) has a head part (M) and an inserted part (N) that are connected to each other. See FIGS. 1 and 2.
wherein the main body further comprises opposite two side surfaces and	The main body (B) has opposite two side surfaces (C). See FIGS. 1, 2 and 4.

Exhibit G - Representative Claim Chart for U.S. Patent No. 9,523,826

U.S. Patent No. 9,523,826 Claim 7	Accelight 100G QSFP LR4
two sliding slots which are located at two sides of the head part and the inserted part opposite to each other, respectively,	Two sliding slots (D) are located at two sides of the head part (M) and the inserted part (N) opposite each other. See FIGS. 2 and 4.
the two sliding slots are located at the two side surfaces, and the two sliding slots extend from the head part to the inserted part, respectively,	The two sliding slots (D) are located at the two side surfaces (C) and the two sliding slots (D) extend from the head part (M) to the inserted part (N), respectively. See FIGS. 2 and 4.
wherein the main body has at least one limiting space and two bottom surfaces forming the two sliding slots, respectively,	The main body (B) has at least one limiting space (E) and two bottom surfaces (F) forming the two sliding slots (D), respectively. See FIGS. 1, 2, 4 and 5.
the two bottom surfaces are parallel to the two side surfaces,	The two bottom surfaces (F) are parallel to the two side surfaces (C). See FIGS. 2 and 4.
the at least one limiting space is located at one of the two side surfaces;	The at least one limiting space (E) is located at one of the two side surfaces (C). See FIG. 2, 4 and 5.
a sliding component comprising a linkage arm and two extending arms,	A sliding component (G) includes a linkage arm (H) and two extending arms (I). See FIG. 3.
wherein the linkage arm is connected between the two extending arms,	The linkage arm (H) is connected between the two extending arms (I). See FIG. 3.
each extending arm has a second fastening part,	Each extending arm (I) has a second fastening part (J). See FIGS. 2 and 3.
the main body is between the two extending arms,	The main body (B) is between the two extending arms (I). See FIGS. 1–3.
the two extending arms are able to slide relative to the two sliding slots to have a fastening position which is farther away from the head part and a releasing position which is closer to the head part,	The two extending arms (I) are able to slide relative to the two sliding slots (D) to have a fastening position, which on information and belief, is further away from the head part (M) and a releasing position which is closer to the head part (M). See FIGS. 2 and 3.
wherein each extending arm has a limited part configured to move in the at least one limiting space;	Each extending arm (I) has a limited part (K) configured to move in the at least one limiting space (E). See FIGS. 3–5.
and an elastic component,	An elastic component (L). See FIGS. 4 and 5.

Exhibit G - Representative Claim Chart for U.S. Patent No. 9,523,826

U.S. Patent No. 9,523,826 Claim 7	Accelight 100G QSFP LR4
wherein the main body has a first limiting surface and a second limiting surface forming the limiting space,	The main body (B) has a first limiting surface (E1) and a second limiting surface (E2) forming the limiting space (E) . See FIGS. 1, 4 and 5.
the first limiting surface is closer to the head part than the second limiting surface, and	The first limiting surface (E1) is closer to the head part (M) than the second limiting surface (E2) . See FIGS. 2 and 5.
the elastic component is located in the limiting space and between the first limiting surface and the limited part and is covered by the extending arm such that the elastic component is confined by the main body and the sliding component.	The elastic component (L) is located in the limiting space (E) and between the first limiting surface (E1) and the limited part (K) and is covered by the extending arm (I) such that the elastic component (L) is confined by the main body (B) and the sliding component (G) . See FIGS. 1, 3, 4 and 5.

Exhibit H

Exhibit H - Representative Claim Chart for U.S. Patent No. 9,523,826

ATI 100G QSFP28 CWDM4

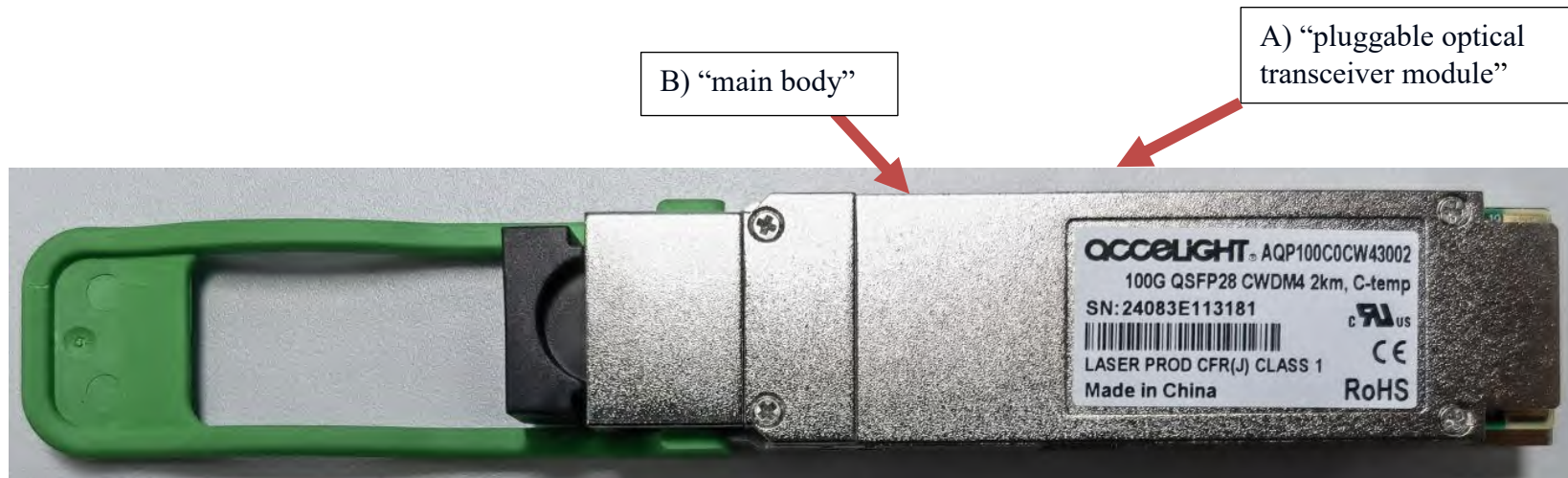


FIG. 1

Exhibit H - Representative Claim Chart for U.S. Patent No. 9,523,826

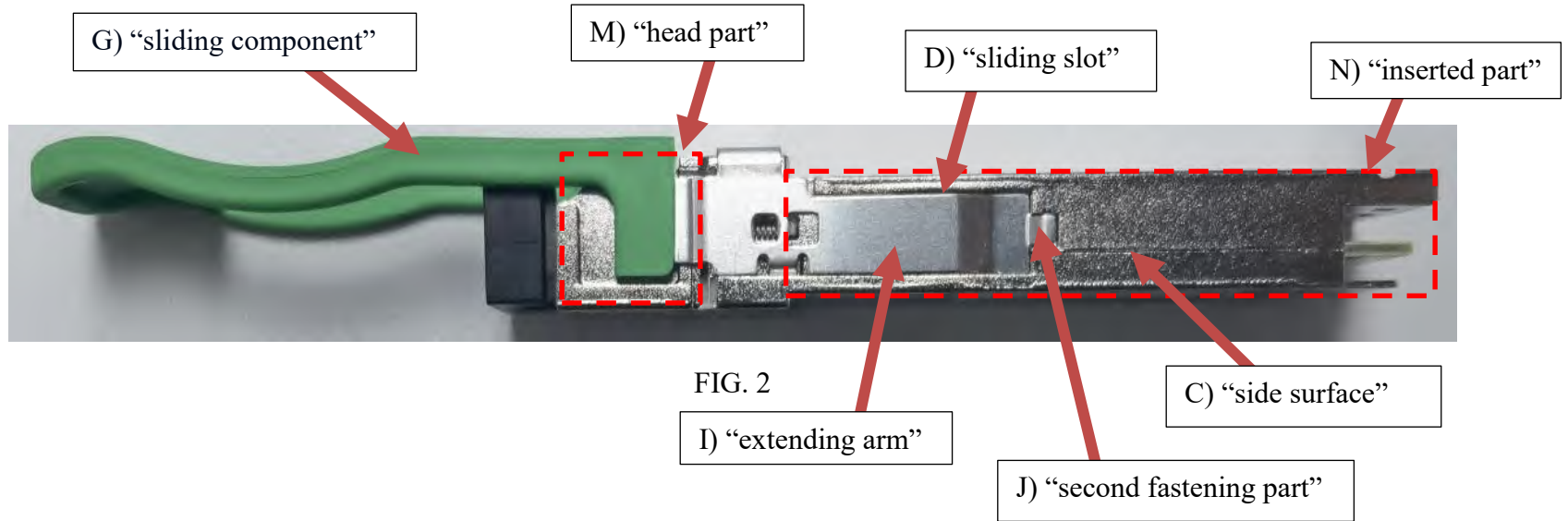


Exhibit H - Representative Claim Chart for U.S. Patent No. 9,523,826

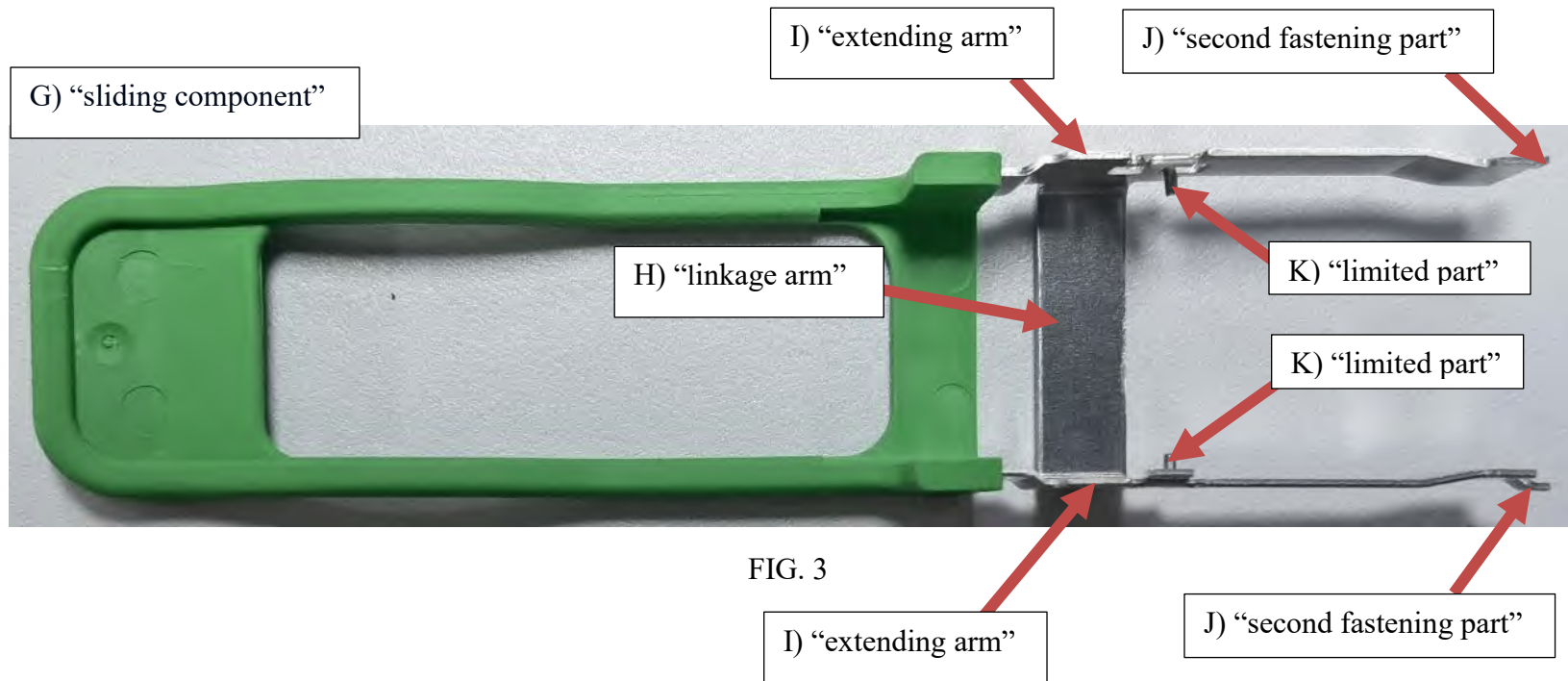


Exhibit H - Representative Claim Chart for U.S. Patent No. 9,523,826

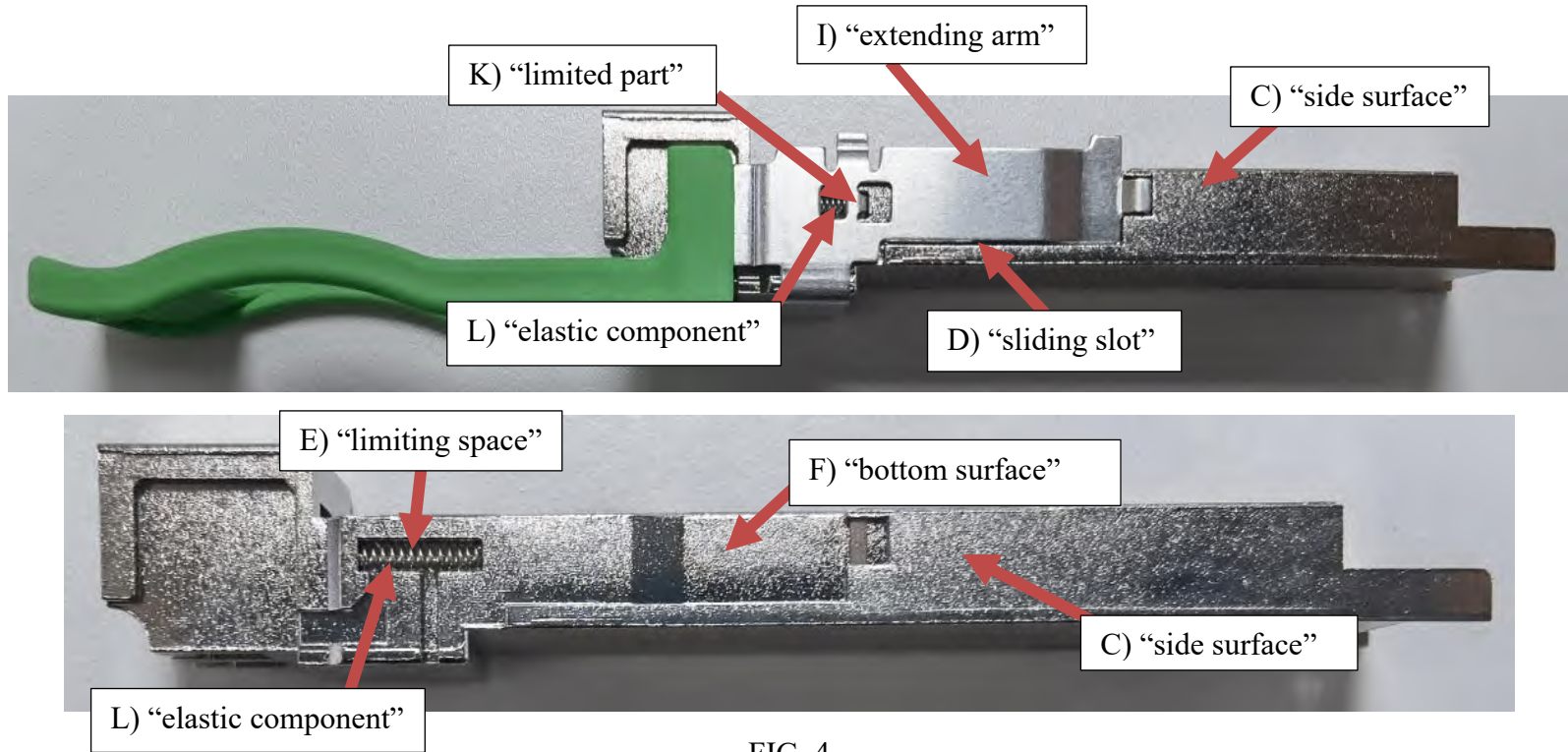


FIG. 4

Exhibit H - Representative Claim Chart for U.S. Patent No. 9,523,826

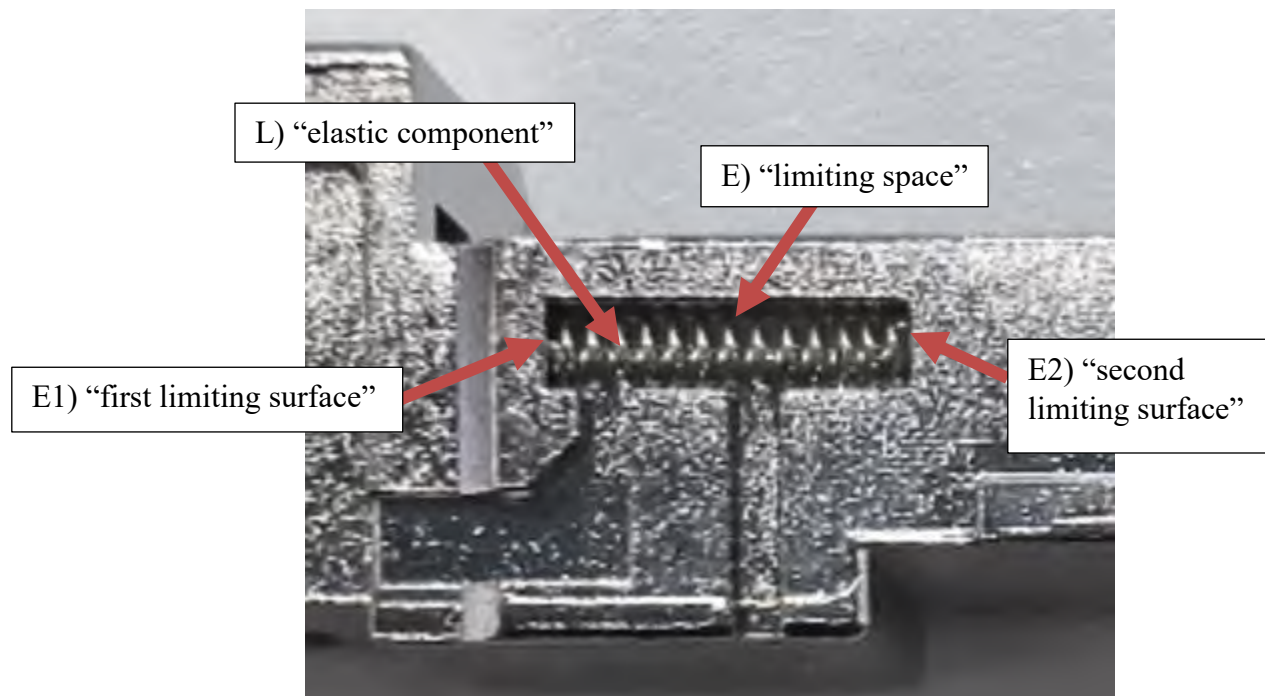


FIG. 5

Exhibit H - Representative Claim Chart for U.S. Patent No. 9,523,826**U.S. Patent No. 9,523,826**

U.S. Patent No. 9,523,826 Claim 1	ATI 100G QSFP28 CWDM4
A pluggable optical transceiver module, for being inserted into a plugging slot of a socket, the socket comprising two first fastening parts located in the plugging slot, the pluggable optical transceiver module comprising:	A pluggable optical transceiver module (A) for being inserted into a plugging slot of a socket. See FIGS. 1–5.
a main body having two side surfaces that are opposite to each other and	A main body (B) has two side surfaces (C) that are opposite to each other. See FIGS. 1, 2 and 4.
two sliding slots located at the two side surfaces, respectively,	Two sliding slots (D) are located at the two side surfaces (C), respectively. See FIGS. 2 and 4.
wherein the main body is configured to be inserted into the plugging slot,	On information and belief, the main body (B) is configured to be inserted into a plugging slot. See FIG. 1–5.
wherein the main body has at least one limiting space and two bottom surfaces forming the two sliding slots, respectively,	The main body (B) has at least one limiting space (E) and two bottom surfaces (F) forming the two sliding slots (D), respectively. See FIGS. 1, 2, 4 and 5.
the two bottom surfaces are parallel to the two side surfaces,	The two bottom surfaces (F) are parallel to the two side surfaces (C). See FIGS. 2 and 4.
the at least one limiting space is located at one of the two side surfaces;	The at least one limiting space (E) is located at one of the two side surfaces (C). See FIG. 2, 4 and 5.
a sliding component comprising a linkage arm and two extending arms,	A sliding component (G) includes a linkage arm (H) and two extending arms (I). See FIG. 3.
wherein the two extending arms are connected to two ends of the linkage arm, respectively,	The two extending arms (I) are connected to two ends of the linkage arm (H), respectively. See FIG. 3.
each extending arm has a second fastening part,	Each extending arm (I) has a second fastening part (J). See FIGS. 2 and 3.
the main body is between the two extending arms,	The main body (B) is between the two extending arms (I). See FIGS. 1–3.
the two extending arms are slidably disposed on the two sliding slots to have a fastening position and a releasing position,	The two extending arms (I) are slidably disposed on the two sliding slots (D) to have a fastening position and a releasing position. See FIGS. 2 and 4.

Exhibit H - Representative Claim Chart for U.S. Patent No. 9,523,826

U.S. Patent No. 9,523,826 Claim 1	ATI 100G QSFP28 CWDM4
the two first fastening parts are fastened to the two second fastening parts when the two extending arms are located at the fastening position,	On information and belief, the two first fastening parts are configured to be fastened to the two second fastening parts (J) when the two extending arms (I) are located at the fastening position. See FIGS. 2 and 3.
and the two second fastening parts press the two first fastening parts, respectively, to make the two first fastening parts be farther away from each other when the two extending arms are located at the releasing position,	On information and belief, the two second fastening parts (J) press the two first fastening parts to make the two first fastening parts to be farther away from each other when the two extending arms (I) are located at the releasing position. See FIGS. 2 and 3.
wherein each extending arm has a limited part configured to move in the at least one limiting space; and	Each extending arm (I) has a limited part (K) configured to move in the at least one limiting space (E) . See FIGS. 3–5.
an elastic component,	An elastic component (L) . See FIGS. 4 and 5.
wherein the main body has a first limiting surface and a second limiting surface forming the limiting space,	The main body (B) has a first limiting (E1) surface and a second limiting surface (E2) forming the limiting space (E) . See FIGS. 1, 4 and 5.
the first limiting surface is closer to the head part than the second limiting surface,	The first limiting surface (E1) is closer to the head part (M) than the second limiting surface (E2) . See FIGS. 2 and 5.
and the elastic component is located in the limiting space and between the first limiting surface and the limited part and is covered by the extending arm such that the elastic component is confined by the main body and the sliding component.	The elastic component (L) is located in the limiting space (E) and between the first limiting surface (E1) and the limited part (K) and is covered by the extending arm such that the elastic component (L) is confined by the main body (B) and the sliding component (G) . See FIGS. 1, 3, 4 and 5.

U.S. Patent No. 9,523,826 Claim 7	ATI 100G QSFP28 CWDM4
A pluggable optical transceiver module, comprising:	A pluggable optical transceiver module (A) . See FIG. 1–5.
a main body having a head part and an inserted part that are connected to each other,	A main body (B) has a head part (M) and an inserted part (N) that are connected to each other. See FIGS. 1 and 2.
wherein the main body further comprises opposite two side surfaces and	The main body (B) has two opposite side surfaces (C) . See FIGS. 1, 2 and 4.

Exhibit H - Representative Claim Chart for U.S. Patent No. 9,523,826

U.S. Patent No. 9,523,826 Claim 7	ATI 100G QSFP28 CWDM4
two sliding slots which are located at two sides of the head part and the inserted part opposite to each other, respectively,	Two sliding slots (D) are located at two sides of the head part (M) and the inserted part (N) opposite each other, respectively. See FIGS. 2 and 4.
the two sliding slots are located at the two side surfaces, and the two sliding slots extend from the head part to the inserted part, respectively,	The two sliding slots (D) are located at the two side surfaces (C) and the two sliding slots (D) extend from the head part (M) to the inserted part (N) , respectively. See FIGS. 2 and 4.
wherein the main body has at least one limiting space and two bottom surfaces forming the two sliding slots, respectively,	The main body (B) has at least one limiting space (E) and two bottom surfaces (F) forming the two sliding slots (D) , respectively. See FIGS. 1, 2, 4 and 5.
the two bottom surfaces are parallel to the two side surfaces,	The two bottom surfaces (F) are parallel to the two side surfaces (C) . See FIGS. 2 and 4.
the at least one limiting space is located at one of the two side surfaces;	The at least one limiting space (E) is located at one of the two side surfaces (C) . See FIGS. 2, 4 and 5.
a sliding component comprising a linkage arm and two extending arms,	A sliding component (G) includes a linkage arm (H) and two extending arms (I) . See FIG. 3.
wherein the linkage arm is connected between the two extending arms,	The linkage arm (H) is connected between the two extending arms (I) . See FIG. 3.
each extending arm has a second fastening part,	Each extending arm (I) has a second fastening part (J) . See FIGS. 2 and 3.
the main body is between the two extending arms,	The main body (B) is between the two extending arms (I) . See FIG. 1–3.
the two extending arms are able to slide relative to the two sliding slots to have a fastening position which is farther away from the head part and a releasing position which is closer to the head part,	The two extending arms (I) are able to slide relative to the two sliding slots (D) to have a fastening position, which on information and belief, is further away from the head part (M) , and a releasing position which is closer to the head part (M) . See FIGS. 2 and 3.
wherein each extending arm has a limited part configured to move in the at least one limiting space;	Each extending arm (I) has a limited part (K) configured to move in the at least one limiting space (E) . See FIG. 3–5.
and an elastic component,	An elastic component (L) . See FIGS. 4 and 5.

Exhibit H - Representative Claim Chart for U.S. Patent No. 9,523,826

U.S. Patent No. 9,523,826 Claim 7	ATI 100G QSFP28 CWDM4
wherein the main body has a first limiting surface and a second limiting surface forming the limiting space,	The main body (B) has a first limiting (E1) surface and a second limiting surface (E2) forming the limiting space (E) . See FIGS. 1, 4 and 5.
the first limiting surface is closer to the head part than the second limiting surface, and	The first limiting surface (E1) is closer to the head part (M)) than the second limiting surface (E2) . . See FIGS. 2 and FIG. 5.
the elastic component is located in the limiting space and between the first limiting surface and the limited part and is covered by the extending arm such that the elastic component is confined by the main body and the sliding component.	The elastic component (L) is located in the limiting space (E) and between the first limiting surface (E1) and the limited part (K) and is covered by the extending arm (I) such that the elastic component (L) is confined by the main body (B) and the sliding component (G) . See FIGS. 1, 3, 4 and 5.

Exhibit I

Exhibit I - Representative Claim Chart for U.S. Patent No. 9,523,826

ATI 400G QSFP-DD SR8

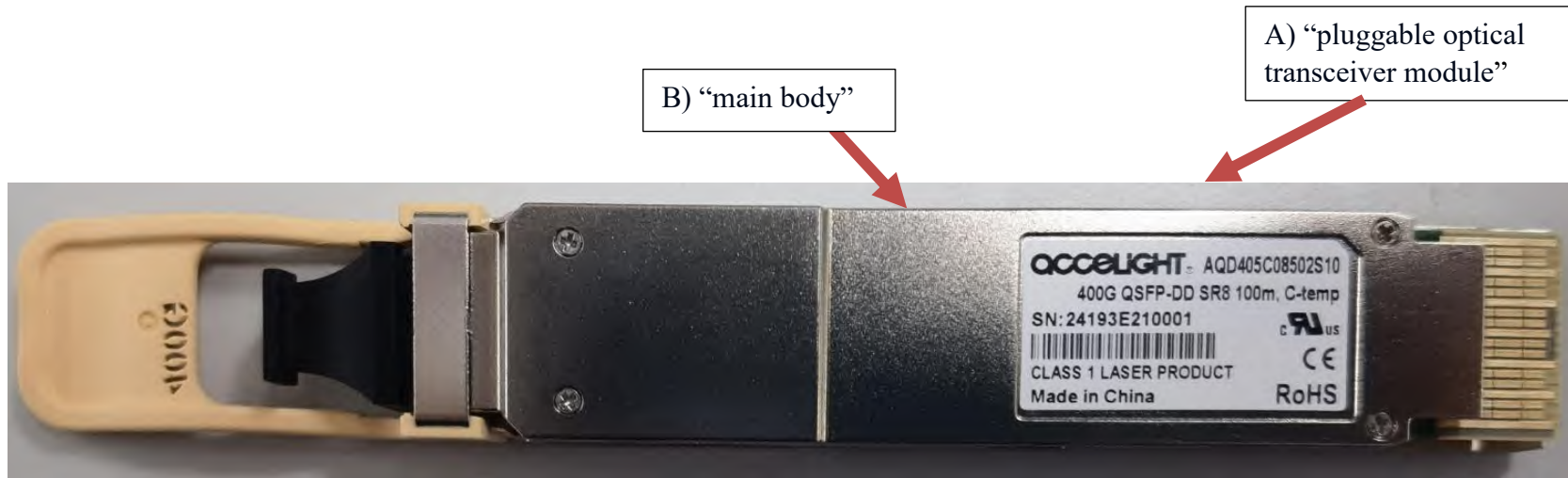


FIG. 1

Exhibit I - Representative Claim Chart for U.S. Patent No. 9,523,826

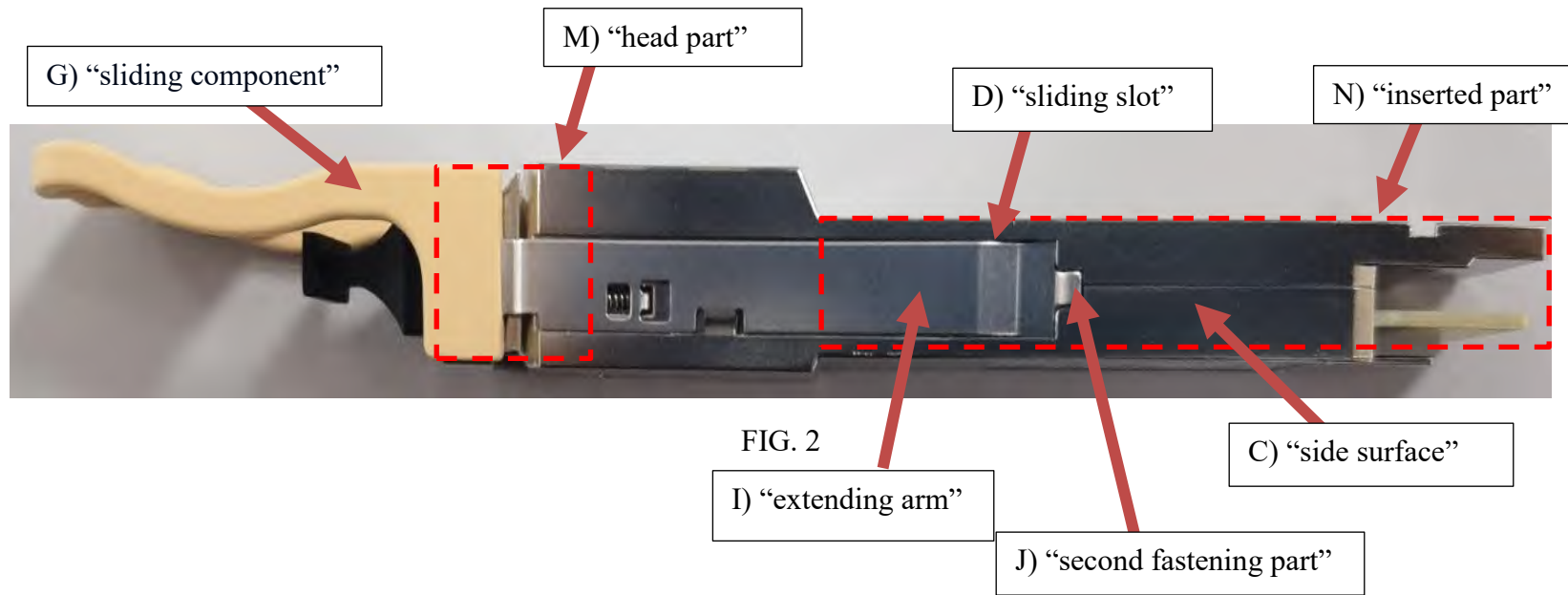


Exhibit I - Representative Claim Chart for U.S. Patent No. 9,523,826

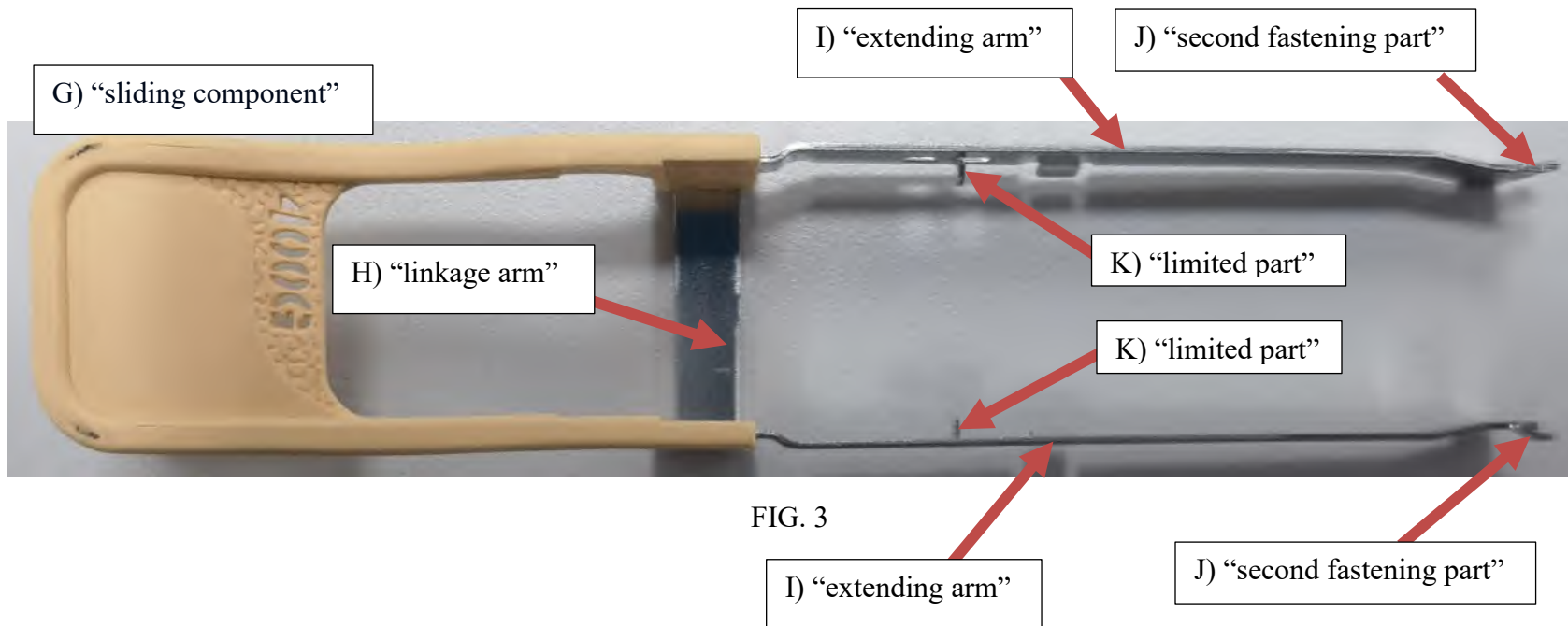


Exhibit I - Representative Claim Chart for U.S. Patent No. 9,523,826

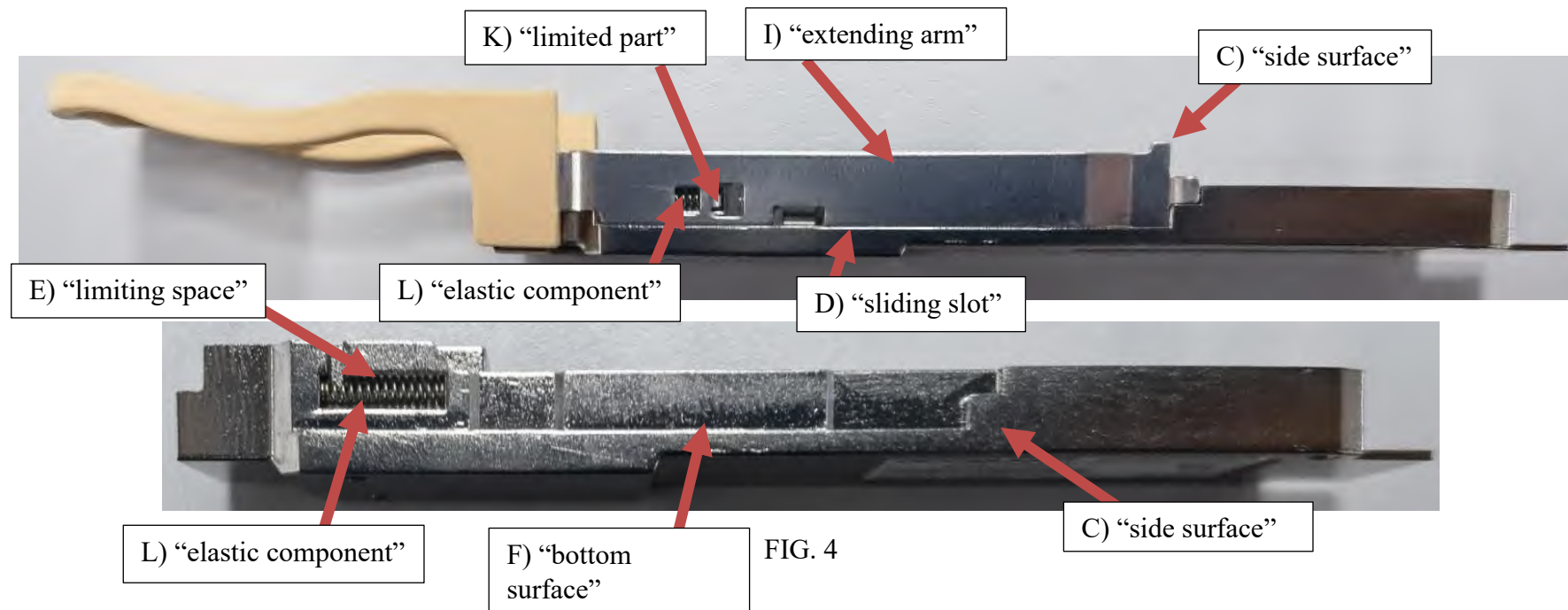


Exhibit I - Representative Claim Chart for U.S. Patent No. 9,523,826

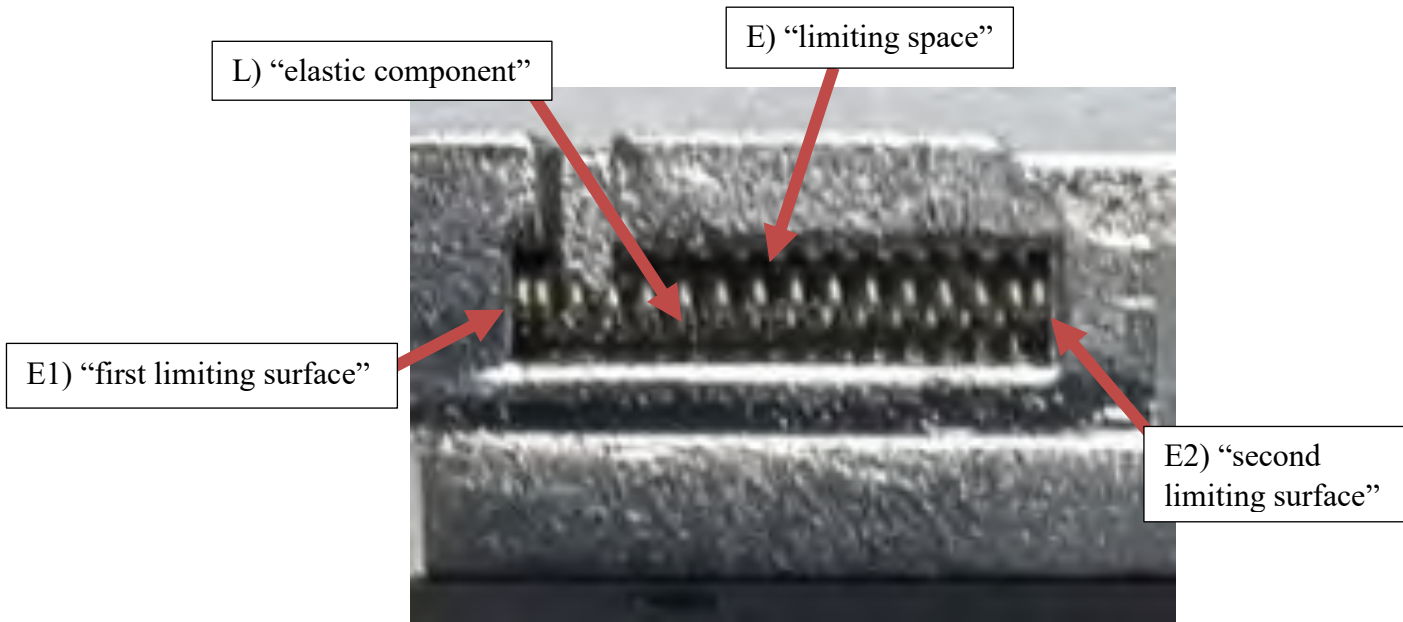


FIG. 5

Exhibit I - Representative Claim Chart for U.S. Patent No. 9,523,826

U.S. Patent No. 9,523,826 Claim 1	ATI 100G QSFP LR4
A pluggable optical transceiver module, for being inserted into a plugging slot of a socket, the socket comprising two first fastening parts located in the plugging slot, the pluggable optical transceiver module comprising:	A pluggable optical transceiver module (A) for being inserted into a plugging slot of a socket. See FIGS. 1–5.
a main body having two side surfaces that are opposite to each other and	A main body (B) has two side surfaces (C) that are opposite to each other. See FIGS. 1, 2 and 4.
two sliding slots located at the two side surfaces, respectively,	Two sliding slots (D) are located at the two side surfaces (C), respectively. See FIGS. 2 and 4.
wherein the main body is configured to be inserted into the plugging slot,	On information and belief, the main body (B) is configured to be inserted into a plugging slot. See FIG. 1–5.
wherein the main body has at least one limiting space and two bottom surfaces forming the two sliding slots, respectively,	The main body (B) has at least one limiting space (E) and two bottom surfaces (F) forming the two sliding slots (D), respectively. See FIGS. 1, 2, 4 and 5.
the two bottom surfaces are parallel to the two side surfaces,	The two bottom surfaces (F) are parallel to the two side surfaces (C). See FIGS. 2 and 4.
the at least one limiting space is located at one of the two side surfaces;	The at least one limiting space (E) is located at one of the two side surfaces (C). See FIGS. 2, 4 and 5.
a sliding component comprising a linkage arm and two extending arms,	A sliding component (G) includes a linkage arm (H) and two extending arms (I). See FIG. 3.
wherein the two extending arms are connected to two ends of the linkage arm, respectively,	The two extending arms (I) are connected to two ends of the linkage arm (H), respectively. See FIG. 3.
each extending arm has a second fastening part,	Each extending arm (I) has a second fastening part (J). See FIGS. 2 and 3.
the main body is between the two extending arms,	The main body (B) is between the two extending arms (I). See FIG. 1–3.
the two extending arms are slidably disposed on the two sliding slots to have a fastening position and a releasing position,	The two extending arms (I) are slidably disposed on the two sliding slots (D) to have a fastening position and a releasing position. See FIGS. 2 and 4.

Exhibit I - Representative Claim Chart for U.S. Patent No. 9,523,826

U.S. Patent No. 9,523,826 Claim 1	ATI 100G QSFP LR4
the two first fastening parts are fastened to the two second fastening parts when the two extending arms are located at the fastening position,	On information and belief, the two first fastening parts are configured to be fastened to the two second fastening parts (J) when the two extending arms (I) are located at the fastening position. See FIGS. 2 and 3.
and the two second fastening parts press the two first fastening parts, respectively, to make the two first fastening parts be farther away from each other when the two extending arms are located at the releasing position,	On information and belief, the two fastening parts (J) press the two fastening parts to make the two first fastening parts to be farther away from each other when the two extending arms (I) are located at the releasing position. See FIGS. 2 and 3.
wherein each extending arm has a limited part configured to move in the at least one limiting space; and	Each extending arm (I) has a limited part (K) configured to move in the at least one limiting space (E) . See FIG. 3–5.
an elastic component,	An elastic component (L) . See FIGS. 4 and 5.
wherein the main body has a first limiting surface and a second limiting surface forming the limiting space,	The main body (B) has a first limiting surface (E1) and a second limiting surface (E2) forming the limiting space (E) . See FIGS. 1, 4 and 5.
the first limiting surface is closer to the head part than the second limiting surface,	The first limiting surface (E1) is closer to head part (M) than the second limiting surface (E2) . See FIGS. 2 and 5.
and the elastic component is located in the limiting space and between the first limiting surface and the limited part and is covered by the extending arm such that the elastic component is confined by the main body and the sliding component.	The elastic component (L) is located in the limiting space (E) and between the first limiting surface (E1) and the limited part (K) and is covered by the extending arm such that the elastic component (L) is confined by the main body (B) and the sliding component (G) . See FIGS. 1, 3, 4 and 5.

U.S. Patent No. 9,523,826 Claim 7	ATI 100G QSFP LR4
A pluggable optical transceiver module, comprising:	A pluggable optical transceiver module (A) . See FIG. 1–5.
a main body having a head part and an inserted part that are connected to each other,	A main body (B) has a head part (M) and an inserted part (N) that are connected to each other. See FIGS. 1 and 2.
wherein the main body further comprises opposite two side surfaces and	The main body (B) has two opposite side surfaces (C) . See FIGS. 1, 2 and 4.

Exhibit I - Representative Claim Chart for U.S. Patent No. 9,523,826

U.S. Patent No. 9,523,826 Claim 7	ATI 100G QSFP LR4
two sliding slots which are located at two sides of the head part and the inserted part opposite to each other, respectively,	Two sliding slots (D) are located at two sides of the head part (M) and the inserted part (N) opposite each other, respectively. See FIGS. 2 and 4.
the two sliding slots are located at the two side surfaces, and the two sliding slots extend from the head part to the inserted part, respectively,	The two sliding slots (D) are located at the two side surfaces (C) and the two sliding slots (D) extend from the head part (M) to the inserted part (N) , respectively. See FIGS. 2 and 4.
wherein the main body has at least one limiting space and two bottom surfaces forming the two sliding slots, respectively,	The main body (B) has at least one limiting space (E) and two bottom surfaces (F) forming the two sliding slots (D) , respectively. See FIGS. 1, 2, 4 and 5.
the two bottom surfaces are parallel to the two side surfaces,	The two bottom surfaces (F) are parallel to the two side surfaces (C) . See FIGS. 2 and 4.
the at least one limiting space is located at one of the two side surfaces;	The at least one limiting space (E) is located at one of the two side surfaces (C) . See FIGS. 2, 4, and 5.
a sliding component comprising a linkage arm and two extending arms,	A sliding component (G) includes a linkage arm (H) and two extending arms (I) . See FIG. 3.
wherein the linkage arm is connected between the two extending arms,	The linkage arm (H) is connected between the two extending arms (I) . See FIG. 3.
each extending arm has a second fastening part,	Each extending arm (I) has a second fastening part (J) . See FIGS. 2 and 3.
the main body is between the two extending arms,	The main body (B) is between the two extending arms (I) . See FIG. 1–3.
the two extending arms are able to slide relative to the two sliding slots to have a fastening position which is farther away from the head part and a releasing position which is closer to the head part,	The two extending arms (I) are able to slide relative to the two sliding slots (D) to have a fastening position, which on information and belief, is further away from the head part (M) and a releasing position which is closer to the head part (M) . See FIGS. 2 and 3.
wherein each extending arm has a limited part configured to move in the at least one limiting space;	Each extending arm (I) has a limited part (K) configured to move in the at least one limiting space (E) . See FIG. 3–5.
and an elastic component,	An elastic component (L) . See FIGS. 4 and 5.

Exhibit I - Representative Claim Chart for U.S. Patent No. 9,523,826

U.S. Patent No. 9,523,826 Claim 7	ATI 100G QSFP LR4
wherein the main body has a first limiting surface and a second limiting surface forming the limiting space,	The main body (B) has a first limiting surface (E1) and a second limiting surface (E2) forming the limiting space (E) . See FIGS. 1, 4 and 5.
the first limiting surface is closer to the head part than the second limiting surface, and	The first limiting surface (E1) is closer to the head part (M)) than the second limiting surface (E2) . See FIGS. 2 and 5.
the elastic component is located in the limiting space and between the first limiting surface and the limited part and is covered by the extending arm such that the elastic component is confined by the main body and the sliding component.	The elastic component (L) is located in the limiting space (E) and between the first limiting surface (E1) and the limited part (K) and is covered by the extending arm (I) such that the elastic component (L) is confined by the main body (B) and the sliding component (G) . See FIGS. 1, 3, 4 and 5.

Exhibit J

Exhibit J - Representative Claim Chart for U.S. Patent No. 10,042,116

ATI 100G QSFP28 CWDM4

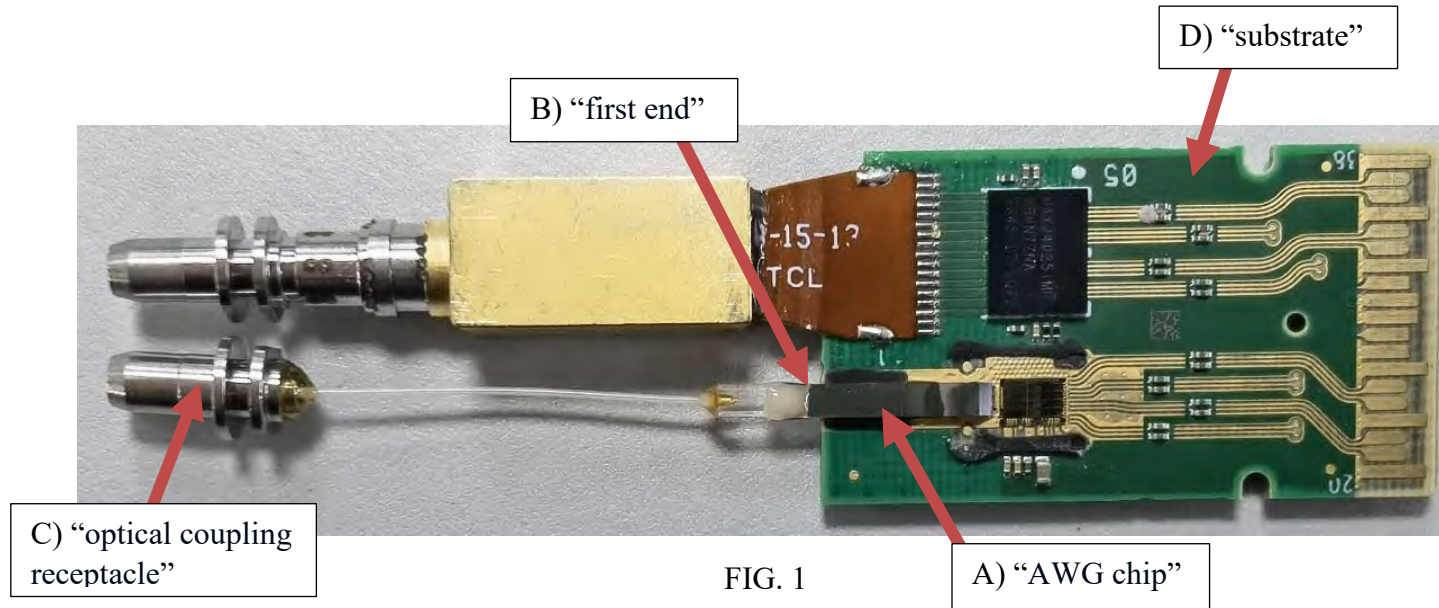


Exhibit J - Representative Claim Chart for U.S. Patent No. 10,042,116

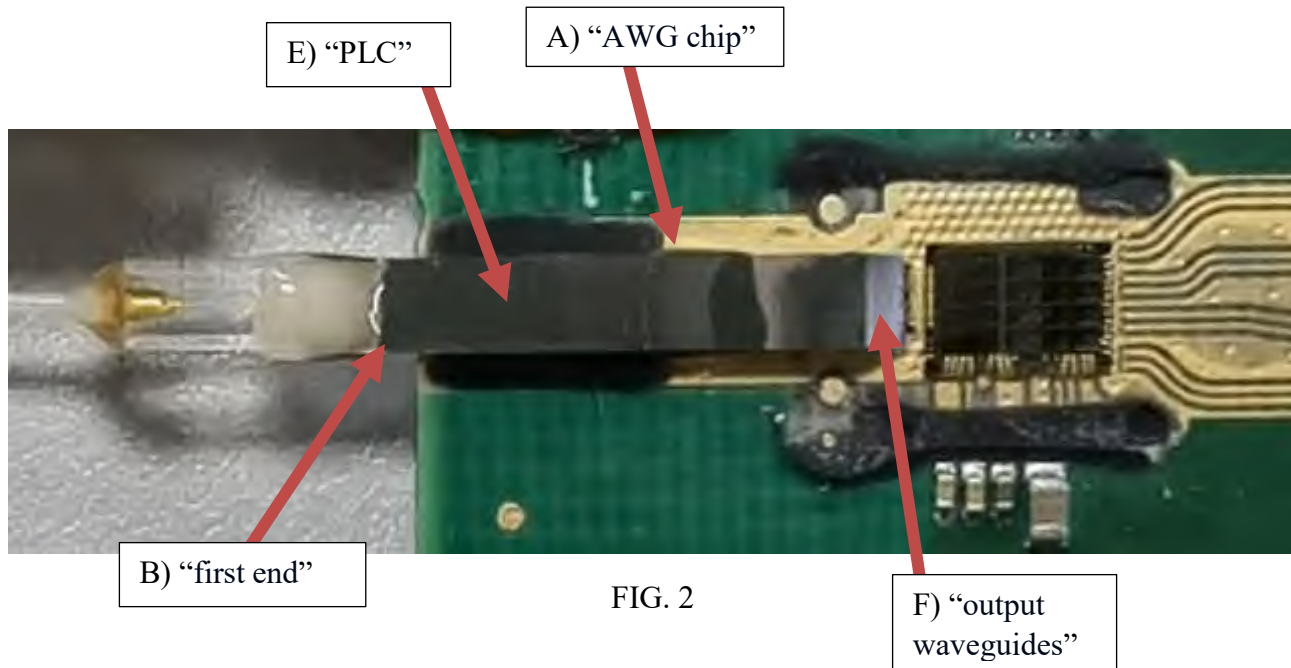


Exhibit J - Representative Claim Chart for U.S. Patent No. 10,042,116

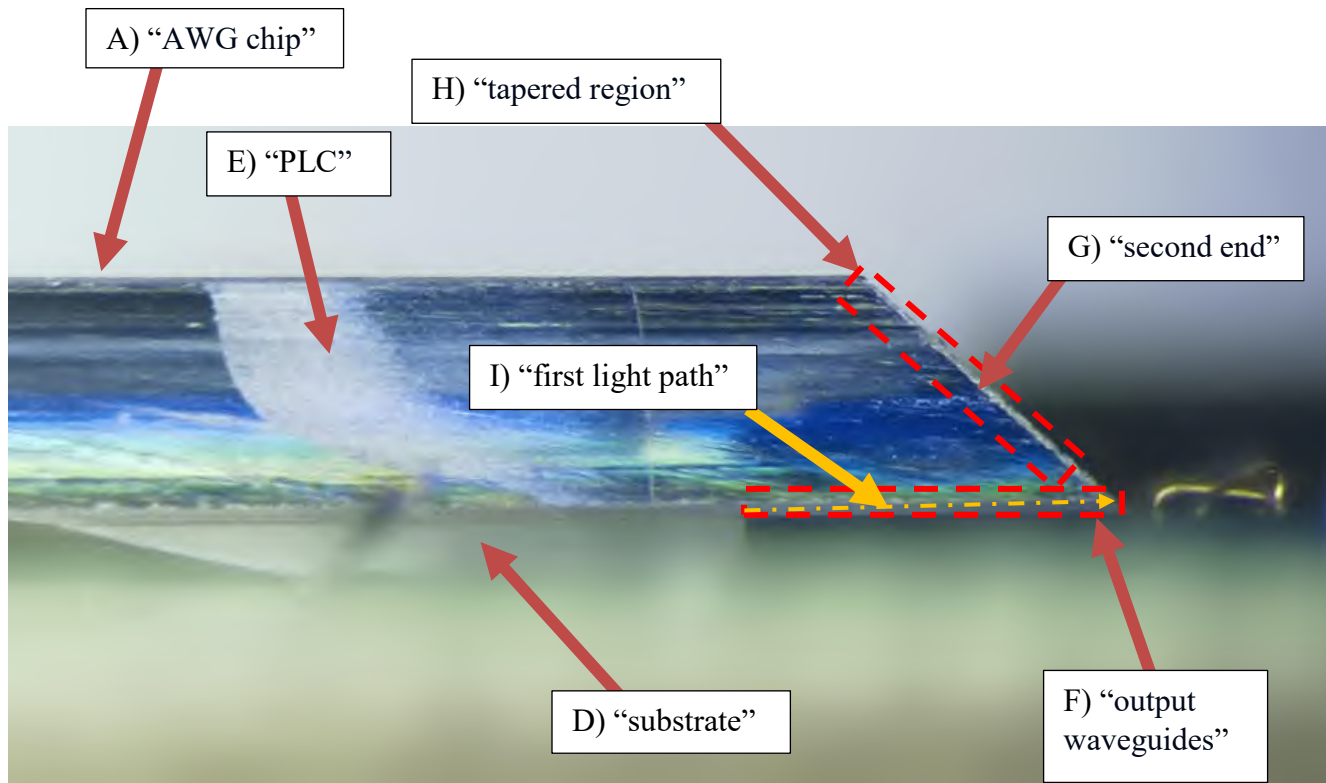


FIG. 3

Exhibit J - Representative Claim Chart for U.S. Patent No. 10,042,116

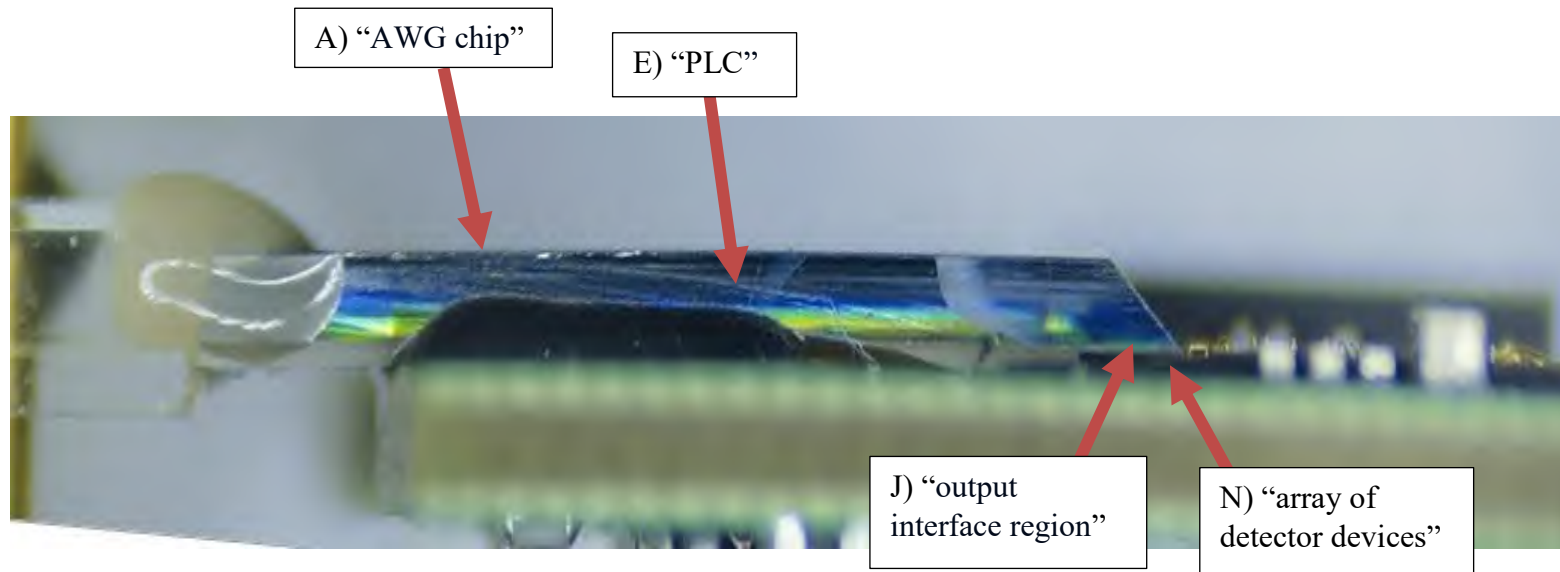


FIG. 4

Exhibit J - Representative Claim Chart for U.S. Patent No. 10,042,116

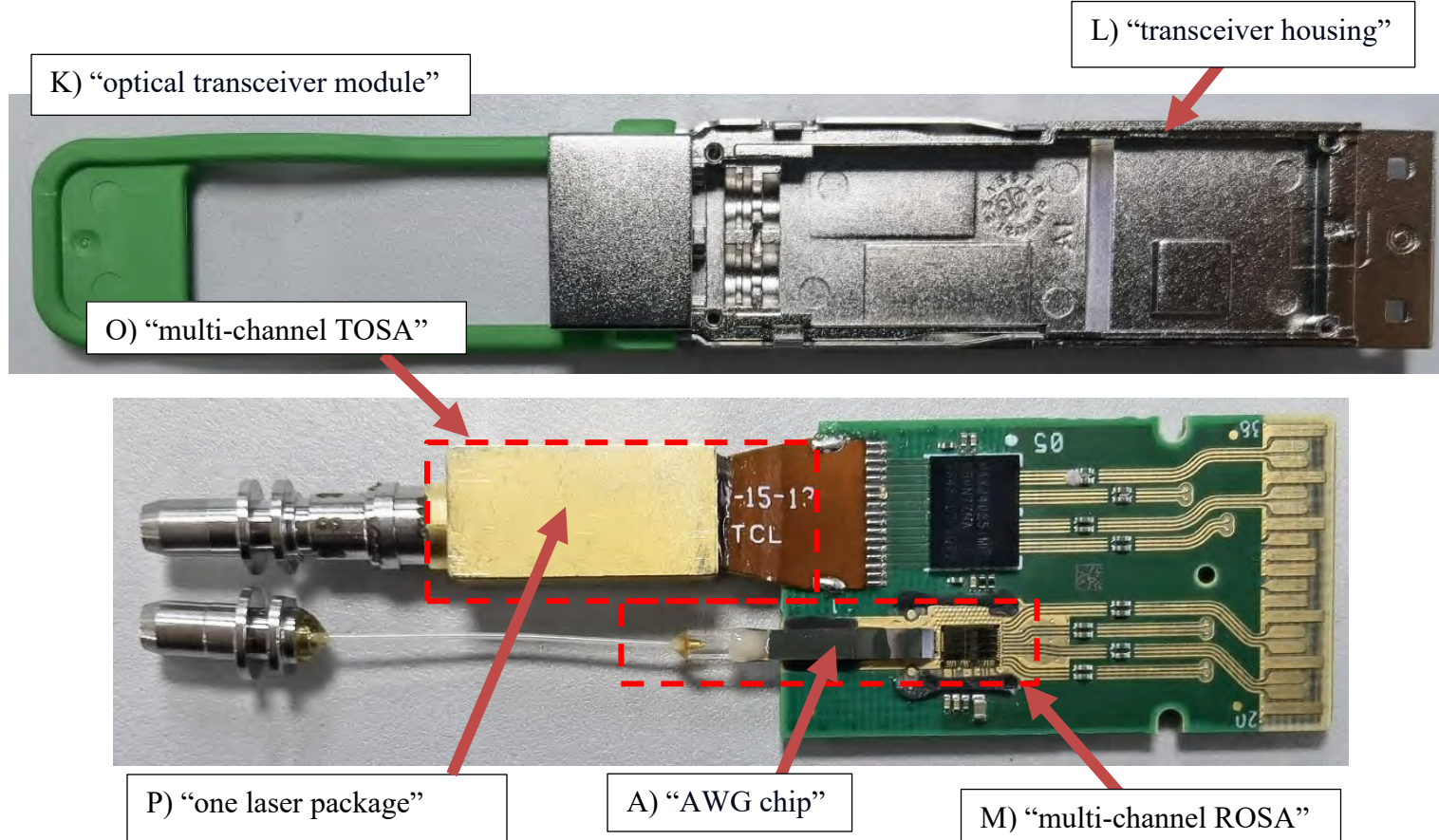


FIG. 5

Exhibit J - Representative Claim Chart for U.S. Patent No. 10,042,116

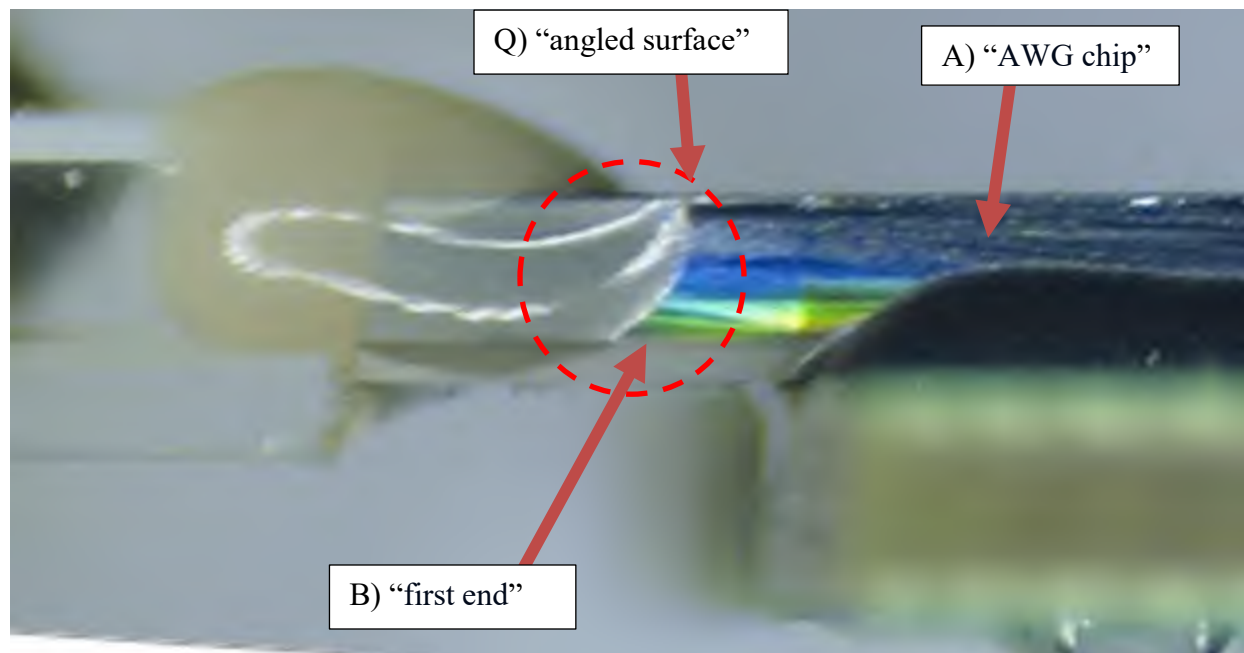


FIG. 6

Exhibit J - Representative Claim Chart for U.S. Patent No. 10,042,116

U.S. Patent No. 10,042,116 Claim 1	ATI 100G QSFP28 CWDM4
An arrayed waveguide grating (AWG) chip comprising:	Arrayed waveguide grating (AWG) chip (A) . See FIGS. 1–6.
a first end for coupling to an optical coupling receptacle to receive an optical signal comprising a plurality of channel wavelengths;	A first end (B) for coupling to an optical coupling receptacle (C) to receive an optical signal comprising a plurality of channel wavelengths. See FIGS. 1, 2, and 6.
a substrate;	Substrate (D) under the AWG chip (A) . See FIGS. 1 and 3.
a planar lightwave circuit (PLC) disposed on the substrate, the PLC coupled to the first end and configured to de-multiplex each channel wavelength of the plurality of channel wavelengths;	Planar lightwave circuit (PLC) (E) is disposed on the substrate (D) . The PLC (E) is coupled to the first end (B) and configured to de-multiplex each channel wavelength of the plurality of channel wavelengths. See FIGS. 1–4, and 6.
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 plurality of output waveguides (F) are coupled to the PLC (E) . Each of the output waveguides (F) is configured to receive light corresponding to an associated de-multiplexed channel wavelength launched from the PLC (E) and provide the light along a first light path (I) that extends towards a second end (G) of the AWG chip (A) . See FIGS. 1–6.
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 exposed output interface region of the AWG chip, wherein the exposed output interface region emits the received light from the AWG chip on the same side as the substrate without passing the received light through the substrate.	A tapered region (H) is disposed at the second end (G) of the AWG chip (A) configured to receive light via the plurality of output waveguides (F) and reflect the same towards an exposed output interface region (J) of the AWG chip (A) . The exposed output interface region (J) emits the received light from the AWG chip (A) on the same side as the substrate (D) without passing the received light through the substrate (D) . See FIGS. 1–6.

U.S. Patent No. 10,042,116 Claim 12	ATI 100G QSFP28 CWDM4
An optical transceiver module comprising:	An optical transceiver module (K) . See FIG. 5.
a transceiver housing;	A transceiver housing (L) . See FIG. 5.

Exhibit J - Representative Claim Chart for U.S. Patent No. 10,042,116

U.S. Patent No. 10,042,116 Claim 12	ATI 100G QSFP28 CWDM4
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 multi-channel receiver optical sub-assembly (ROSA) (M) is located in the transceiver housing (L) and includes an arrayed waveguide grating (AWG) chip (A) . See FIG. 5.
a first end for coupling to an optical coupling receptacle to receive an optical signal comprising a plurality of channel wavelengths, wherein the first end for coupling to the optical coupling receptacle includes an angled surface to reduce back reflections of an optical signal launched into the AWG chip;	A first end (B) for coupling to an optical coupling receptacle (C) to receive an optical signal comprising a plurality of channel wavelengths. See FIGS. 1 and 2. The first end (B) for coupling to the optical coupling receptacle (C) includes an angled surface (Q) to reduce back reflections of an optical signal launched into the AWG chip (A) . See FIGS. 1 and 6.
a planar lightwave circuit (PLC) coupled to the first end configured to de-multiplex each channel wavelength of the plurality of channel wavelengths;	A planar lightwave circuit (PLC) (E) is coupled to the first end (B) and configured to de-multiplex each channel wavelength of the plurality of channel wavelengths. See FIGS. 1 and 2.
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 plurality of output waveguides (F) are coupled to the PLC (E) . Each of the output waveguides (F) is configured to receive light corresponding to an associated de-multiplexed channel wavelength launched from the PLC (E) and provide the light along a first light path (I) that extends towards a second end (G) of the AWG chip (A) . See FIGS. 2 and 3.
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;	A tapered region (H) is disposed at the second end (G) of the AWG chip (A) and configured to receive light via the plurality of output waveguides (F) and reflect the same towards an output interface region (J) of the AWG chip (A) . See FIGS. 3 and 4.
an array of detector devices disposed adjacent to the output interface region of the AWG chip; and	an array of detector devices (N) is disposed adjacent to the output interface region (J) of the AWG chip (A) . See FIG. 4.
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.	A multi-channel transmitter optical assembly (TOSA) (O) includes at least one laser package (P) located in the transceiver housing (L) for transmitting optical signals at different channel wavelengths. See FIG. 5.

Exhibit K

Exhibit K - Representative Claim Chart for U.S. Patent No. 9,448,367

ATI 400G QSFP-DD FR4

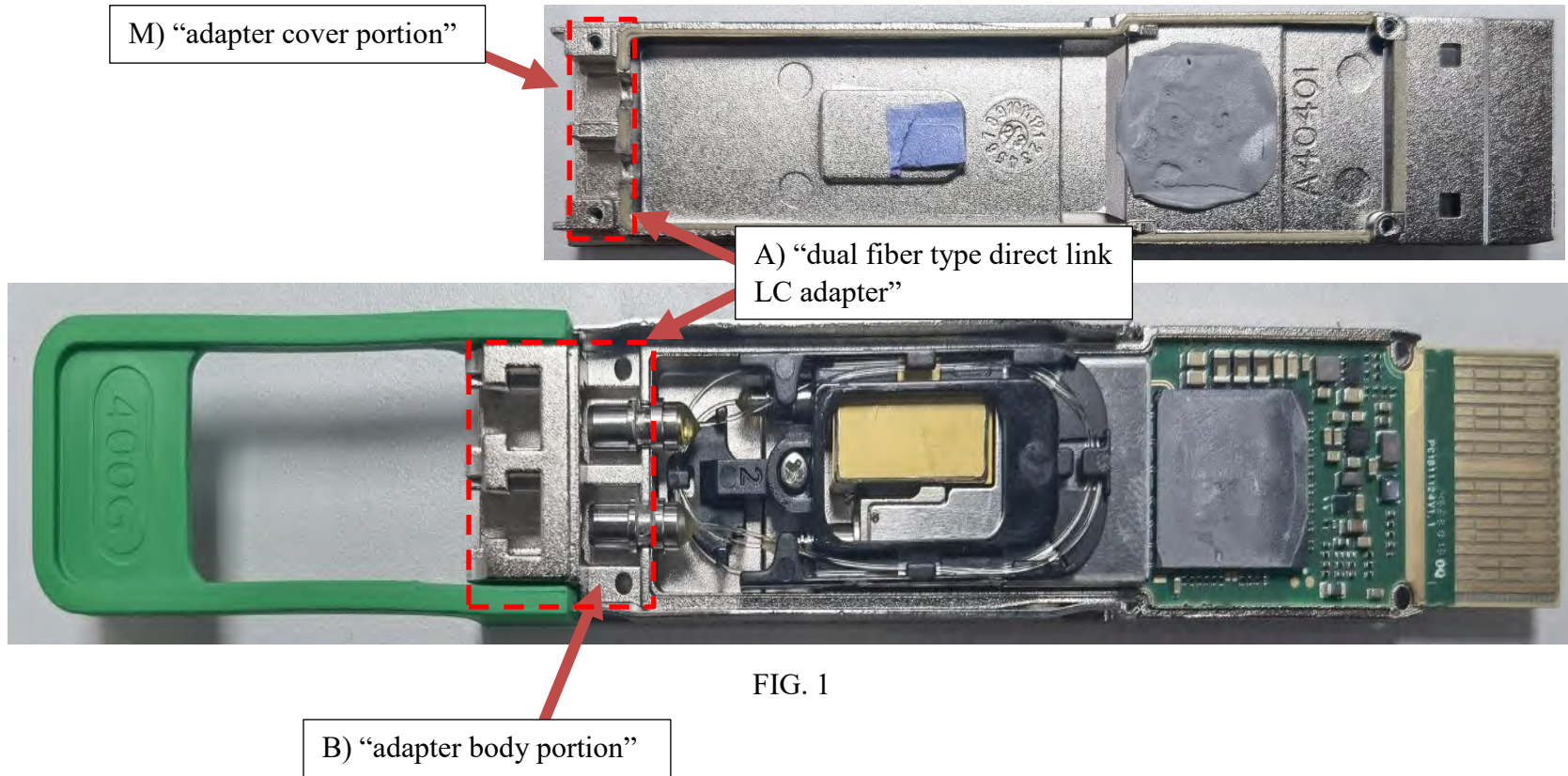


Exhibit K - Representative Claim Chart for U.S. Patent No. 9,448,367

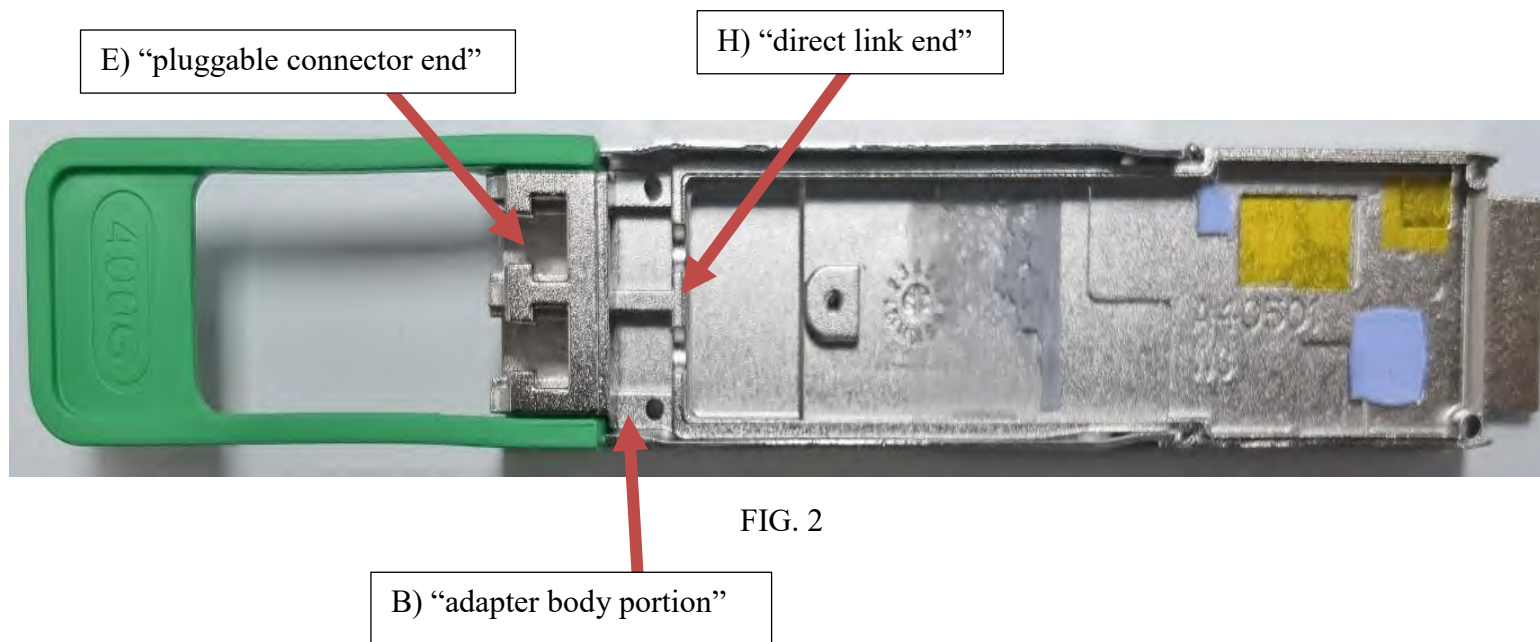


Exhibit K - Representative Claim Chart for U.S. Patent No. 9,448,367

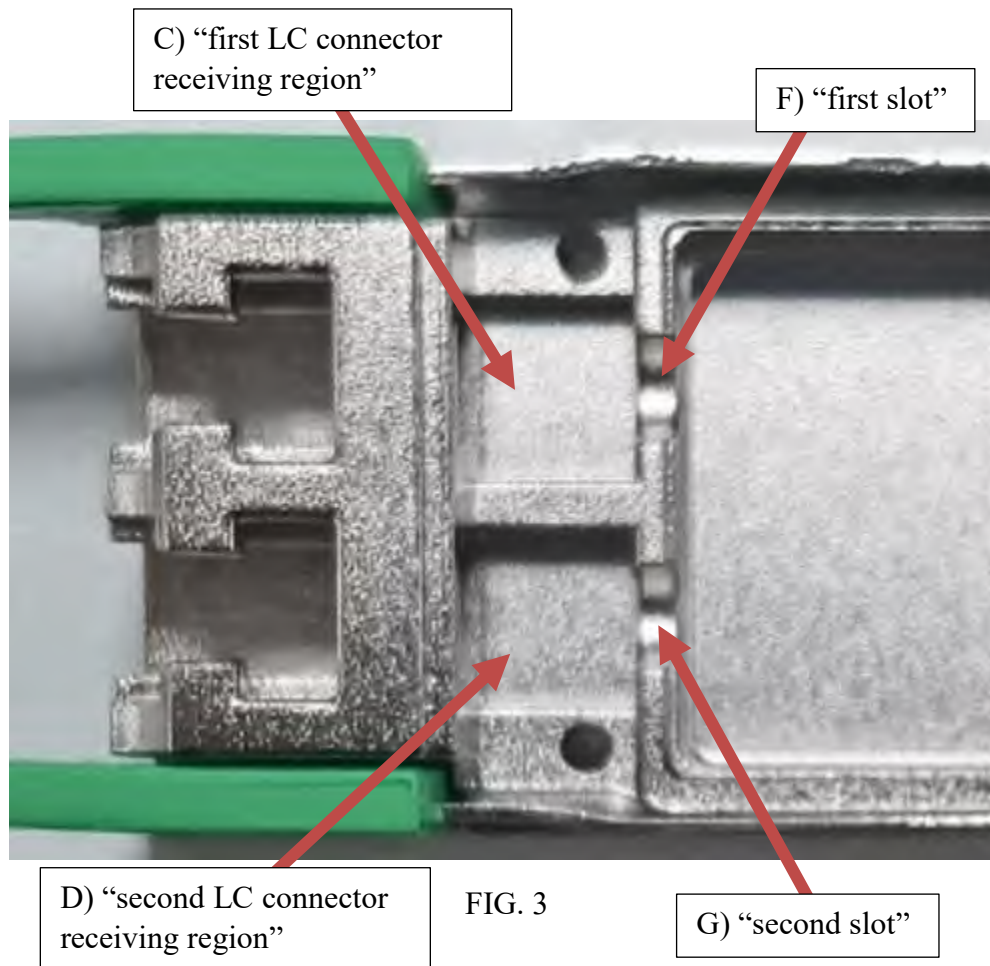


Exhibit K - Representative Claim Chart for U.S. Patent No. 9,448,367

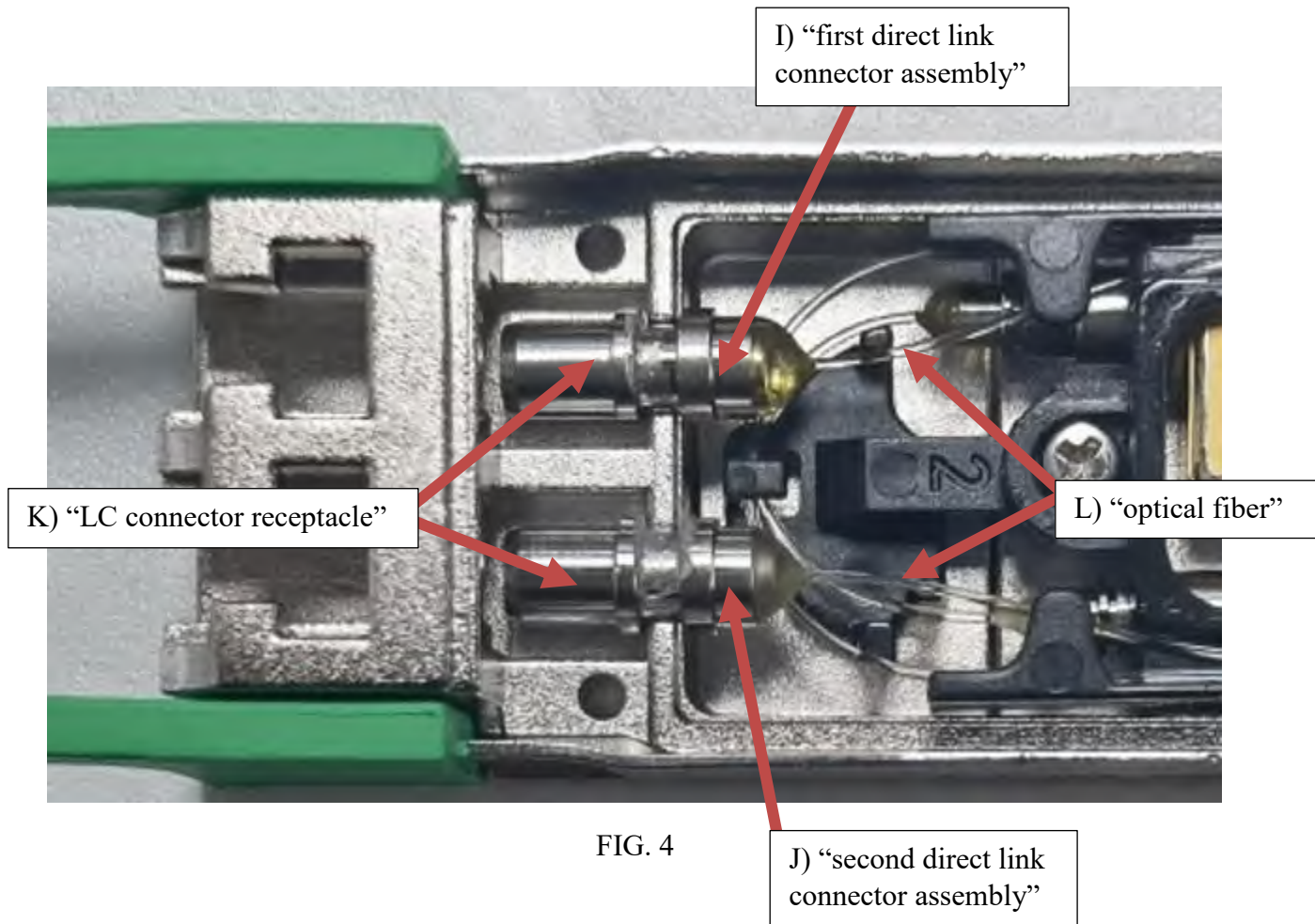


Exhibit K - Representative Claim Chart for U.S. Patent No. 9,448,367**U.S. Patent No. 9,448,367**

U.S. Patent No. 9,448,367 Claim 1	ATI 400G QSFP-DD FR4
A dual fiber type direct link LC adapter comprising:	A dual fiber type direct link LC adapter (A). See FIG. 1.
an adapter body portion defining first and second LC connector receiving regions at a pluggable connector end and defining first and second slots at a direct link end;	An adapter body portion (B) defines a first LC connector receiving region (C) and a second LC connector receiving region (D) at a pluggable connector end (E), and defines a first slot (F) and a second slot (G) at a direct link end (H). See FIGS. 2 and 3.
first and second direct link connector assemblies configured to be received in the first and second slots, respectively, each of the direct link connector assemblies defining an LC connector receptacle at one end, wherein the LC connector receptacle extends into a respective one of the LC connector receiving regions and is configured to receive a portion of an LC connector for optical coupling, and wherein each of the direct link connector assemblies is configured to be mechanically coupled to an optical fiber at another end; and	A first direct link connector assembly (I) and a second direct link connector assembly (J) are configured to be received in the first and second slots (F, G), respectively. See FIGS. 3 and 4. Each of the direct link connector assemblies (I, J) defines an LC connector receptacle (K) at one end. The LC connector receptacle (K) extends into a respective one of the LC connector receiving regions (C, D) and is configured to receive a portion of an LC connector for optical coupling. Each of the direct link connector assemblies (I, J) is configured to be mechanically coupled to an optical fiber (L) at another end. See FIGS. 3 and 4.
an adapter cover portion configured to cover the first and second slots for retaining the direct link connector assemblies in the respective slots.	an adapter cover portion (M) configured to cover the first and second slots (F, G) for retaining the direct link connector assemblies (I, J) in the respective slots (F, G). See FIGS. 1–4.

Exhibit L

Exhibit L - Representative Claim Chart for U.S. Patent No. 10,379,301

ATI 100G QSFP28 CWDM4

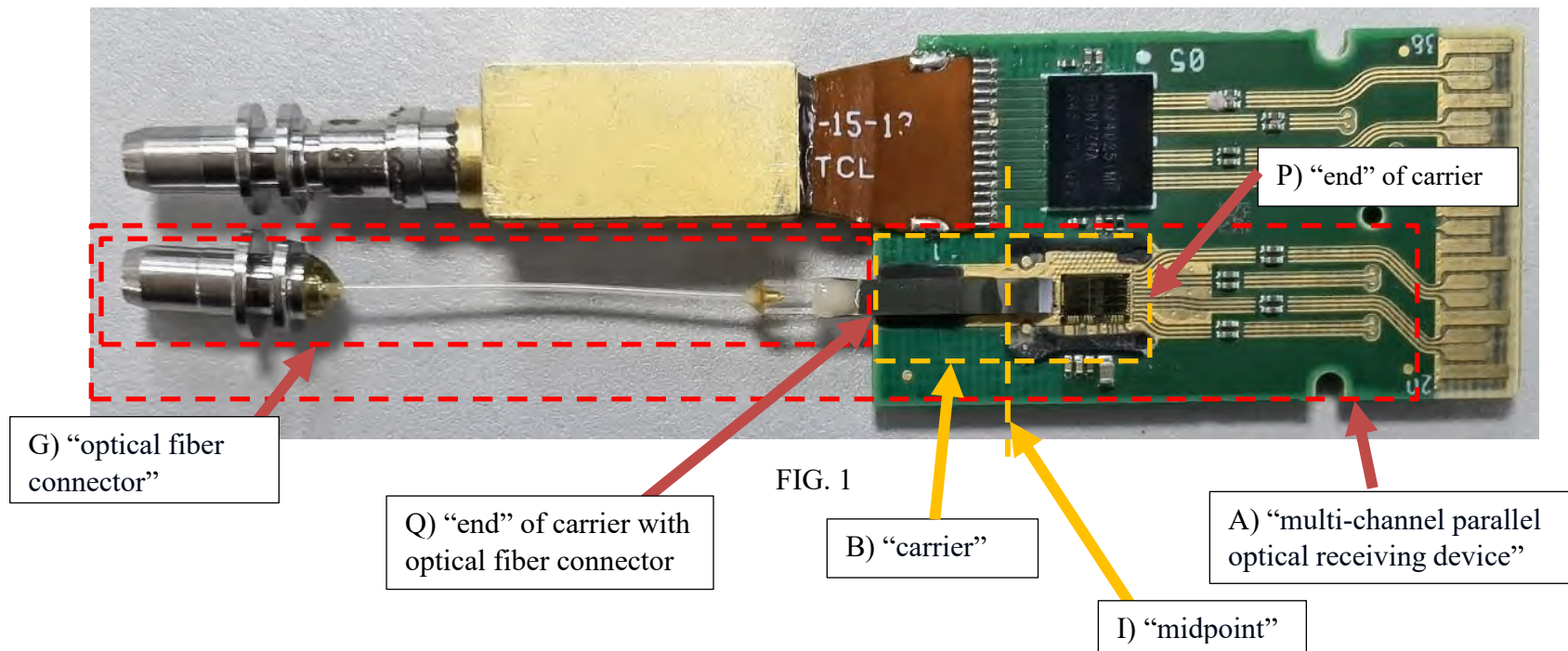


Exhibit L - Representative Claim Chart for U.S. Patent No. 10,379,301

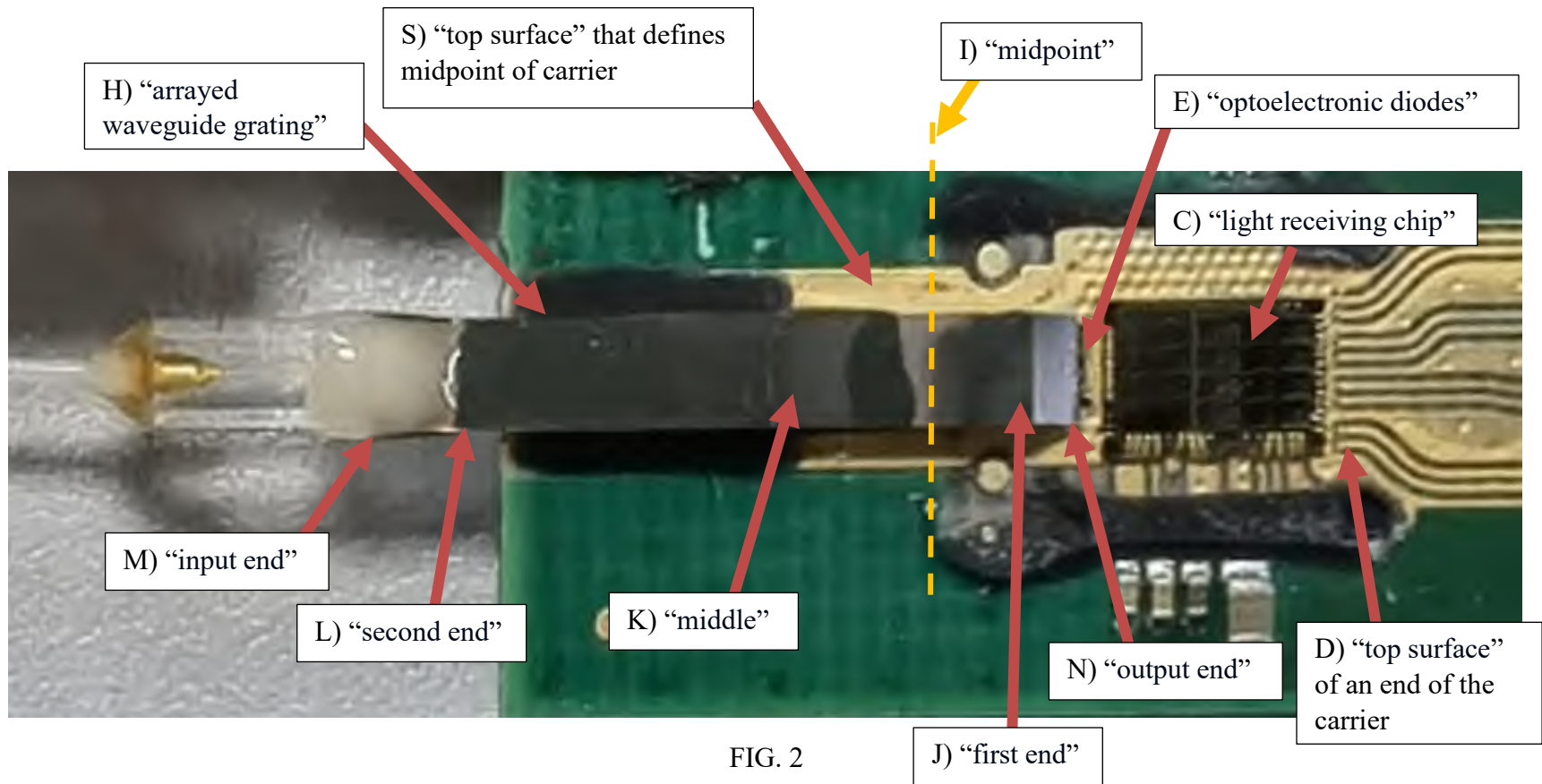


Exhibit L - Representative Claim Chart for U.S. Patent No. 10,379,301

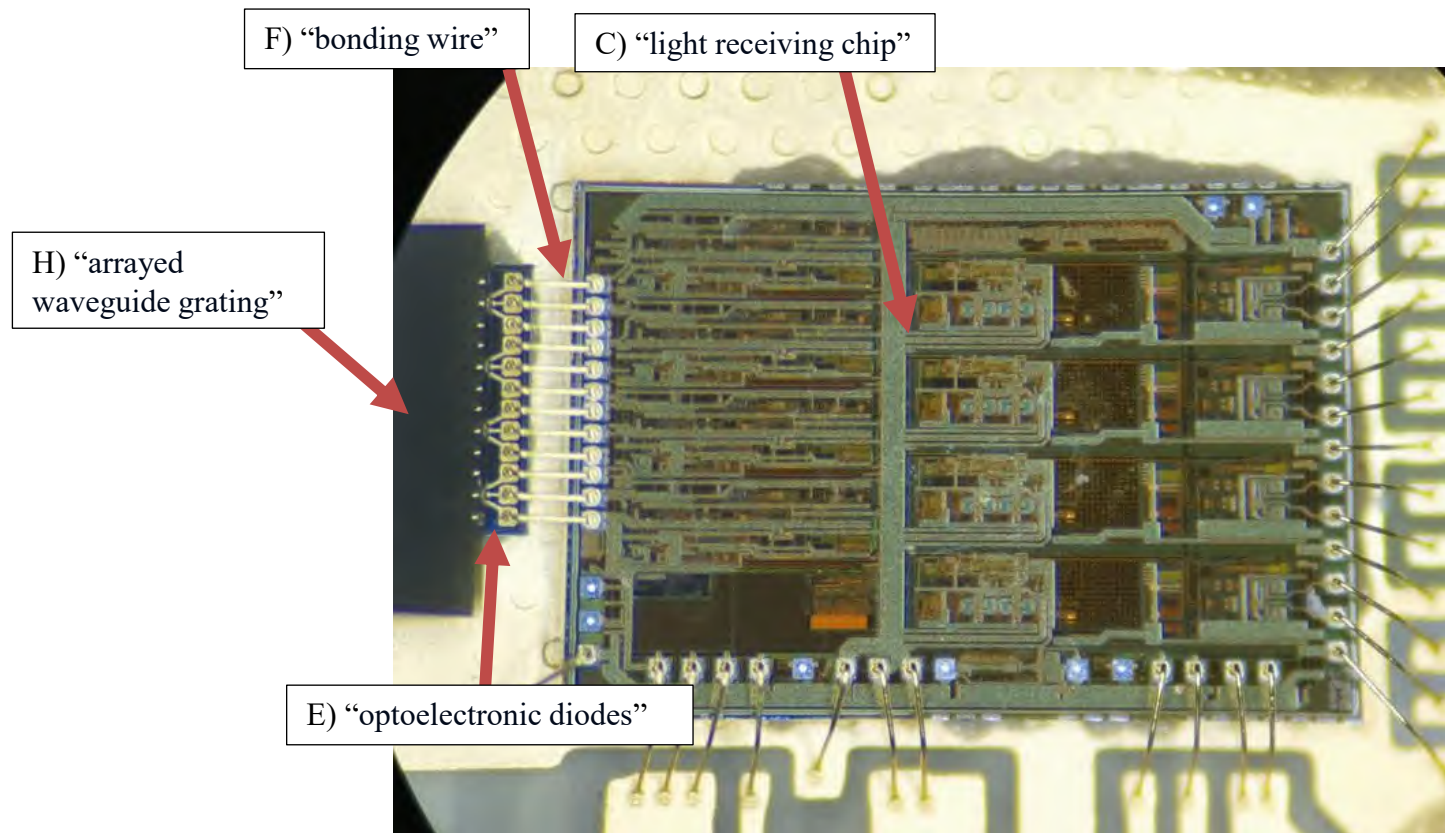


FIG. 3

Exhibit L - Representative Claim Chart for U.S. Patent No. 10,379,301

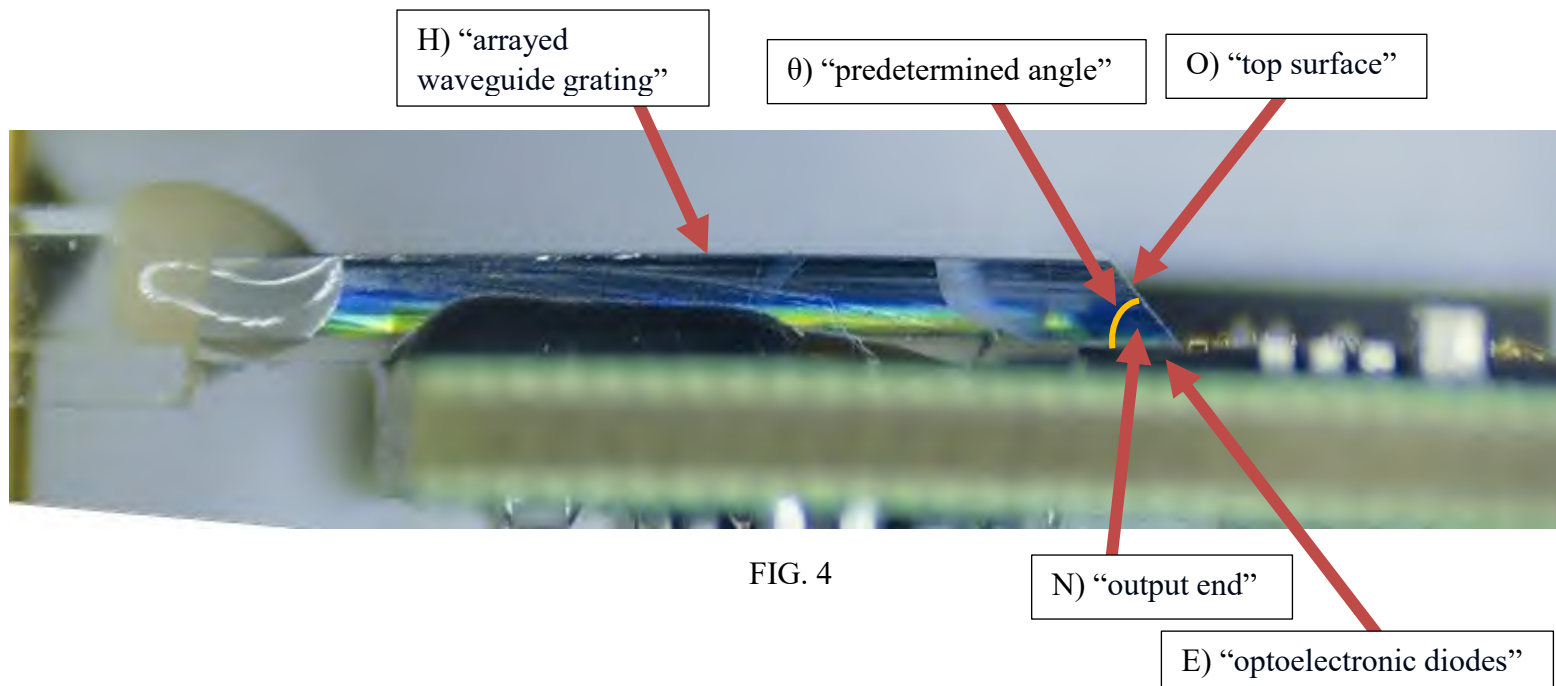


FIG. 4

Exhibit L - Representative Claim Chart for U.S. Patent No. 10,379,301

U.S. Patent No. 10,379,301 Claim 1	ATI 100G QSFP28 CWDM4
A multi-channel parallel optical receiving device, comprising: a carrier;	A multi-channel parallel optical receiving device (A) . See FIG. 1. A carrier (B) . See FIG. 1.
a light receiving chip disposed on a top surface of an end of the carrier;	A light receiving chip (C) is disposed on a top surface (D) of an end (P) of the carrier (B) . See FIGS. 1 and 2.
a plurality of optoelectronic diodes disposed on the top surface of the end of the carrier, and the plurality of optoelectronic diodes electrically connected to the light receiving chip via bonding wire, wherein the optoelectronic diodes and the light receiving chip are disposed directly on the same top surface of the end of the carrier;	A plurality of optoelectronic diodes (E) is disposed on the top surface (D) of the end (P) of the carrier (B) , and the plurality of optoelectronic diodes (E) are electrically connected to the light receiving chip (C) via bonding wire (F) . The optoelectronic diodes (E) and the light receiving chip (C) are disposed directly on the same top surface (D) of the end (P) of the carrier (B) . See FIGS. 1–3.
an optical fiber connector disposed in an end of the carrier;	An optical fiber connector (G) is disposed in an end (Q) of the carrier (B) . See FIG. 1.
an arrayed waveguide grating further disposed on a top surface of the carrier that defines a midpoint of the carrier, the arrayed waveguide grating having a first end, a middle, and a second end disposed opposite the first end, and an input end of the arrayed waveguide grating connected to the optical fiber connector for receiving an optical signal from the optical fiber, wherein the top surface of the carrier underlies the middle of the arrayed waveguide grating; and	An arrayed waveguide grating (H) is disposed on a top surface (S) of the carrier (B) that defines a midpoint (I) of the carrier (B) . The arrayed waveguide grating (H) has a first end (J) , a middle (K) , and a second end (L) disposed opposite the first end (J) , and an input end (M) of the arrayed waveguide grating (H) is connected to the optical fiber connector (G) for receiving an optical signal from the optical fiber. The top surface (S) of the carrier (B) underlies the middle (K) of the arrayed waveguide grating (H) . See FIGS. 1 and 2.
wherein the optical signal is divided into multi-channel optical signals in parallel by the arrayed waveguide grating based on their wavelengths, a top surface defined by an output end of the arrayed waveguide grating is at a predetermined angle, causing the multi-channel optical signals reflected by the top surface defined by the output end of the arrayed waveguide grating to be reflected to a photosensitive surface of the plurality of optoelectronic diodes	The optical signal is divided into multi-channel optical signals in parallel by the arrayed waveguide grating (H) based on their wavelengths. See FIG. 2. A top surface (O) defined by an output end (N) of the arrayed waveguide grating (H) is at a predetermined angle (θ) , causing the multi-channel optical signals reflected by the top surface (O)

Exhibit L - Representative Claim Chart for U.S. Patent No. 10,379,301

U.S. Patent No. 10,379,301 Claim 1	ATI 100G QSFP28 CWDM4
arranged in parallel, wherein the predetermined angle of the top surface defined by the output end of the arrayed waveguide grating is in a range of 41 to 46 degrees such that the top surface provides the reflection.	defined by the output end (N) of the arrayed waveguide grating (H) to be reflected to a photosensitive surface of the plurality of optoelectronic diodes (E) arranged in parallel. The predetermined angle (θ) of the top surface (O) defined by the output end (N) of the arrayed waveguide grating (H) is in a range of 41 to 46 degrees such that the top surface (O) provides the reflection. See FIG. 2 and FIG. 4.

Exhibit M

Exhibit M - Representative Claim Chart for U.S. Patent No. 10,313,024

ATI 100G QSFP LR4

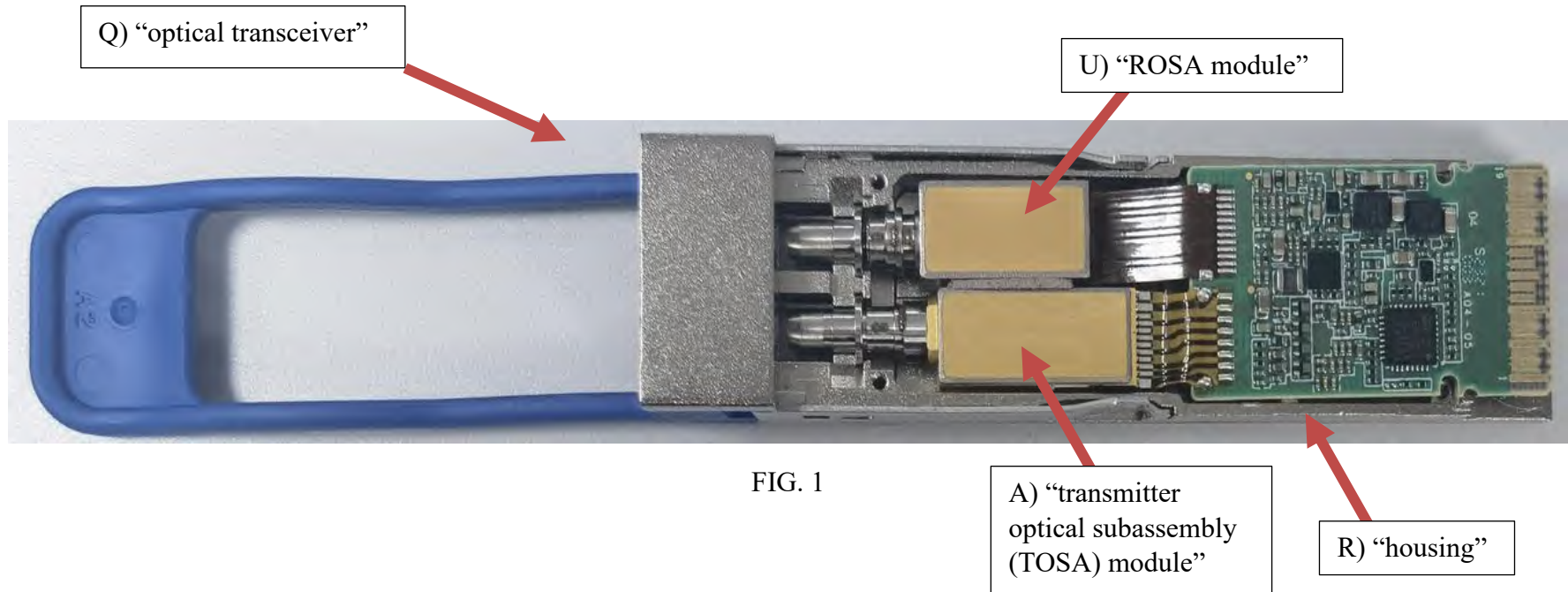


Exhibit M - Representative Claim Chart for U.S. Patent No. 10,313,024

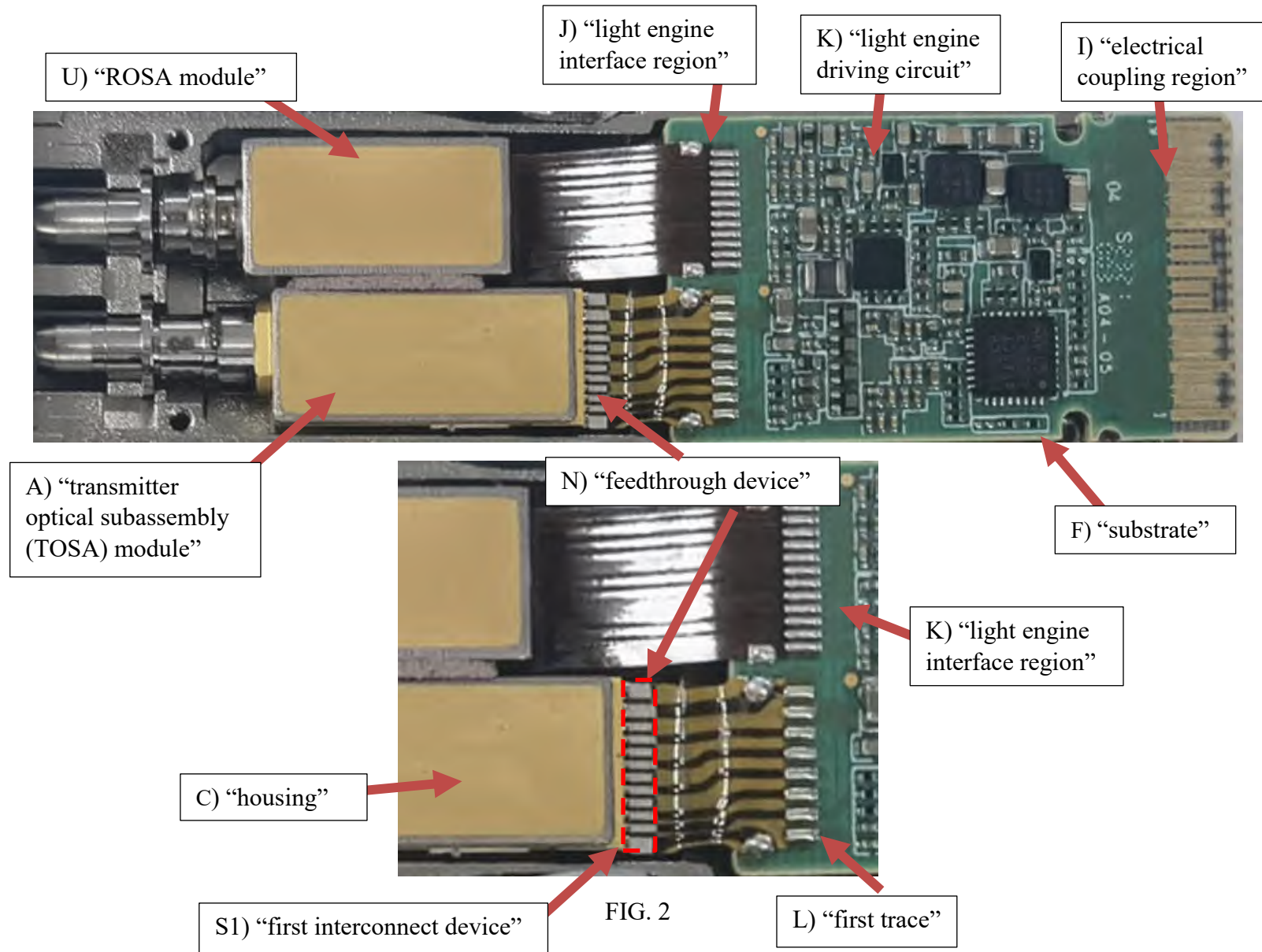


Exhibit M - Representative Claim Chart for U.S. Patent No. 10,313,024

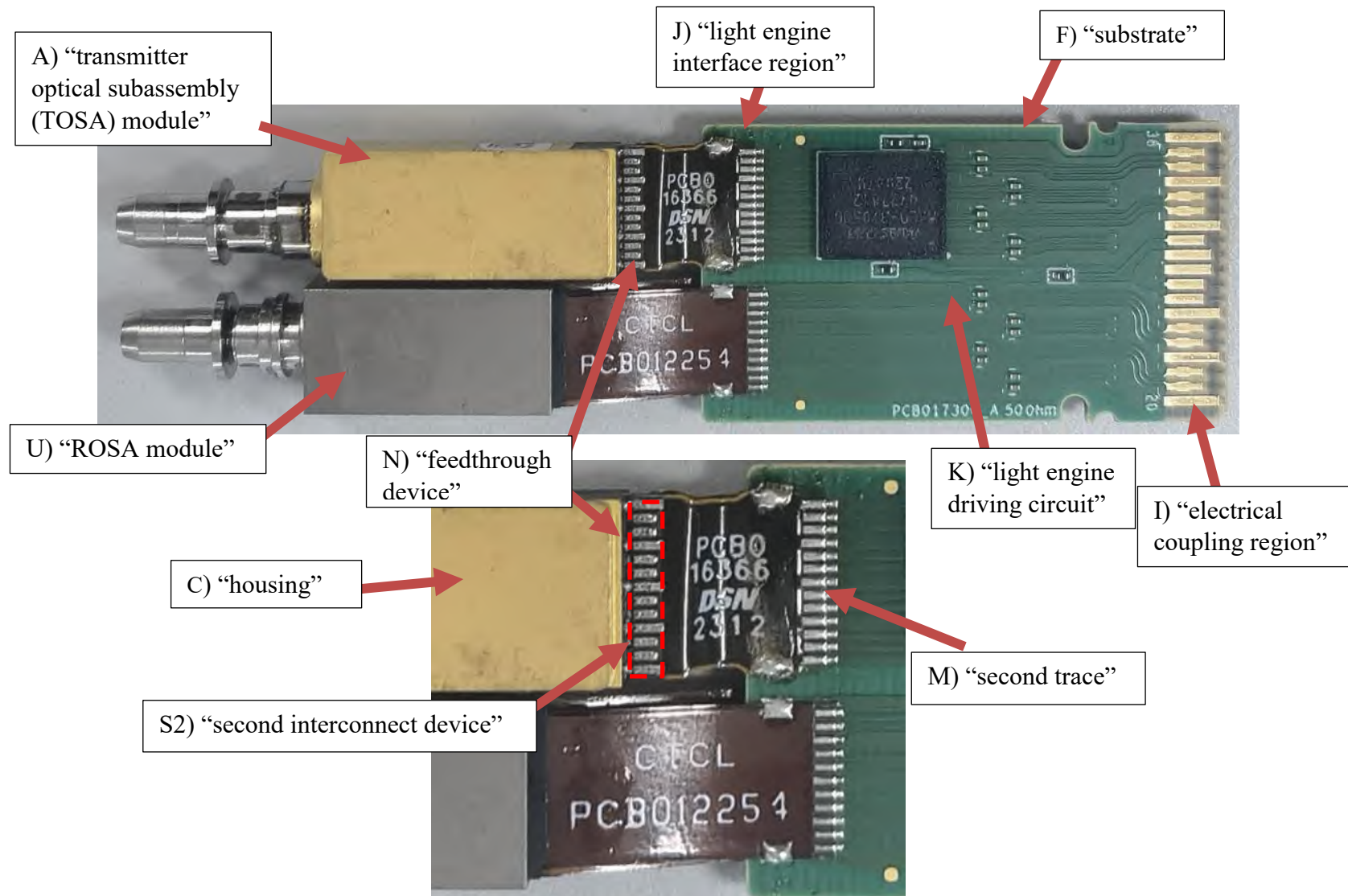


FIG. 3

Exhibit M - Representative Claim Chart for U.S. Patent No. 10,313,024

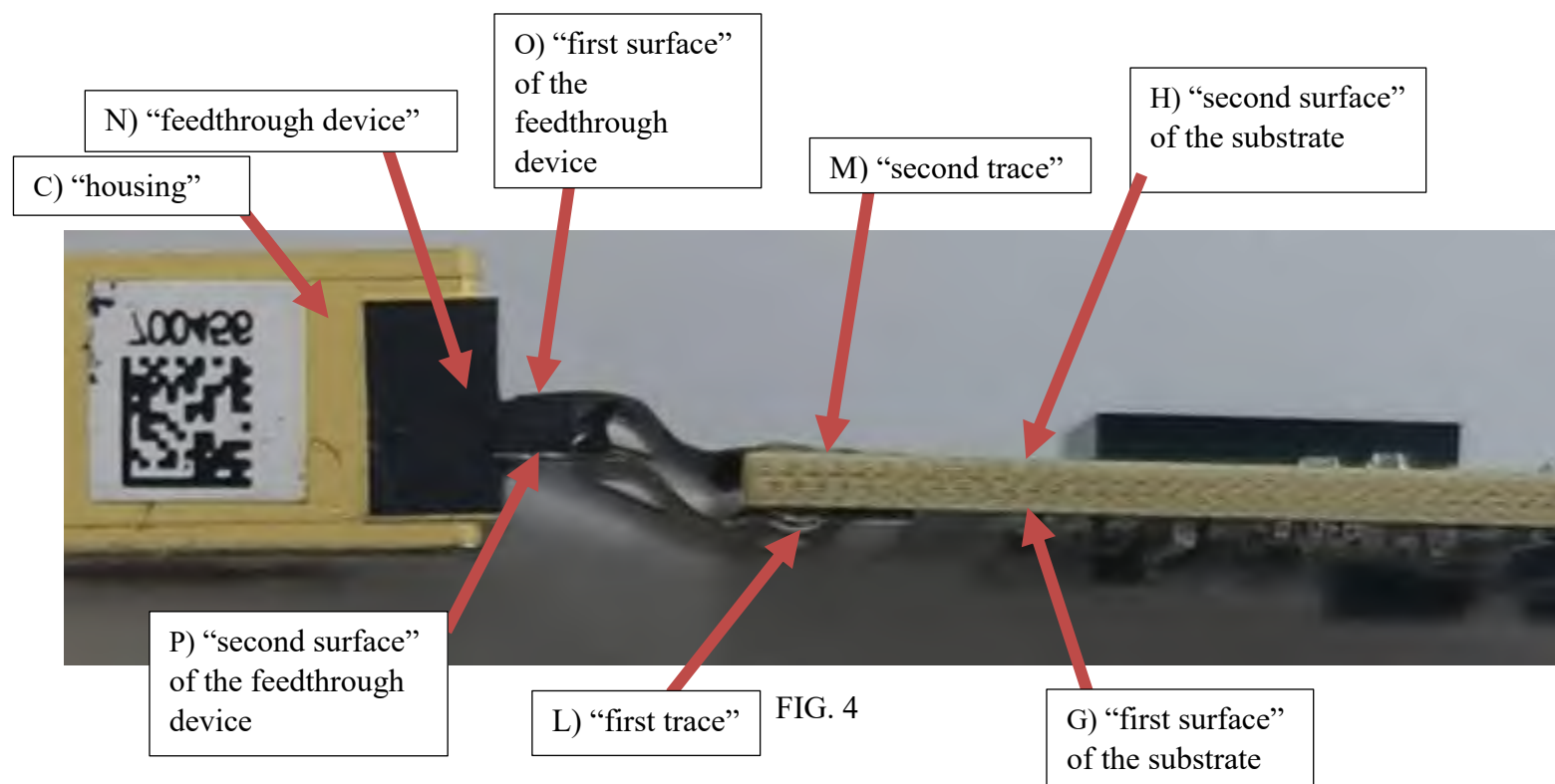


Exhibit M - Representative Claim Chart for U.S. Patent No. 10,313,024

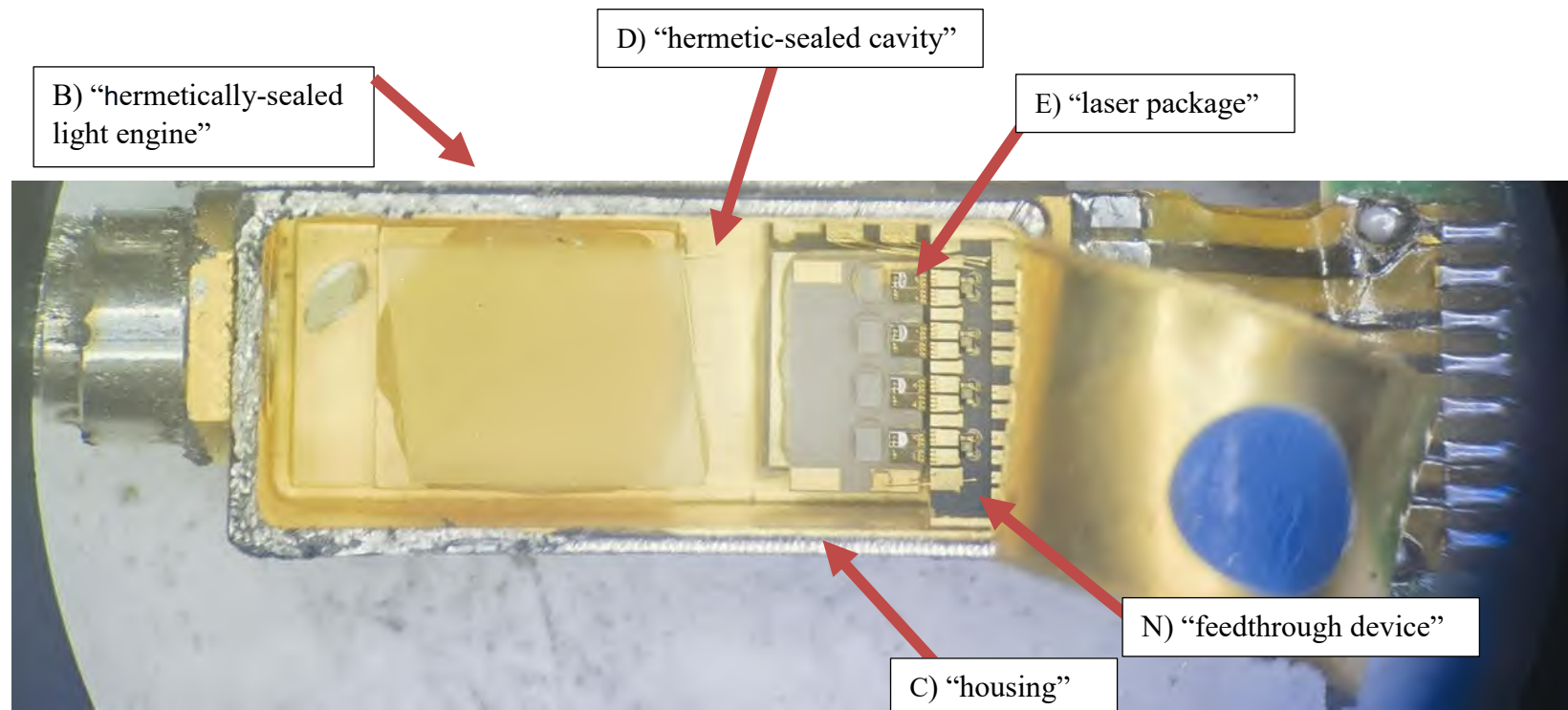


FIG. 5

Exhibit M - Representative Claim Chart for U.S. Patent No. 10,313,024

U.S. Patent No. 10,313,024 Claim 1	ATI 100G QSFP LR4
A transmitter optical subassembly (TOSA) module comprising:	A transmitter optical subassembly (TOSA) module (A) . See FIG. 1.
a hermetically-sealed light engine with a housing that defines a hermetic-sealed cavity and at least one laser package for emitting an associated channel wavelength disposed within the hermetic-sealed cavity;	A hermetically-sealed light engine (B) with a housing (C) that defines a hermetic-sealed cavity (D) and at least one laser package (E) for emitting an associated channel wavelength disposed within the hermetic-sealed cavity (D) . See FIG. 5.
a substrate defined by first and second surfaces disposed opposite each other, the substrate including an electrical coupling region for electrically coupling with a transmit connecting circuit and a light engine interface region for electrically coupling with the hermetically-sealed light engine;	A substrate (F) is defined by first surface (G) and second surface (H) disposed opposite each other. The substrate (F) includes an electrical coupling region (I) for electrically coupling with a transmit connecting circuit and a light engine interface region (J) for electrically coupling with the hermetically-sealed light engine (B) . See FIGS. 2, 4, and 5.
a light engine driving circuit disposed on the substrate to provide a radio frequency (RF) signal and a power signal to drive the hermetically-sealed light engine to output one or more channel wavelengths;	A light engine driving circuit (K) is disposed on the substrate (F) to provide a radio frequency (RF) signal and a power signal to drive the hermetically-sealed light engine (B) to output one or more channel wavelengths. See FIG. 2, 3, and 5.
wherein the substrate includes at least a first trace disposed on the first surface to provide the power signal and at least a second trace disposed on the second surface to provide the RF signal, the first and second traces being disposed in an opposing arrangement to provide electrical isolation to reduce electrical interference between the power signal and the RF signal;	The substrate (F) includes a first trace (L) disposed on the first surface (G) to provide the power signal and a second trace (M) disposed on the second surface (H) to provide the RF signal. See FIGS. 2–4. The first and second traces (L, M) are disposed in an opposing arrangement to provide electrical isolation to reduce electrical interference between the power signal and the RF signal. See FIG. 4.
a feedthrough device to electrically couple the at least one laser package to the light engine driving circuit; and	A feedthrough device (N) to electrically couple the at least one laser package (E) to the light engine driving circuit (K) . See FIGS. 2–5.

Exhibit M - Representative Claim Chart for U.S. Patent No. 10,313,024

U.S. Patent No. 10,313,024 Claim 1	ATI 100G QSFP LR4
wherein the feedthrough device is defined by at least a first surface disposed opposite a second surface, and wherein the first and second surfaces extend substantially parallel with the first and second surfaces of the substrate.	The feedthrough device (N) is defined by at least a first surface (O) disposed opposite a second surface (P) , and the first and second surfaces (O, P) extend substantially parallel with the first and second surfaces (G, H) of the substrate (F) . See FIGS. 2–4.

U.S. Patent No. 10,313,024 Claim 12	ATI 100G QSFP LR4
An optical transceiver comprising:	An optical transceiver (Q) . See FIG. 1.
a housing;	A housing (R) . See FIG. 1.
a transmitter optical subassembly (TOSA) module disposed in the housing, the TOSA module comprising:	A transmitter optical subassembly (TOSA) module (A) is disposed in the housing (R) . See FIG. 1.
a hermetically-sealed light engine with a housing that defines a hermetic-sealed cavity and at least one laser package disposed within the hermetic-sealed cavity;	A hermetically-sealed light engine (B) with a housing (C) that defines a hermetic-sealed cavity (D) and at least one laser package (E) disposed within the hermetic-sealed cavity (D) . See FIGS. 2, 3, and 5.
a substrate defined by first and second surfaces disposed opposite each other, the substrate including an electrical coupling region for electrically coupling with a transmit connecting circuit and a light engine interface region for electrically coupling with the hermetically-sealed light engine;	A substrate (F) is defined by first surface (G) and second surface (H) disposed opposite each other. The substrate (F) includes an electrical coupling region (I) for electrically coupling with a transmit connecting circuit and a light engine interface region (J) for electrically coupling with the hermetically-sealed light engine (B) . See FIGS. 2–5.
a light engine driving circuit disposed on the substrate to provide a radio frequency (RF) signal and a power signal to drive the hermetically-sealed light engine to output one or more channel wavelengths; and	A light engine driving circuit (K) is disposed on the substrate (F) to provide a radio frequency (RF) signal and a power signal to drive the hermetically-sealed light engine (B) to output one or more channel wavelengths. See FIGS. 2, 3, and 5.
wherein the substrate includes at least a first trace disposed on the first surface to provide the power signal, and at least a second trace disposed on the second surface to provide the RF signal, the first and second traces being disposed in an opposing arrangement to provide	The substrate (F) includes a first trace (L) disposed on the first surface (G) to provide the power signal and a second trace (M) disposed on the second surface (H) to provide the RF signal. See FIGS. 2–4.

Exhibit M - Representative Claim Chart for U.S. Patent No. 10,313,024

U.S. Patent No. 10,313,024 Claim 12	ATI 100G QSFP LR4
electrical isolation to reduce electrical interference between the power signal and the RF signal;	The first and second traces (L , M) are disposed in an opposing arrangement to provide electrical isolation to reduce electrical interference between the power signal and the RF signal. See FIG. 4.
at least a first interconnect device of a first type electrically coupled to the first trace and a corresponding trace of the hermetically-sealed light engine to provide the power signal, and at least a second interconnect device of a second type electrically coupled to the second trace and a corresponding trace of the hermetically-sealed light engine to provide the RF signal, the first and second types of interconnect devices being different;	A first interconnect device (S1) of a first type electrically coupled to the first trace (L) and a corresponding trace of the hermetically-sealed light engine (B) to provide the power signal. See FIGS. 2 and 5. A second interconnect device (S2) of a second type electrically coupled to the second trace (M) and a corresponding trace of the hermetically-sealed light engine (B) to provide the RF signal, See FIGS. 3 and 5. The first and second types of interconnect devices are different. See FIGS. 2 and 3.
a receive optical subassembly (ROSA) module disposed in the housing.	A receive optical subassembly (ROSA) module (U) is disposed in the housing (R). See FIG. 1.

Exhibit N

Exhibit N - Representative Claim Chart for U.S. Patent No. 10,788,690

ATI 400G QSFP-DD DR4



Figure. 1

Exhibit N - Representative Claim Chart for U.S. Patent No. 10,788,690

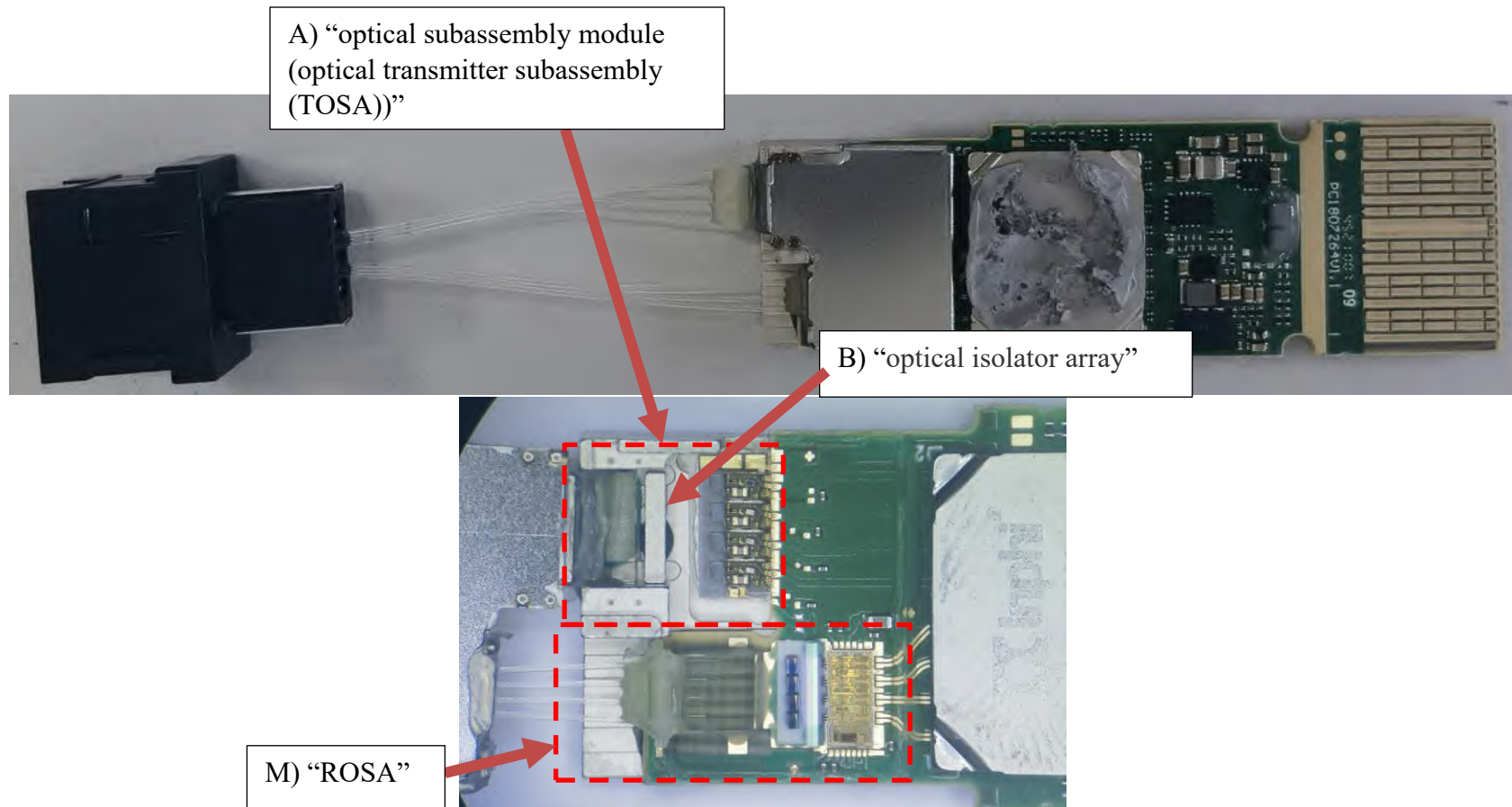


Figure. 2

Exhibit N - Representative Claim Chart for U.S. Patent No. 10,788,690

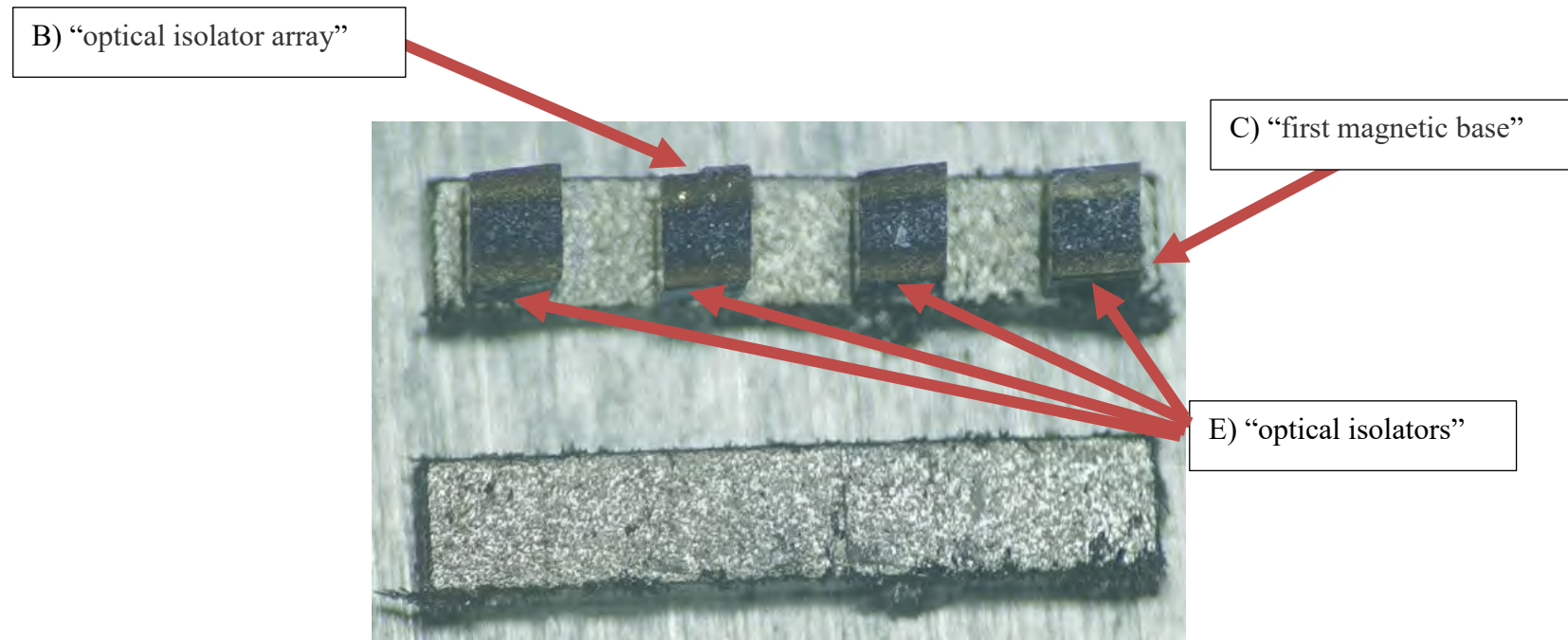


Figure. 3

Exhibit N - Representative Claim Chart for U.S. Patent No. 10,788,690

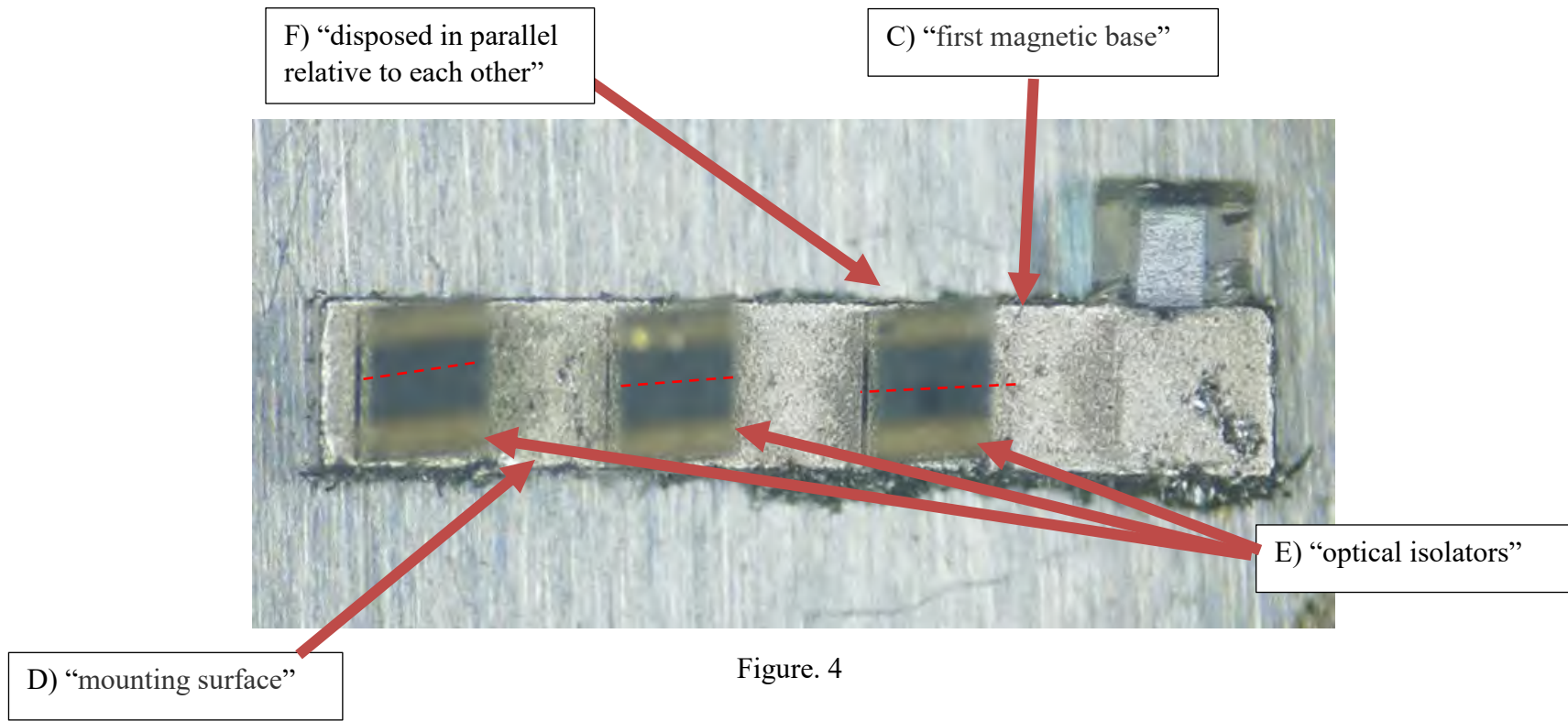


Figure. 4

Exhibit N - Representative Claim Chart for U.S. Patent No. 10,788,690

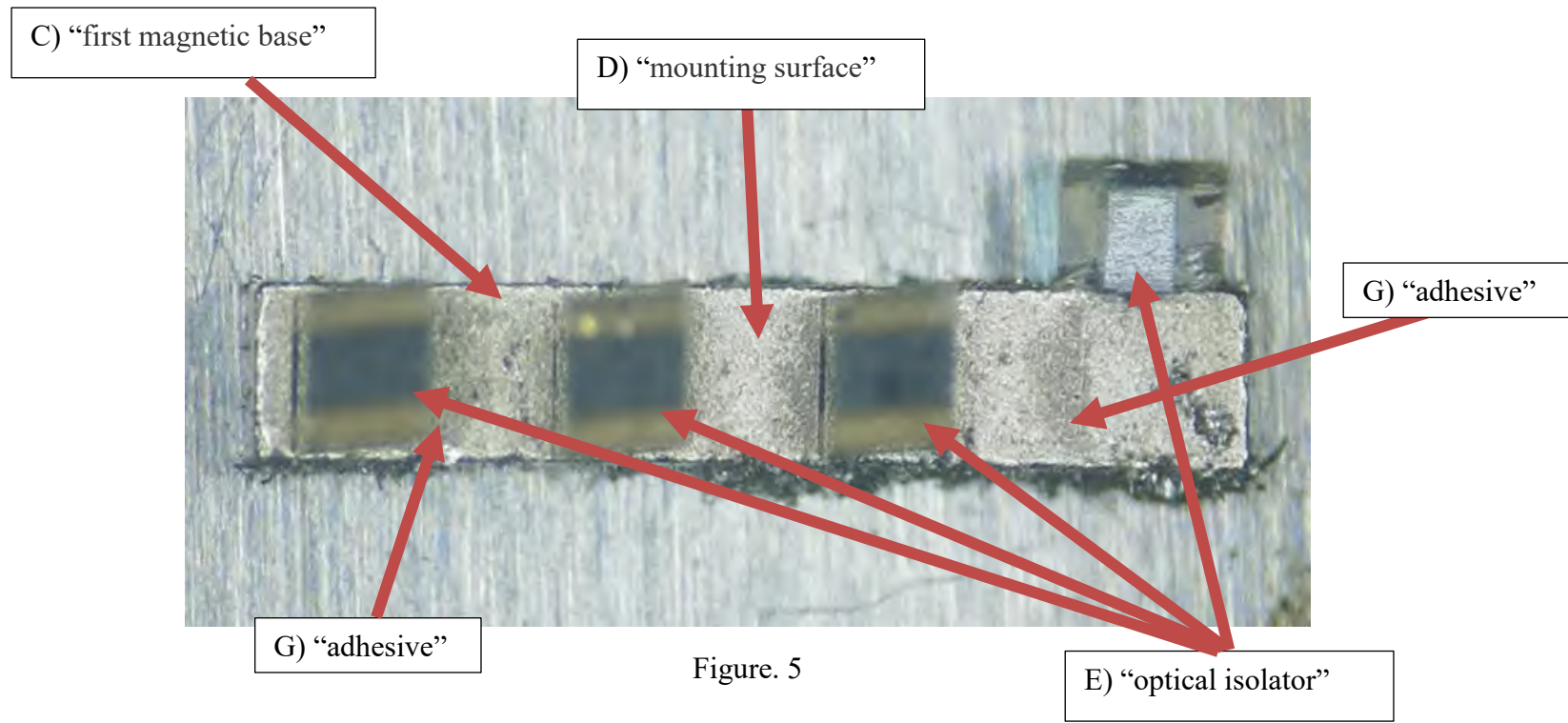


Exhibit N - Representative Claim Chart for U.S. Patent No. 10,788,690

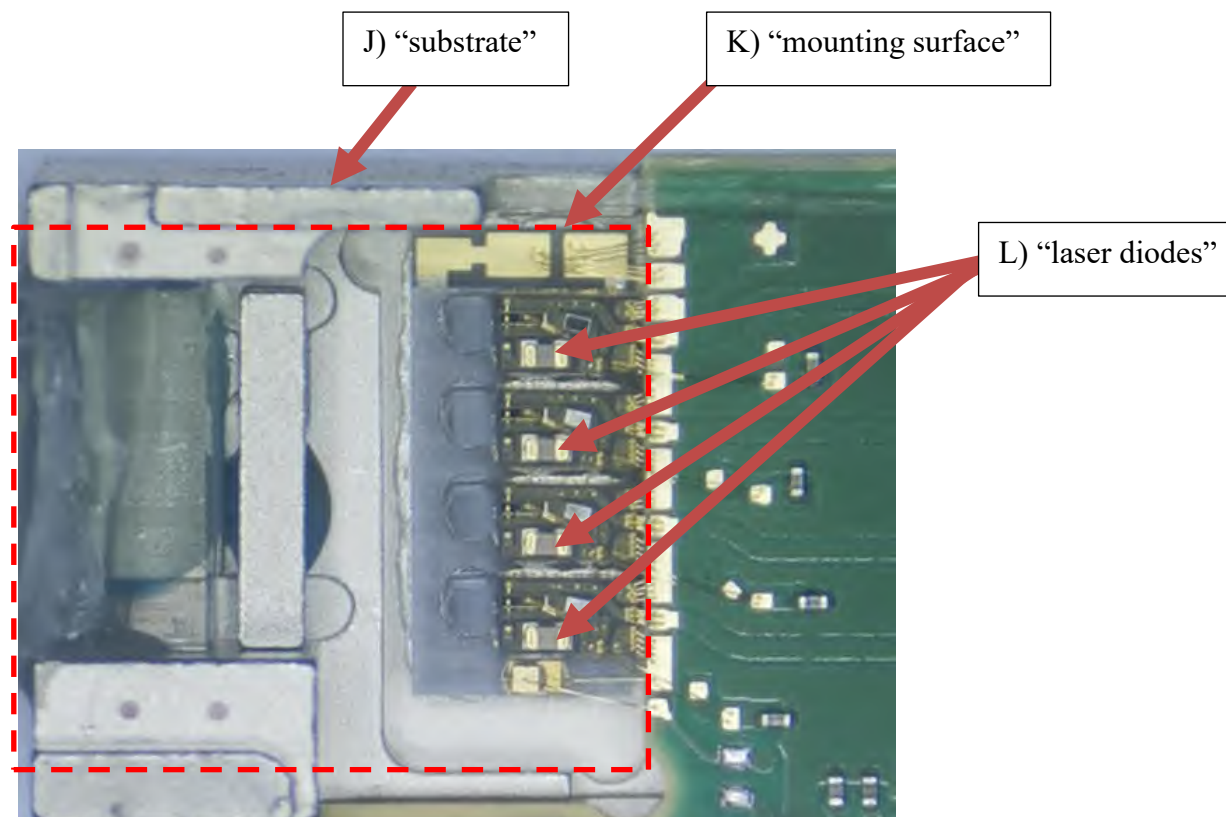


Figure. 6

Exhibit N - Representative Claim Chart for U.S. Patent No. 10,788,690

U.S. Patent No. 10,788,690 Claim 1	ATI 400G QSFP-DD DR4
An optical isolator array for use in an optical subassembly module, the optical isolator array comprising:	Optical isolator array (B) is for use in an optical subassembly module (A) . See FIG. 2.
a first magnetic base defining at least one mounting surface;	First magnetic base (C) defines a mounting surface (D) . See FIGS. 3 and 4.
a plurality of optical isolators mounted to the at least one mounting surface, each of the plurality of optical isolators disposed substantially in parallel relative to each other; and	A plurality of optical isolators (E) are mounted to the mounting surface (D) . Each of the plurality of optical isolators (E) are disposed in parallel (F) relative to each other. See FIG. 4.
at least one layer of adhesive disposed on the at least one mounting surface to couple the plurality of optical isolators to the first magnetic base and to hold each optical isolator of the plurality of optical isolators at a predefined position relative to each other.	A layer of adhesive (G) is disposed on the mounting surface (D) to couple the plurality of optical isolators (E) to the first magnetic base (C) and to hold each optical isolator (E) of the plurality of optical isolators (E) at a predefined position relative to each other. See FIG. 5.

U.S. Patent No. 10,788,690 Claim 11	ATI 400G QSFP-DD DR4
An optical transceiver, the optical transceiver comprising:	An optical transceiver (H) . See FIG. 1.
a transceiver housing;	A transceiver housing (I) . See FIG. 1.
at least one optical transmitter subassembly (TOSA) arrangement disposed in the transceiver housing, the at least one TOSA arrangement comprising:	An optical transmitter subassembly (TOSA) arrangement (optical subassembly module (A)) is disposed in the transceiver housing (I) . See FIGS. 1 and 2.
a substrate defined by at least one mounting surface;	The TOSA arrangement (optical subassembly module (A)) includes a substrate (J) defined by at least one mounting surface (K) . See FIGS. 2 and 6.
a plurality of laser diodes mounted to the at least one mounting surface of the substrate, each laser diode of the plurality of laser diodes to emit a different associated channel wavelength along a corresponding light path of a plurality of light paths; and	A plurality of laser diodes (L) are mounted to the mounting surface (K) of the substrate (J) . Each laser diode of the plurality of laser diodes (L) emits a different associated channel wavelength along a corresponding light path of a plurality of light paths. See FIG. 6.

Exhibit N - Representative Claim Chart for U.S. Patent No. 10,788,690

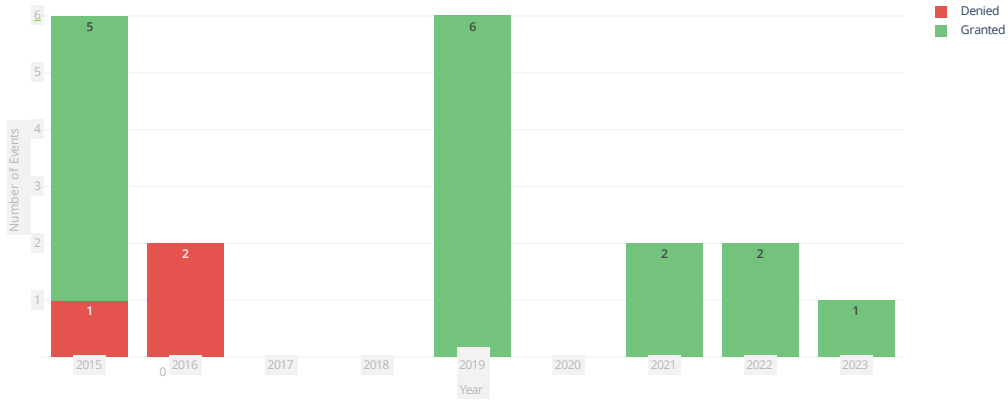
U.S. Patent No. 10,788,690 Claim 11	ATI 400G QSFP-DD DR4
an optical isolator array mounted to the at least one mounting surface adjacent the plurality of laser diodes such that the plurality of light paths intersect with the optical isolator array, the optical isolator array comprising a at least a first magnetic base and a plurality of optical isolators coupled thereto, and wherein each optical isolator is optically aligned with a corresponding laser diode of the plurality of laser diodes via a corresponding light path;	An optical isolator array (B) is mounted to the at least one mounting surface (K) adjacent the plurality of laser diodes (L) such that the plurality of light paths intersect with the optical isolator array (B) . The optical isolator array (B) includes at least a first magnetic base (C) and a plurality of optical isolators (E) coupled thereto. Each optical isolator (E) is optically aligned with a corresponding laser diode (L) of the plurality of laser diodes (L) via a corresponding light path. See FIGS. 3 and 6.
an optical receiver subassembly (ROSA) disposed in the transceiver housing.	An optical receiver subassembly (ROSA) (M) is disposed in the transceiver housing (I) . See FIGS. 1 and 2.

EXHIBIT E

Haywood S. Gilliam

 Motion Success

Stay



This chart shows the [Results](#) of the selected [Type of Document](#) decided by the selected Judge. [Results](#) are grouped into one of three broad categories: Granted, Denied, and Partial. Learn more [here](#).

EXHIBIT F

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE OFFICE OF THE UNDER SECRETARY OF COMMERCE
FOR INTELLECTUAL PROPERTY AND DIRECTOR OF THE
UNITED STATES PATENT AND TRADEMARK OFFICE

TWITCH INTERACTIVE, INC.,
Petitioner,

v.

RAZDOG HOLDINGS LLC,
Patent Owner.

IPR2025-00307 (Patent 9,729,658 B2)
IPR2025-00308 (Patent 10,334,068 B2)

Before COKE MORGAN STEWART, *Acting Under Secretary of
Commerce for Intellectual Property and Acting Director of the United States
Patent and Trademark Office.*

DECISION

Denying Patent Owner's Request for Discretionary Denial

Razdog Holdings LLC (“Patent Owner”) filed a Request for Discretionary Denial (Paper 11, “DD Req.”) in the above-captioned cases, and Petitioner filed an opposition (Paper 13, “DD Opp.”).¹ The parties were authorized to file a Joint Notice updating the record on the status of the parallel litigation (Paper 16, “Notice”) and Patent Owner was authorized to file a Reply (Paper 17) to Petitioner’s Opposition.

After considering the parties’ arguments and the record, and in view of all relevant considerations, discretionary denial of institution is not appropriate in this proceeding. This determination is based on the totality of the evidence and arguments the parties have presented.

Patent Owner’s request is primarily based on a parallel district court proceeding in the Northern District of California. *See generally* DD Req. However, there is no currently scheduled trial date in the co-pending district court litigation. Ex. 1078, 1 (order reassigning case and stating, “[a]ll hearing and trial dates presently scheduled are vacated”); Notice 1. According to Petitioner, even if a trial were to be scheduled, the median time-to-trial statistics suggest trial will begin in February 2027, which would be significantly after the projected final written decision (July 30, 2026). DD Opp. 13 (citing Ex. 1078; Ex. 1069). Furthermore, Petitioner has provided persuasive evidence that “[t]here is good reason to believe that a stay will be granted.” *Id.* at 12. Specifically, Petitioner indicates that “[o]ver the past twelve years, judges in the district have granted or partially granted 76% of all post-institution motions to stay pending *inter partes*

¹ Citations are to papers in IPR2025-00307. The parties filed similar papers in IPR2025-00308.

IPR2025-00307 (Patent 9,729,658 B2)
IPR2025-00308 (Patent 10,334,068 B2)

review” and “Judge Gilliam has granted all post-institution stay motions since 2016.” *Id.* (citing Ex. 1074; Ex. 1079).

Patent Owner also makes several arguments in its request regarding alleged weaknesses of the Petition (DD Req. 17–18), alleged improper or undue reliance on expert opinion (*id.* at 18–19), alleged settled expectations of the parties (*id.* at 19–20), and alleged importance of an *ex parte* reexamination challenging U.S. Patent No. 10,334,068 patent (*id.* at 20, Reexam. Control No. U.S. 90/019,860). However, none of these allegations are sufficiently explained.

Although certain arguments are highlighted above, the determination not to exercise discretion to deny institution is based on a holistic assessment of all of the evidence and arguments presented. Accordingly, the Petition is referred to the Board to handle the case in the normal course, including by issuing a decision on institution addressing the merits and other non-discretionary considerations, as appropriate.

In consideration of the foregoing, it is:

ORDERED that Patent Owner’s Request for Discretionary Denial is *denied*;

FURTHER ORDERED that the Petition is referred to the Board; and

FURTHER ORDERED that neither party shall file a request for rehearing or Director Review of this decision until the Board issues a decision on institution.

IPR2025-00307 (Patent 9,729,658 B2)
IPR2025-00308 (Patent 10,334,068 B2)

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EXHIBIT G

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA

APPLE INC.,
Plaintiff,
v.
ALIVECOR, INC.,
Defendant.

Case No. [22-cv-07608-HSG](#)

**ORDER GRANTING MOTION TO
STAY**

Re: Dkt. No. 62

On October 23, 2023, Defendant AliveCor, Inc. (“Defendant” or “AliveCor”) filed a motion to stay the case pending completion of *inter partes review* (“IPR”) proceedings. Dkt. No. 62 (“Mot.”). The Court, in its discretion, finds this matter suitable for resolution without oral argument. *See* Civ. L.R. 7–1(b). For the reasons articulated below, the Court **GRANTS** AliveCor’s motion and stays this action pending the institution decisions regarding its IPR petitions.

I. BACKGROUND

Plaintiff Apple, Inc. (“Apple”) filed this action for patent infringement on December 12, 2022. Dkt. No. 1. In the Complaint, Apple alleges direct and indirect infringement of four patents, all related to electrocardiogram (“EKG”) technology and related applications: U.S. Patent Nos. 10,076,257 (“the ’257 Patent”); 10,270,898 (“the ’898 Patent”); 10,866,619 (“the ’619 Patent”); 10,568,533 (“the ’533 Patent”) (collectively “Asserted Patents”). *See id.* ¶¶ 13, 16, 19, 22. Apple asserts at least claim 1 of the ’257 Patent (*id.* ¶ 30); at least claim 1 of the ’619 Patent (*id.* ¶ 57); at least claim 1 of the ’898 Patent (*id.* ¶ 86); and at least claim 20 of the ’533 Patent (*id.* ¶ 119). The accused products are AliveCor’s KardiaMobile Card, KardiaMobile, KardiaMobile 6L, Kardia App, KardiaPro (and related products) and Kardia care (and related products)

(collectively, “Accused Products”). *Id.*, ¶ 24.

On June 7, 2023, AliveCor filed two petitions for *inter partes* review (“IPR”) at the United States Patent and Trademark Office (“USPTO”), challenging the patentability of the ’619 Patent (IPR2023-00948 and IPR2023-00949) and one petition for IPR challenging the patentability of the ’257 Patent (IPR2023-00950). Mot. at 2. On September 27, 2023, and October 30, 2023, AliveCor filed further petitions for IPR challenging the patentability of the ’898 Patent and ’533 Patent, respectively (IPR2023-01434 and IPR2024-00095). *Id.* On October 23, 2023, AliveCor filed this motion, requesting that the Court stay this action pending resolution of the IPRs. The USPTO is expected to issue decisions whether to institute IPR2023-00948 and IPR2023-00949 on January 12, 2024, and whether to institute IPR 2023-00950 on January 11, 2024. *Id.* The institution decision for IPR2023-01434 is expected on April 5, 2024, and IPR2024-00095 is expected shortly thereafter. Finally, the USPTO has instituted an IPR proceeding as to the ’257 Patent, brought by Masimo Corporation, on October 16, 2023. *Id.*

II. LEGAL STANDARD

“Courts have inherent power to manage their dockets and stay proceedings, including the authority to order a stay pending [IPR].” *Ethicon, Inc. v. Quiggin*, 849 F.2d 1422, 1426–27 (Fed. Cir. 1988) (internal citations omitted); *IXI Mobile (R & D) Ltd. v. Samsung Elecs. Co.*, No. 15-cv-03752-HSG, 2015 WL 7015415, at *2 (N.D. Cal. Nov. 12, 2015). Courts consider three factors in determining whether to grant a stay pending IPR: “(1) whether discovery is complete and whether a trial date has been set; (2) whether a stay will simplify the issues in question and trial of the case; and (3) whether a stay would unduly prejudice or present a clear tactical disadvantage to the non-moving party.” *IXI Mobile (R & D) Ltd.*, 2015 WL 7015415, at *2 (quoting *Evolutionary Intelligence, LLC v. Facebook, Inc.*, No. 13-cv-04202-SI, 2014 WL 261837, at *1 (N.D. Cal. Jan. 23, 2014)). The moving party bears the burden of demonstrating that a stay is appropriate. *DSS Tech. Mgmt., Inc. v. Apple, Inc.*, No. 14-cv-05330-HSG, 2015 WL 1967878, at *2 (N.D. Cal. May 1, 2015).

Courts in this district have often recognized “a liberal policy in favor of granting motions to stay” pending IPR. *See Pragmatus AV, LLC v. Facebook, Inc.*, No. 11-cv-02168-EJD, 2011

WL 4802958, at *2 (N.D. Cal. Oct. 11, 2011); *IXI Mobile (R & D) Ltd.*, 2015 WL 7015415, at *2. Courts, however, must evaluate stay requests on a case-by-case basis. *See GoPro, Inc. v. C&A Marketing, Inc.*, No. 16-cv-03590-JST, 2017 WL 2591268, at *2 (N.D. Cal. June 15, 2017). Ultimately, whether to issue a stay is a matter of the Court’s discretion.

III. DISCUSSION

A. Factor 1: Stage of Proceedings

“The first factor the Court considers is whether the litigation is at an early stage.” *Cooler Master Co. v. Asetek Danmark A/S*, No. 21-CV-04627-HSG, 2022 WL 2673089, at *2 (N.D. Cal. June 14, 2022) (citing *AT&T Intellectual Property I v. Tivo, Inc.*, 774 F. Supp. 2d 1049, 1052 (N.D. Cal. 2011)). Specifically, courts consider “whether discovery is complete and whether a trial date has been set.” *Evolutionary Intelligence*, 2014 WL 261837, at *1.

AliveCor contends that this factor weighs in favor of a stay because “[t]his case undoubtedly remains in the initial stages of litigation” and “[t]his is not a case where a substantial amount of fact discovery has been completed.” Mot. at 4. AliveCor represents that neither party has taken a single deposition, nor engaged in expert discovery. *Id.* Apple contends that this factor weighs against a stay as claim construction is underway, and Apple has filed its opening claim construction brief. *See* Dkt. No. 88.

While the Court recognizes that claim construction has begun, the Court finds that this case is still at a relatively early stage overall. Discovery is far from complete, and no trial date has been set. Accordingly, this factor weighs in favor of a stay, certainly at least until the USPTO issues institution decisions as to the AliveCor IPR petitions.

B. Factor 2: Simplification of Case

AliveCor argues that a stay would simplify the issues in this case, “by rendering some or all of Apple’s infringement claims moot, simplifying AliveCor’s invalidity arguments at trial, and providing the Court with the USPTO’s expert opinion on the claims at issue.” Mot. at 5.

Apple does not meaningfully dispute that the IPRs could simplify the issues in this case, instead arguing that it is unlikely the USPTO will institute based on AliveCor’s IPR petitions because “AliveCor’s IPR petitions are unusually weak on the merits.” Dkt No. 65 (“Opp.”) at 5.

Apple urges the Court to consider the merits of AliveCor’s IPR petitions and conclude that the USPTO likely will decline institution, such that a stay would unnecessarily delay this case. The Court declines to do so. The institution decisions regarding the AliveCor IPR petitions are expected soon, and a stay until those decisions are issued will not unduly delay the case. There is no reason for the Court to delve into the merits of these IPR petitions when the USPTO’s decisions are imminent. And once Apple’s invitation to prejudge the outcome of those decisions is set to the side, this case squarely presents the usual situation in which the results of any instituted IPRs obviously could simplify the case. Therefore, this factor also weighs in favor of a stay pending the institution decisions.

C. Factor 3: Prejudice and Disadvantage

The final factor considers whether a stay would unduly prejudice the nonmoving party. In assessing this factor, courts “address four considerations when evaluating prejudice: (1) the timing of the IPR petition; (2) the timing of the stay request; (3) the status of review; and (4) the relationship of the parties.” *Cooler Master*, 2022 WL 2673089, at *2 (citing *SAGE Electrochromics, Inc. v. View, Inc.*, No. 12-cv-06441-JST, 2015 WL 66415, at *3 (N.D. Cal. Jan. 5, 2015)).

i. Timing of IPR Petitions and Request to Stay

AliveCor filed its earliest IPR petitions on June 7, 2023, and filed this motion on October 23, 2023, roughly a week before the filing of its final IPR petition. Stays pending IPR can result in substantial delay in the district court proceeding, but the current record does not support a finding of purposeful delay or lack of diligence by AliveCor. The Court finds that the timing of the IPR petitions and motion to stay weighs in favor of a stay.

ii. Status of Proceedings

Institution decisions in the AliveCor IPR petitions are expected shortly, with the earliest within a few weeks of the date of this order. Moreover, the USPTO has instituted one IPR proceeding against the ’257 Patent, which AliveCor represents as including “some overlapping prior art asserted in AliveCor’s petition.” Dkt. No. 69 (“Reply”) at 5. Thus, this subfactor also weighs in favor of a stay.

iii. Relationship of the Parties

In considering the relationship of the parties, the Court asks if the parties are direct competitors, which would increase the risk of prejudice to the non-moving party. *See TPK Touch Sols. Inc. v. Wintek Electro-Optics Corp.*, No. 13-cv-02218 JST, 2013 WL 6021324, at *5 (N.D. Cal. Nov. 13, 2013). However, courts in this district require “evidence to substantiate an argument that direct competition will result in prejudice to the non-moving party.” *Cypress Semiconductor Corp. v. GSI Tech., Inc.*, No. 13–CV–02013–JST, 2014 WL 5021100, at *5 (N.D. Cal. Oct. 7, 2014) (collecting cases). AliveCor represents that it and Apple were, but no longer are, direct competitors. *See* Mot. at 7; Reply at 3. For its part, Apple does not contend that the parties are currently direct competitors, but argues that AliveCor’s positions in this motion are inconsistent with positions it has taken in other cases. Opp. at 3.

Apple’s primary argument on this factor is that the risk of prejudice is high because the relationship between the parties is “unique,” in that this case is part of a “broader set of legal disputes between the parties.” Opp. at 2. It argues that AliveCor is seeking an “unfair advantage” here by asking to delay this proceeding while simultaneously seeking resolution of other disputes where it is the petitioning party, including in this District and before the United States International Trade Commission. *Id.* The Court is not convinced that Apple has established “evidence to substantiate its general assertions that a stay will result in competitive injury.” *Cooler Master*, 2022 WL 2673089, at *3. Apple’s sole argument here is that there are other proceedings in which AliveCor has not sought a stay, but those proceedings involve entirely different patents – or in the case of the antitrust lawsuit, entirely different claims – such that a stay may or may not have been appropriate given the circumstances in those cases. Apple provides no evidence as to why the relationship of the parties, or the existence of those pending parallel actions, would uniquely prejudice Apple beyond the delay necessarily inherent in any stay. *See PersonalWeb Techs., LLC v. Apple Inc.*, 69 F. Supp. 3d 1022, 1029 (N.D. Cal. 2014). Absent such evidence, the Court does not find that a stay at least until institution decisions issue on the AliveCor IPR petitions would uniquely or unduly prejudice Apple here.

1 **IV. CONCLUSION**

2 Having considered the relevant factors in their entirety, the Court finds in its discretion that
3 a stay of this case pending at least the first institution decisions on AliveCor's IPR petitions is
4 warranted. Accordingly, the Court **GRANTS** AliveCor's motion to stay pending an initial
5 decision by the USPTO concerning whether to institute AliveCor's IPR petitions. Within seven
6 days of the issuance of the USPTO's decisions on whether to institute IPR on the '619 and '257
7 Patents, the parties shall file a joint status report of no more than one page, without any argument,
8 simply notifying the Court of the decisions and attaching copies. Once it reviews that report, the
9 Court will decide whether to lift or continue the stay, which remains in place unless and until
10 otherwise ordered.

11 **IT IS SO ORDERED.**

12 Dated: December 29, 2023



HAYWOOD S. GILLIAM, JR.
United States District Judge

EXHIBIT H

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA

COOLER MASTER CO., LTD., et al.,

Plaintiffs,

v.

ASETEK DANMARK A/S,

Defendant.

Case No. [21-cv-04627-HSG](#)

**ORDER GRANTING MOTION TO
STAY**

Re: Dkt. No. 34

In June 2021, Plaintiffs Cooler Master Co., Ltd. and CMI USA, Inc. (collectively “Cooler Master”) filed a complaint against Asetek Danmark A/S (“Asetek”) seeking a declaratory judgment that Cooler Master is not infringing seven Asetek patents. *See* Dkt. No. 1. In December 2021, Asetek filed counterclaims, which it later amended, against Cooler Master Co., Ltd. and CMI USA, Inc. alleging they had infringed two Asetek patents. *See* Dkt. Nos. 20, 26.

Now pending before the Court is Asetek’s motion to stay pending *inter partes* review (“IPR”), briefing for which is complete. Dkt. Nos. 34 (“Mot.”), 38 (“Opp.”), 39 (“Reply”). After carefully considering the parties’ arguments, the Court **GRANTS** Asetek’s motion to stay.

I. BACKGROUND

Cooler Master seeks a declaratory judgment of non-infringement regarding seven patents: 8,240,362 (the “’362 patent”), 8,245,764 (the “’764 patent”), 9,733,681 (the “’681 patent”), 10,078,354 (the “’354 patent”), 10,078,355 (the “’355 patent”), 10,599,196 (the “’196 patent”), and 10,613,601 (the “’601 patent”). *See* Dkt. No. 1. According to Cooler Master, the patents consist of two patent families. The first is the ’362 patent family, which includes patents ’354 and ’601. *Id.* ¶ 18. The second is the ’764 family, which includes patents ’681, ’355, and ’196. *Id.* Asetek’s counterclaims for patent infringement concern the ’362 and ’764 patents. Dkt. No. 20 at

¶¶ 12-13, 23-24.

Asetek alleges that five of the seven patents at issue in this case are also the subject of instituted IPRs or appeals before the Federal Circuit as a result of separate litigation between CoolIT Systems, Inc. (“CoolIT”) and Asetek. Mot. at 3. For patents ’681, ’354, and ’355, the IPR proceedings resulted in final written decisions in August 2021, and appeals to the Federal Circuit were filed in October 2021. *Id.* at 3-4. For patents ’196 and ’601, IPR proceedings were instituted in December 2021, and final written decisions are expected by the end of this year. *Id.*; see 35 U.S.C. § 316(a)(11); 37 C.F.R. § 42.100(c). Additionally, Asetek represents that claims involving the ’196, ’601, and ’362 patents are set to go to trial before Judge Chen in *Asetek Danmark A/S v. Coolit Systems Inc.*, Case No. 3:19-cv-00410-EMC. *Id.* at 4. A review of that case’s docket shows that trial is set for March 2023.

II. LEGAL STANDARD

“Courts have inherent power to manage their dockets and stay proceedings, including the authority to order a stay pending [IPR].” *Ethicon, Inc. v. Quigg*, 849 F.2d 1422, 1426–27 (Fed. Cir. 1988) (internal citations omitted); *IXI Mobile (R & D) Ltd. v. Samsung Elecs. Co.*, No. 15-cv-03752-HSG, 2015 WL 7015415, at *2 (N.D. Cal. Nov. 12, 2015). Courts consider three factors in determining whether to grant a stay pending IPR: “(1) whether discovery is complete and whether a trial date has been set; (2) whether a stay will simplify the issues in question and trial of the case; and (3) whether a stay would unduly prejudice or present a clear tactical disadvantage to the non-moving party.” *IXI Mobile (R & D) Ltd.*, 2015 WL 7015415, at *2 (quoting *Evolutionary Intelligence, LLC v. Facebook, Inc.*, No. 13-cv-04202-SI, 2014 WL 261837, at *1 (N.D. Cal. Jan. 23, 2014)). The moving party bears the burden of demonstrating that a stay is appropriate. *DSS Tech. Mgmt., Inc. v. Apple, Inc.*, No. 14-cv-05330-HSG, 2015 WL 1967878, at *2 (N.D. Cal. May 1, 2015).

Courts in this district have often recognized “a liberal policy in favor of granting motions to stay” pending IPR. *See Pragmatus AV, LLC v. Facebook, Inc.*, No. 11-cv-02168-EJD, 2011 WL 4802958, at *2 (N.D. Cal. Oct. 11, 2011); *IXI Mobile (R & D) Ltd.*, 2015 WL 7015415, at *2. Courts, however, must evaluate stay requests on a case-by-case basis. *See GoPro, Inc. v. C&A*

Marketing, Inc., No. 16-cv-03590-JST, 2017 WL 2591268, at *2 (N.D. Cal. June 15, 2017). And whether to stay is always within the court’s discretion.

III. DISCUSSION

A. Factor 1: Stage of the Proceedings

The first factor the Court considers is whether the litigation is at an early stage. *See AT&T Intellectual Property I v. Tivo, Inc.*, 774 F. Supp. 2d 1049, 1052 (N.D. Cal. 2011). Specifically, courts consider “whether discovery is complete and whether a trial date has been set.” *Evolutionary Intelligence*, 2014 WL 261837, at *1.

Asetek contends that this factor favors a stay because the “case is indisputably in a very early stage.” Mot. at 5. Asetek represents that the parties have not engaged in any fact or expert discovery or exchanged infringement or invalidity contentions. *Id.* The claim construction process has not begun, no substantive or dispositive motions have been filed, and the Court has yet to enter a case schedule. Cooler Master agrees that the case is at a relatively early stage. Opp. at 2.

Given the early stage of this litigation, the Court find that this factor weighs in favor of a stay.

B. Factor 2: Simplification of the Case

Asetek contends that “a majority of the patents Cooler Master brought into this action are involved in already-instituted IPRs, appeals therefrom, and/or imminent jury trial, which strongly favors a stay.” Mot. at 7. Asetek argues that these proceedings will simplify the “issues in question and trial of the case.” *Id.* Cooler Master likewise agrees that the proceedings could simplify this case and that the factor tends to favor a stay. *See* Opp. at 2-3.

The Court agrees that this factor weighs in favor of a stay. As other courts have noted, a crucial consideration under this factor is the status of the institution decision. *See GoPro, Inc.*, 2017 WL 2591268, at *4. The PTAB issued final written decisions regarding three of the patents at issue in this case, and those decisions are currently on appeal before the Federal Circuit. Mot. at 7. And since PTAB is expected to issue final written decisions on two additional patents by the end of this year, *id.*, there is a real possibility that the IPR process, and the results of the pending

appeals, will simplify the case.

C. Factor 3: Prejudice and Disadvantage

The final factor considers whether a stay would unduly prejudice the nonmoving party. Courts here consider whether the moving party engaged in dilatory tactics, such as seeking review in an untimely fashion. *See GoPro, Inc.*, 2017 WL 2591268, at *4. Courts address four considerations when evaluating prejudice: (1) the timing of the IPR petition; (2) the timing of the stay request; (3) the status of review; and (4) the relationship of the parties. *See SAGE Electrochromics, Inc. v. View, Inc.*, No. 12-cv-06441-JST, 2015 WL 66415, at *3 (N.D. Cal. Jan. 5, 2015) (quoting *Ever Win Int'l Corp. v. Radioshack Corp.*, 902 F. Supp. 2d 503, 508 (D. Del. 2012)).

i. Timing of IPR Petition and Request for Stay

Asetek answered Cooler Master's complaint and filed its counterclaims in December 2021. By that time, Asetek and CoolIT had already appealed PTAB's decisions regarding three of the patents at issue here. That same month, IPR proceedings for another two patents were instituted. On February 9, 2022, Asetek filed the instant motion to stay. Stays pending IPR can result in substantial delay in the district court proceeding, but the current record does not support a finding of purposeful delay or lack of diligence by Asetek. The Court finds that the timing of the IPR petition and motion to stay weighs in favor of a stay.

ii. Status of Proceedings

The IPR proceedings are well underway. For three of the patents, the proceedings have already resulted in final written decisions now being appealed. And the IPR proceedings for two other patents were instituted in December 2021 with final written decisions expected by December 2022. Given the advanced stage of the IPR proceedings, the Court finds that this consideration weighs in favor of a stay.

iii. Relationship of the Parties

Where parties are direct competitors, the risk of prejudice to the non-moving party is higher than it would be otherwise. *See TPK Touch Sols. Inc. v. Wintek Electro-Optics Corp.*, No. 13-cv-02218 JST, 2013 WL 6021324, at *5 (N.D. Cal. Nov. 13, 2013). However, courts in this

1 district require “evidence to substantiate an argument that direct competition will result in
2 prejudice to the non-moving party.” *Cypress Semiconductor Corp. v. GSI Tech., Inc.*, No. 13–
3 CV–02013–JST, 2014 WL 5021100, at *5 (N.D. Cal. Oct. 7, 2014) (collecting cases).

4 Cooler Master represents that it and Asetek are “head-to-head competitors,” and alleges
5 that Asetek “continues to poison the market” by broadcasting that Cooler Master is infringing on
6 Asetek’s patents. Opp. at 2. Cooler Master argues that a stay in this case allows Asetek to
7 continue to “disparage” Cooler Master’s products, which disparagement “can be expected to have
8 a chilling effect on Cooler Master’s sales and harm Cooler Master’s business relations, etc.” *Id.* at
9 3.

10 Because of this, Cooler Master requests that the Court enjoin Asetek “from making *any*
11 assertions of infringement or violations of Court orders in the marketplace during the pendency of
12 the stay” and asks that Asetek “be required to post a bond in an amount according to proof during
13 the pendency of the stay.” Opp. at 3. Cooler Master’s request for an injunction is procedurally
14 improper and therefore denied. If it has a meritorious basis for seeking an injunction, Cooler
15 Master should file a motion and fully explain the grounds for its request. The Court also finds that
16 a bond is not warranted at this time, in significant part because Cooler Master’s complaint seeks a
17 declaratory judgment, not monetary damages.

18 Asetek agrees that it is a direct competitor with Cooler Master, but argues that Cooler
19 Master “is a large company with many product lines, and that the liquid cooling products at issue
20 in this case represent only a very small part of Cooler Master’s overall business.” Reply at 4-5.
21 Asetek also argues that Cooler Master’s lack of urgency in pursuing this case, like the eight-month
22 delay in filing its declaratory judgment complaint, demonstrates that Cooler Master “has not
23 suffered undue prejudice and will not suffer undue prejudice during a stay.” Reply at 4-5; *see also*
24 Mot. at 8-9.

25 Although the parties are direct competitors, Cooler Master has offered no evidence to
26 substantiate its general assertions that a stay will result in competitive injury. Without at least
27 some probative evidence, the Court cannot credit Cooler Master’s assertion of prejudice. The
28 Court finds that this consideration, at most, weighs weakly against a stay.

1 **iv. Conclusion as to Prejudice**

2 Balancing the factors, the Court finds that the prejudice and disadvantage factor does not
3 weigh against or in favor of a stay.

4 **IV. CONCLUSION**

5 Having considered the relevant factors in their entirety, the Court finds in its discretion that
6 a stay is warranted, and **GRANTS** Asetek's motion. The parties shall file a joint status report
7 every six months from the date of this order to update the Court on the status of the appeals and
8 the IPR proceedings. The parties shall also file a joint status report within five days of (1) the
9 issuance of final written decisions regarding patents '196 and '601 or (2) a ruling by the Federal
10 Circuit resolving the appeals regarding patents '681, '354, and '355. The Court will assess every
11 six months whether lifting the stay is warranted.

12 **IT IS SO ORDERED.**

13 Dated: 6/14/2022

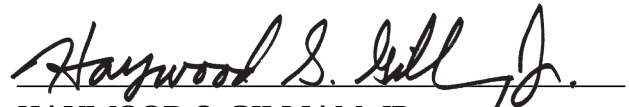
14 
15 HAYWOOD S. GILLIAM, JR.
16 United States District Judge

EXHIBIT I

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA

GOOGLE LLC,
Plaintiff,
v.
ECOFACOR, INC.,
Defendant.

Case No. 21-cv-03220-HSG

**ORDER GRANTING MOTION TO
STAY**

Re: Dkt. No. 131

On April 30, 2021, plaintiff Google LLC (“Google”) filed this complaint seeking declaratory judgment of non-infringement regarding U.S. Patent Nos. 8,740,100 (the “100 patent”); 8,751,186 (the “186 patent”); 9,194,597 (the “597 patent”); and 10,584,890 (the “890 patent”) (collectively, the “Asserted Patents”) against defendant EcoFactor, Inc. (“EcoFactor”). See Dkt. No. 1. On July 13, 2021, EcoFactor answered the complaint and filed counterclaims for infringement of the Asserted Patents. See Dkt. No. 17, (“Answer”).

Now pending before the Court is Google’s motion, briefing for which is complete, to stay pending resolution of *inter partes* review (“IPR”) of three of the four Asserted Patents. See Dkt. Nos. 131-133.¹ After carefully considering the parties’ arguments, the Court **GRANTS** Google’s motion to stay.

I. BACKGROUND

Google seeks a declaratory judgment of non-infringement regarding the Asserted Patents, in response to a complaint filed by EcoFactor in the Western District of Texas. See Dkt. No. 1. The parties agree that the accused products in the Western District of Texas action relate to smart thermostat, HVAC, and control systems. See Answer, ¶ 3.

¹ The Court has carefully considered the arguments of the parties in the papers submitted, and finds this matter suitable for resolution without oral argument under Civil Local Rule 7-1(b).

The PTAB has “instituted IPR proceedings on all challenged claims of the ’186, ’597, and ’100 patents[.]” *See* Dkt. No. 131, Motion, (“Mot.”). The PTAB denied institution of proceedings and denied rehearing as to the one remaining patent in this suit – the ’890 patent. *See id*; Dkt. No. 134. Because the PTAB instituted proceedings on the other three Asserted Patents in August 2022, the parties expect a final written decision regarding those patents by August 2023. *See* 35 U.S.C. § 316(a)(11).

Google does not argue that the ’890 patent is formally related to the other three Asserted Patents, but it does contend that they have “related subject matter.” *Id.* at 7.

II. LEGAL STANDARD

“Courts have inherent power to manage their dockets and stay proceedings, including the authority to order a stay pending [IPR].” *Ethicon, Inc. v. Quigg*, 849 F.2d 1422, 1426–27 (Fed. Cir. 1988) (internal citations omitted); *IXI Mobile (R & D) Ltd. v. Samsung Elecs. Co.*, No. 15-cv-03752-HSG, 2015 WL 7015415, at *2 (N.D. Cal. Nov. 12, 2015). Courts consider three factors in determining whether to grant a stay pending IPR: “(1) whether discovery is complete and whether a trial date has been set; (2) whether a stay will simplify the issues in question and trial of the case; and (3) whether a stay would unduly prejudice or present a clear tactical disadvantage to the non-moving party.” *IXI Mobile (R & D) Ltd.*, 2015 WL 7015415, at *2 (quoting *Evolutionary Intelligence, LLC v. Facebook, Inc.*, No. 13-cv-04202-SI, 2014 WL 261837, at *1 (N.D. Cal. Jan. 23, 2014)). The moving party bears the burden of demonstrating that a stay is appropriate. *DSS Tech. Mgmt., Inc. v. Apple, Inc.*, No. 14-cv-05330-HSG, 2015 WL 1967878, at *2 (N.D. Cal. May 1, 2015).

Courts in this district have often recognized “a liberal policy in favor of granting motions to stay” pending IPR. *See Pragmatus AV, LLC v. Facebook, Inc.*, No. 11-cv-02168-EJD, 2011 WL 4802958, at *2 (N.D. Cal. Oct. 11, 2011); *IXI Mobile (R & D) Ltd.*, 2015 WL 7015415, at *2. Courts, however, must evaluate stay requests on a case-by-case basis. *See GoPro, Inc. v. C&A Marketing, Inc.*, No. 16-cv-03590-JST, 2017 WL 2591268, at *2 (N.D. Cal. June 15, 2017). And whether to stay is always within the court’s discretion.

III. DISCUSSION

A. Factor 1: Stage of the Litigation

Google argues that this case, despite having been filed more than a year ago, “remains in its early stages.” *See* Mot. at 9. In analyzing the first factor, “the Court considers [] whether the litigation has progressed significantly enough for a stay to be disfavored.” *Finjan, Inc. v. Symantec Corp.*, 139 F. Supp. 3d 1032, 1035 (N.D. Cal. 2015) (internal citation omitted). In particular, “courts have considered (1) whether parties have engaged in costly expert discovery and dispositive motion practice; (2) whether the court has issued its claim construction order; and (3) whether the court has set a trial date.” *Id.* (internal citation omitted). Grant of “[a] stay is particularly appropriate for cases in the initial stages of litigation or in which there has been little discovery.” *Id.* (internal citations and quotations omitted).

Here, the parties have engaged in virtually no discovery, which EcoFactor does not contest. *See* Opp. at 4-5 (conceding that additional discovery will be needed in spite of allegedly related past discovery in prior cases between the parties). Though a section 101 motion and claim construction have been litigated, the Court has not issued its claim construction order. No trial date has been set.

The Court concludes that this factor weighs in favor of a stay.

B. Factor 2: Simplification of the Case

Google next argues that this litigation could be simplified and streamlined by proceedings in the PTAB. *See* Motion at 5. “Under the second factor, the court considers whether granting a stay could simplify the litigation.” *Finjan, Inc. v. Symantec Corp.*, 139 F. Supp. 3d at 1036.

Proceedings before the PTAB are highly likely to simplify this case, with review of three of the four Asserted Patents instituted. *See PersonalWeb Techs., LLC v. Apple Inc.*, 69 F. Supp. 3d 1022, 1027-1028 (N.D. Cal. 2014). That the PTAB declined to institute proceedings on the ’890 patent is not dispositive in any event, but the overlap of claims and subject matter between the instituted patents and the ’890 patent weighs in favor of a stay. *See id.* 53 of the 70 claims that EcoFactor asserts in this case are being reviewed by the PTAB and subject to potential invalidation, and that proceeding may also simplify this case with respect to some of the

remaining claims with overlapping language.

The Court concludes that this factor weighs strongly in favor of a stay.

C. Factor 3: Prejudice and Disadvantage

The third “factor considers whether a stay would unduly prejudice the nonmoving party.” *Zomm, LLC v. Apple Inc.*, 391 F. Supp. 3d 946, 957 (N.D. Cal. 2019). “[C]ourts address four considerations when evaluating prejudice: (1) the timing of the IPR petition; (2) the timing of the stay request; (3) the status of review; and (4) the relationship of the parties.” *Id.* (internal citations omitted).

1. Timing of the Petition

EcoFactor argues that Google’s delay in seeking IPR of the Asserted Patents weighs against a stay. Delay in filing an IPR weighs against a stay. *See Zomm*, 391 F. Supp. 3d at 957. However, delay in filing should be considered in the context of the particular facts of the case. *See Software Rts. Archive, LLC v. Facebook, Inc.*, No. C-12-3970 RMW, 2013 WL 5225522, at *6 (N.D. Cal. Sept. 17, 2013).

Google delayed nearly eight months between filing this complaint and seeking institution of IPR. *See Opp.* at 9. However, Google explains that this delay resulted in part from EcoFactor’s delay in identifying asserted claims and serving infringement contentions. *See Reply* at 7. While Google fairly points out that EcoFactor’s delay in identifying its asserted claims and serving infringement contentions mitigates Google’s delay in filing its petitions, EcoFactor correctly notes that Google’s resource-intensive litigation of the section 101 motion for judgment on the pleadings and claim construction filings in the interim is also a relevant consideration. *See Opp.* at 8-9.

The Court finds that this subfactor is neutral overall.

2. Timing of the Motion

EcoFactor argues next that Google’s timing of its motion weighs in favor of a stay because Google filed its IPR petitions months ago. *See Dkt. No. 132* at 9. Delay in moving for a stay weighs against a stay. *See Zomm*, 391 F. Supp. 3d at 957.

However, EcoFactor’s authorities are distinguishable because in those cases, the moving party waited at least seven weeks to move for a stay after IPR was *instituted*, not *filed*. *See Jiaying*

1 *Super Lighting Elec. Appliance Co. v. MaxLite, Inc.*, No. CV194047PSGMAAX, 2020 WL
2 5079051, at *4 (C.D. Cal. June 17, 2020); *Affinity Labs of Texas v. Apple Inc.*, No. 09-04436 CW,
3 2010 WL 1753206, at *2 (N.D. Cal. Apr. 29, 2010). Here, by contrast, Google moved for a stay
4 less than a month after IPR was instituted.

5 This subfactor weighs in favor of a stay.

6 **3. Status of Review**

7 Where a review has been instituted already, this subfactor weighs in favor of a stay. *See*
8 *Zomm, LLC*, 391 F. Supp. 3d at 957. Review has been instituted on three of the four Asserted
9 Patents, and thus this subfactor weighs in favor of a stay.

10 **4. Relationship of the Parties**

11 If the parties are not direct competitors, this factor weighs in favor of a stay. *See Finjan*,
12 139 F.Supp.3d at 1038. Google and EcoFactor dispute whether they are direct competitors. *See*
13 *Mot.* at 8-9; *Opp.* at 10-12. EcoFactor may compete with Google even if Google does not
14 consider EcoFactor a competitor. The parties' litigation history, including Google's initiation of
15 this suit, may weigh in favor of a finding that the parties are competitors. However, while not
16 dispositive, EcoFactor's failure to pursue a preliminary injunction undermines any argument that it
17 could not be made whole with monetary relief. *See Symantec Corp. v. Zscaler, Inc.*, No. 17-CV-
18 04426-JST, 2018 WL 3539267, at *3 (N.D. Cal. July 23, 2018). This subfactor is neutral.

19 The Court concludes the third factor — prejudice and disadvantage — weighs in favor of a
20 stay.

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IV. CONCLUSION

Having considered the relevant factors, the Court in its discretion **GRANTS** Google’s motion to stay pending conclusion of *inter partes* review. The parties shall file a joint status report every six months from the date of this order to update the Court on the status of the IPR proceedings and any appeals therefrom. The parties shall also file a joint status report within five days of the issuance of final written decisions regarding the ’100, ’186, and ’597 patents. The Clerk is directed to administratively close the file.

IT IS SO ORDERED.

Dated: 10/11/2022


HAYWOOD S. GILLIAM, JR.
United States District Judge