



(51) International Patent Classification:
H04Q 11/00 (2006.01)

(21) International Application Number:
PCT/US2018/061179

(22) International Filing Date:
15 November 2018 (15.11.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/588,667 20 November 2017 (20.11.2017) US

(71) Applicant: **CORNING RESEARCH & DEVELOPMENT CORPORATION** [US/US]; 1 Riverfront Plaza, Corning, New York 14831 (US).

(72) Inventors: **CHASE, Sara Ann**; 3725 Mack Ballard Rd., Maiden, North Carolina 28650 (US). **RHONEY, Brian Keith**; 7952 Silver Jade Ln., Denver, North Carolina 28037 (US). **WORKS, Antwan Joco'ques**; 1697 Big Bend Drive, Lewisville, Texas 75077 (US).

(74) Agent: **RAMETTA, Brad Christopher**; Corning Optical Communications LLC, Intellectual Property Department SP-TI-03-1, Corning, New York 14831 (US).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,

(54) Title: OPTICAL INTERCONNECT ASSEMBLIES AND ASSOCIATED SYSTEMS FOR LARGE-SCALE SPINE AND LEAF TOPOLOGIES

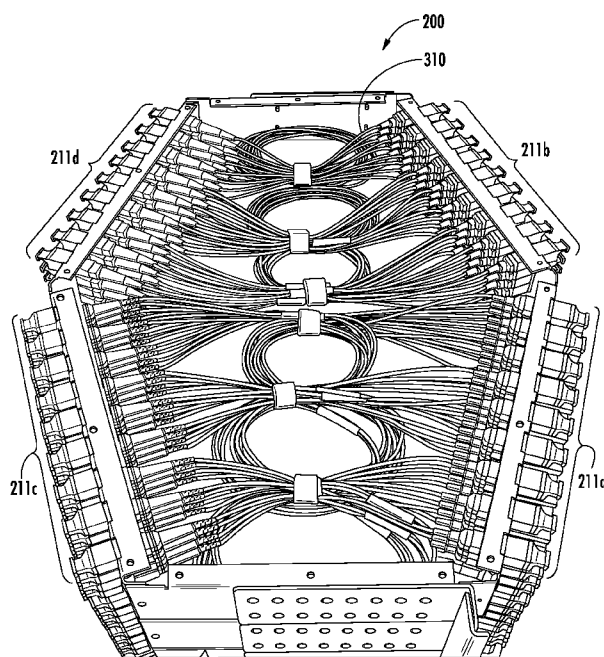


FIG. 7

(57) Abstract: An optical interconnect module comprises a housing including a front-facing portion including a first face and a second face, the first face of the front-facing portion angled relative to the second face of the front-facing portion. The housing also includes a rear-facing portion opposing the front facing portion, the rear-facing portion including a first face and a second face, the first face of the rear-facing portion angled relative to the second face of the rear-facing portion. The housing further includes an internal chamber disposed between the front-facing portion and the rear-facing portion. A first plurality of multifiber connectors is disposed on the front-facing portion of the housing, and a first plurality of multifiber connectors disposed on the rear-facing portion of the housing. Each connector of the first plurality of multifiber connectors disposed on the front-facing portion is optically connected to each connector of the first plurality of multifiber connectors disposed on the rear-facing portion by at least a pair of optical fibers.

SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

Description

OPTICAL INTERCONNECT ASSEMBLIES AND ASSOCIATED SYSTEMS FOR LARGE-SCALE SPINE AND LEAF TOPOLOGIES

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application Serial No. 62/588,667 filed on November 20, 2017, the content of which is relied upon and incorporated herein by reference in its entirety.

Technical Field

[0002] The present disclosure relates generally to equipment for large-scale spine and leaf networks and, more particularly, to high-capacity optical interconnect assemblies and systems for facilitating large-scale spine and leaf topologies in a data center environment.

Background

[0003] A data center is a location that houses computers and related telecommunications equipment and components for the purpose of processing (e.g., receiving, storing, managing and transmitting) data. Data centers often need to be expanded or "scaled out," wherein hardware is added to accommodate the increasing data-processing demands. It is thus desirable that the data-center hardware be configured in a manner that is scalable, i.e., that can support scale out of the hardware such that the data-processing performance of the data center improves in direct proportion to the added capacity.

[0004] Traditional data-center architectures have relied on a three-tier switching architecture whereby network reliability and scale-out capability is accomplished through switch redundancy. However, the three-tier switching architecture is not optimal for certain types of data centers, such as Internet data centers, that process relatively large amounts of data. For example, as the size of the network grows, conventional three-tiered models can lead to inefficiencies in the network because of the unpredictability of distances between routing pathways that link different devices. Such delays increase network latency – a problem that is exacerbated as the data center is “scaled out” to accommodate increased traffic volume, particularly for “east-west” traffic within the data center.

[0005] As an alternative to the three-tiered switching topology, leaf-spine network topologies were developed to address latency issues caused by the more complicated three-tiered model. The leaf-spine topology relies on a wiring scheme in which a wiring mesh is created to ensure that all the devices in the data center are the same number of segments away, thereby ensuring that the delay or latency of information traveling through the “mesh” is consistent throughout the network. Further, because every leaf switch is interconnected with each and every spine switch and because the latency between each segment is relatively uniform, each route in the network can be active, allowing all connections to be utilized at the same time, increasing the overall efficiency of the data center.

[0006] The presently disclosed optical interconnect assemblies and systems for facilitating large-scale spine and leaf topologies in a data center environment are directed toward overcoming one or more of the problems set forth above.

Summary

[0007] In accordance with one aspect, the present disclosure is directed toward a high-capacity optical interconnect module for facilitating large-scale spine and leaf topologies, comprising a housing including a front-facing portion that includes a first face and a second face, the first face of the front-facing portion being angled relative to the second face of the front-facing portion. The housing may also include a rear-facing portion opposing the front facing portion, the rear-facing portion including a first face and a second face, the first face of the rear-facing portion being angled relative to the second face of the rear-facing portion. The housing may further include an internal chamber disposed between the front-facing portion and the rear-facing portion. a first plurality of multifiber connectors disposed on the front-facing portion of the housing, and a first plurality of multifiber connectors disposed on the rear-facing portion of the housing. Each connector of the first plurality of multifiber connectors disposed on the front-facing portion may be optically connected to each connector of the first plurality of multifiber connectors disposed on the rear-facing portion via at least a pair of optical fibers.

[0008] According to another aspect, the present disclosure is directed toward a data center network environment, comprising a high-capacity optical interconnect module for

facilitating large-scale spine and leaf topologies. The high-capacity optical interconnect module may include a front-facing portion that includes a first face and a second face. The high-capacity optical interconnect module may also include a rear-facing portion opposing the front facing portion, the rear-facing portion including a first face and a second face. The high-capacity optical interconnect module may further include an internal chamber disposed between the front-facing portion and the rear-facing portion. A first plurality of multifiber connectors may be disposed on the front-facing portion, wherein the first plurality of multifiber connectors disposed on the front-facing portion is aligned in a first column of the front-facing portion. A first plurality of multifiber connectors may be disposed on the rear-facing portion, wherein the first plurality of multifiber connectors disposed on the rear-facing portion is aligned in a first column of the rear-facing portion. Each connector of the first plurality of multifiber connectors disposed on the front-facing portion is optically connected to each connector of the first plurality of multifiber connectors disposed on the rear-facing portion by at least a pair of optical fibers.

Brief Description of the Drawings

[0009] Fig. 1 illustrates as exemplary wiring schematic for implementing spine-and-leaf network topologies in which a single spine switch optically connected to a single leaf switch via a single optical interconnection assembly, consistent with certain disclosed embodiments;

[0010] Fig. 2 provides a diagrammatic perspective view of a rack-mountable 1U module for large-scale implementation of the spine-and-leaf network topology using, in part, the exemplary wiring schematic illustrated in Fig. 1, in accordance with certain disclosed embodiments;

[0011] Fig. 3 provides an overhead perspective view of a portion of the internal wiring (and corresponding wiring schematic) of an exemplary 1U module for large scale implementation of a spine-and-leaf network topology, consistent with certain disclosed embodiments;

[0012] Fig. 4 illustrates an exemplary wiring harness/cable assembly (and corresponding wiring schematic) for use with the module for large-scale implementation of the spine-and-leaf network topology, in accordance with one or more disclosed embodiments;

[0013] Fig. 5 provides a diagrammatic perspective view illustrating a plurality of 1U modules for large-scale implementation of the spine-and-leaf network topology that have

using, in part, the exemplary wiring schematic illustrated in Fig. 1, in accordance with certain disclosed embodiments;

[0014] Fig. 6 provides an overhead view of a housing of an exemplary 1U module for large scale implementation of a spine-and-leaf network topology, consistent with certain disclosed embodiments;

[0015] Fig. 7 shows an overhead perspective view of an exemplary 1U system for large-scale implementation of a spine-and-leaf network topology with the cover of the housing removed, in accordance with certain disclosed embodiments;

[0016] Figs. 8A, 8B, and 8C illustrate respective top, side and wiring schematic views of an exemplary 1U system for large-scale implementation of a spine-and-leaf network topology, consistent with certain disclosed embodiments;

[0017] Figs. 9A, 9B, 9C, and 9D illustrate alternative views of an exemplary modular mesh wiring block designed to fit within a corresponding slot in an exemplary 1U module for large scale implementation of a spine-and-leaf network topology, in accordance with certain disclosed embodiments;

[0018] Figs. 10A and 10B illustrate alternative views of an exemplary modular mesh wiring block designed to fit within a corresponding slot in an exemplary 1U module for large scale implementation of a spine-and-leaf network topology, consistent with certain disclosed embodiments; and

[0019] Figs. 11A, 11B, and 11C illustrate alternative views of yet another configuration of an exemplary modular mesh wiring block designed to fit within a corresponding slot in an exemplary 1U module for large scale implementation of a spine-and-leaf network topology, consistent with certain disclosed embodiments.

Detailed Description

[0020] Fig. 1 illustrates a schematic diagram of an exemplary spine-and-leaf network 100 that includes an optical interconnection assembly 120 connecting a single spine switch (110a) to a single leaf switch (110b), via one or more patch cords 140 and/or trunks 130. Spine-and-leaf network topology 100 may include or embody any combination of network components that facilitates providing distinctive data connectivity/interconnection paths to as many

different network nodes (e.g., switches, routers, etc.) as possible in a “mesh” configuration, essentially creating what is referred to as a network “fabric.” In certain applications, such connectivity may be provided using mesh wiring schemes using one or more optical interconnection assemblies, such as optical interconnection module 120 of Fig. 1.

[0021] The optical interconnection assembly 120 may embody a fiber optic module having a plurality of connectors at a first connection location (e.g., the front face of the module or “spine-side”) and a second connection location (e.g., the rear face of the module or “leaf-side”). According to one embodiment, the plurality of connectors may include a plurality of multifiber connectors, such as MTP or MPO connectors. For example, as illustrated in Fig. 1, spine-side multifiber components and leaf-side multifiber components may comprise MTP connectors, such as MTP1, MTP2, MTP3, and MTP4 (MTP1-MTP4) and MTP A, MTP B, MTP C, and MTP D (MTPA-MTPD) respectively.

[0022] Furthermore, example spine-side patch cords and leaf-side patch cords 140 are shown as respectively including optical fibers and that terminate at their respective ends with MTP connectors. In one exemplary embodiment, MTP connectors associated with patch cords 140 are MTP connectors that are plugged into multifiber components in the form of quad-small-form-factor-pluggable (QSFP) transceivers on spine switches 110a and leaf switches 110b.

[0023] Fig. 2 illustrates an exemplary high-capacity optical interconnect module 200 for facilitating large-scale spine and leaf topologies. According to the embodiment illustrated in Fig. 2, high-capacity optical interconnect module 200 may comprising a housing 210, a front-facing portion that includes a first face 211a and a second face 211b. As shown in Fig. 2 and in accordance with at least one embodiment, the first face 211a of the front-facing portion being angled relative to the second face 211b of the front-facing portion. Housing 210 may also include a rear-facing portion opposing the front facing portion, the rear-facing portion including a first face 211c and a second face 211d, the first face 211c of the rear-facing portion being angled relative to the second face 211d of the rear-facing portion. Housing 210 may also include an internal chamber (not separately numbered, but shown in Fig. 3 when cover of housing 210 is removed) disposed between the front-facing portion and the rear-facing portion. Housing 210 may also include a plurality of brackets 212a and 212b for mounting of high-capacity optical interconnect module 200 in a standard telecommunications

or data center rack. As will be explained in greater detail below, it is contemplated that, although high-capacity optical interconnect module 200 is illustrated as being sized to fit in a standard “1U” (or 1 rack-unit) space, it is contemplated that high-capacity optical interconnect module 200 may include or embody any size or shape (e.g., 2U, 4U, etc.) Alternatively or additionally, it is also contemplated that high-capacity optical interconnect module 200 may be configured for use in applications other than conventional rack-mounting, such as wall-mount, floor mount, etc.

[0024] As shown in Fig. 2, front-facing portion of housing 210 may include a first plurality of multifiber connectors disposed on the front-facing portion. Similarly, rear-facing portion of housing 210 may include a first plurality of multifiber connectors disposed on the rear-facing portion. According to one exemplary embodiment, multifiber connectors may include or embody MTP connectors, MPO connectors, or any other suitable multifiber connector.

[0025] Fig. 3 provides an overhead view of a portion of the internal wiring construction of high-capacity optical interconnect module 200. As illustrated in Fig. 3, high-capacity optical interconnect module 200 may include one or more internal wiring harnesses or cable assemblies for facilitating the mesh (or spine-and-leaf wiring topology), such as that shown in the wiring scheme in Fig. 3, in which each connector of the first plurality of multifiber connectors disposed on the front-facing portion is optically connected to each connector of the first plurality of multifiber connectors disposed on the rear-facing portion by at least a pair of optical fibers.

[0026] According to one embodiment, each of the multifiber connectors may include or embody 8-fiber connectors, with 4 channels of each connector dedicated to support transmit (e.g., leaf-to-spine) network traffic, and the remaining 4 channels of each connector dedicate to support receive (e.g., spine-to-leaf) network traffic. As such, the mesh is realized by the interconnection of each of the 4 multifiber connectors on the front-facing portion of the high-capacity optical interconnect module 200 with the 4 multifiber connectors on the rear-facing portion of the high-capacity optical interconnect module 200 using a pair of fibers (one fiber of the pair for transmit (e.g., leaf-to-spine) traffic and one fiber of the pair for receive (e.g., spine-to-leaf) traffic).

[0027] According to one embodiment, in connection with the 8-fiber mesh examples above, it is contemplated that the spine-and-leaf mesh wiring scheme is facilitated by a wiring harness 310, such as that illustrated in Fig. 4. As shown in Fig. 4, the furcation/cable assembly 412 is manufactured to achieve the wiring scheme shown in Fig. 4. While Fig. 4 illustrates a 8-connector (including 4 spine-side connectors 411ba and 4 leaf-side connectors 411b), 8-fiber-per-connector harness that is wired for spine-and-leaf mesh polarity, it is contemplated that any of a number of multifiber variations can be used without departing from the scope of the present disclosure.

[0028] Fig. 5 illustrates one embodiment of a 4U version of high-capacity optical interconnect module 200. In the embodiment of Fig. 5, the 4U housing may be realized by the “stacking” of four 1U high-capacity optical interconnect modules 200a-200d, such as is illustrated in Fig. 2. Alternatively or additionally, it is contemplated that a 4U version of high-capacity optical interconnect module 200 may be implemented using a single, common housing.

[0029] Fig. 6 illustrates a top-down view of high-capacity optical interconnect module 200. The view of Fig. 6 is intended to highlight the increased density afforded by the relative angling of each of the faces of front-facing portion and rear-facing portion to increase the amount of surface area that is available for multifiber connectors, while still maintaining finger access spacing. It is, however, contemplated that the faces of front-facing and rear-facing portions of high-capacity optical interconnect module 200 may not be angled with respect to one another. In one embodiment, the number of optical connections provided by each of the front-facing and rear-facing portions of high-capacity optical interconnect module 200 are configured to support at least 576 optical connections per 1U high-capacity optical interconnect module 200.

[0030] Fig. 7 provides a perspective side view of high-capacity optical interconnect module 200 with the lid removed. As shown in Fig. 7, multifiber connectors on first and second faces 211a, 211b of front facing portion are connected via wiring harnesses 310 to multifiber connectors one first and second faces 211c, 211d of rear-facing portion. As explained, the spine-and-leaf mesh wiring topology is carried out within each of wiring harnesses 310 to ensure that each connector of a first plurality of multifiber connectors disposed on the front-facing portion is optically connected to each connector of a first

plurality of multifiber connectors disposed on the rear-facing portion by at least a pair of optical fibers. According to one embodiment, the first plurality of multifiber connectors disposed on the front-facing portion correspond to the first four multifiber connectors of the first column of connectors on the first face 211a of the front-facing portion of high-capacity optical interconnect module 200. The first plurality of multifiber connectors disposed on the rear-facing portion correspond to the first four multifiber connectors of the first column of connectors on the first face 211c of the rear-facing portion of high-capacity optical interconnect module 200. In other words, the first four multifiber connectors of the first column of connectors on the first face 211a of the front-facing portion of high-capacity optical interconnect module 200 and the first four multifiber connectors of the first column of connectors on the first face 211c of the rear-facing portion of high-capacity optical interconnect module 200 are optically coupled to one another by a spine-and-leaf mesh wiring harness 310 to create a first mesh unit of high-capacity optical interconnect module 200. Additional connectors of additional columns from front-facing portion and rear-facing portion are wired together to create a plurality of 8-fiber transmit and receive mesh topologies.

[0031] Components and systems consistent with the disclosed embodiments provide solutions for high-capacity optical interconnect module 200. As an alternative or in addition to the rack-mounted module described in Figs. 1-7, there is a benefit to providing an even more modular system that is mesh-expandable. Indeed, because certain embodiments consistent with the present disclosure are described in relation to 8-, 12-, or 24-fiber mesh topologies, solutions that allow for modular “mesh-units” to be added within a rack-mounted housing that is configured to receive the individual modules.

[0032] As shown in Figs. 8A-8C, certain embodiments contemplate that high-capacity optical interconnect module 200 comprises a plurality of individual mesh wiring sets that are removably and selectively insertable within a rack housing unit. For example, as illustrated in Fig. 8A, one mesh wiring unit (denoted by the boxed portion) may be a single mesh module that can be removed and inserted within the housing. Fig. 8B shows the side view of the mesh wiring unit 710. As illustrated in Fig. 8B, the mesh wiring unit may comprise a module that includes a mesh wiring unit (wiring schematic shown in Fig. 8C) having 4 8-

fiber MTPs disposed on the front of the module, 4 8-fiber MTPs disposed on the rear of the unit, and where each connector of a first plurality of multifiber connectors disposed on the front-facing portion is optically connected to each connector of a first plurality of multifiber connectors disposed on the rear-facing portion by at least a pair of optical fibers. It is contemplated that additional and different numbers of connectors or fibers may be used to realize the mesh wiring module.

[0033] It is contemplated that a plurality of individual mesh wiring units 710 may be used together with an expandable housing to facilitate a high-capacity optical interconnect module 200 that can be expanded modularly (e.g., in phases) or all at once, allowed for maximum flexibility and cost controls. Furthermore, certain embodiments consistent with the present disclosure contemplate that the individual mesh wiring units 710 of Figs. 8A-8C may be used in an angled housing. As such, mesh wiring units 710 toward the center of the high-capacity optical interconnect module 200 need to be of different length than those toward the edges of the high-capacity optical interconnect module 200. Figs. 9A-9D provide alternate views of a mesh wiring unit 710 having a body with an adjustable length. As shown in the embodiments of Figs. 9A-9D, mesh wiring units 710 may be configured to telescope along a longitudinal axis, such that the length of mesh wiring unit(s) 710 may be adjustable, depending upon the location (slot) that mesh wiring unit 710 will be inserted within high-capacity optical interconnect module 200.

[0034] Figs. 10A-10B and Figs. 11A-11C illustrate alternative embodiments of the telescoping mesh wiring units 710 to compensate for the angle of pitch of the faces of high-capacity optical interconnect module 200. For example, Figs. 10A-10B illustrate a telescoping mesh wiring unit 710 having angled portions toward the front and rear of the module, whereby the angle of the faces corresponds to the angle of the pitch of the front and rear face, respectively, of high-capacity optical interconnect module 200. Similarly, the curvature of the opposing ends of the mesh wiring units 710 of Figs. 11A-11C are designed to correspond to compensate for the pitch of the front and rear face, respectively, of high-capacity optical interconnect module 200. In either embodiment, it is contemplated that the mesh wiring units are configured to telescope along the length of the mesh wiring unit 710 in order to be adjustably and removably inserted within pitch of the front and rear face, respectively, of high-capacity optical interconnect module 200.

[0035] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed high-capacity optical interconnect assemblies and systems for facilitating large-scale spine and leaf topologies in a data center environment without departing from the scope of the disclosure. Other embodiments of the present disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the present disclosure. It is intended that the specification and examples be considered as exemplary only, with a true scope of the present disclosure being indicated by the following claims and their equivalents.

Claims

What is claimed is:

1. A high-capacity optical interconnect module for facilitating large-scale spine and leaf topologies, comprising:
 - a housing including:
 - a front-facing portion that includes a first face and a second face, the first face of the front-facing portion being angled relative to the second face of the front-facing portion;
 - a rear-facing portion opposing the front facing portion, the rear-facing portion including a first face and a second face, the first face of the rear-facing portion being angled relative to the second face of the rear-facing portion; and
 - an internal chamber disposed between the front-facing portion and the rear-facing portion;
 - a first plurality of multifiber connectors disposed on the front-facing portion;
 - a first plurality of multifiber connectors disposed on the rear-facing portion;
 - wherein each connector of the first plurality of multifiber connectors disposed on the front-facing portion is optically connected to each connector of the first plurality of multifiber connectors disposed on the rear-facing portion by at least a pair of optical fibers.
2. The optical interconnect module of claim 1, further comprising:
 - a second plurality of multifiber connectors disposed on the front-facing portion;
 - a second plurality of multifiber connectors disposed on the rear-facing portion;
 - wherein each connector of the second plurality of multifiber connectors disposed on the front-facing portion is optically connected to each connector of the second plurality of multifiber connectors disposed on the rear-facing portion by at least a pair of optical fibers.

3. The optical interconnect module of claim 2, wherein the first plurality of multifiber connectors disposed on the front-facing portion are aligned in a first column of the front-facing portion.

4. The optical interconnect module of claim 2, wherein the first plurality of multifiber connectors disposed on the rear-facing portion are aligned in a first column of the rear-facing portion.

5. The optical interconnect module of claim 2, wherein the second plurality of multifiber connectors disposed on the front-facing portion are aligned in a second column of the front-facing portion.

6. The optical interconnect module of claim 2, wherein the second plurality of multifiber connectors disposed on the rear-facing portion are aligned in a second column of the rear-facing portion.

7. The optical interconnect module of claim 2, wherein the housing further includes opposing brackets for mounting in a standard 1U telecommunications equipment rack and includes at least 72 multifiber connectors on each of the front-facing portion and the rear-facing portion.

8. The optical interconnect module of claim 7, wherein each of the multifiber connectors are at least 8-fiber multifiber connectors.

9. The optical interconnect module of claim 7, wherein each of the multifiber connectors are at least 12-fiber multifiber connectors.

10. A data center network environment, comprising:

a high-capacity optical interconnect module for facilitating large-scale spine and leaf topologies, comprising:

- a front-facing portion that includes a first face and a second face;
- a rear-facing portion opposing the front facing portion, the rear-facing portion including a first face and a second face; and
- an internal chamber disposed between the front-facing portion and the rear-facing portion;
- a first plurality of multifiber connectors disposed on the front-facing portion, wherein the first plurality of multifiber connectors disposed on the front-facing portion are aligned in a first column of the front-facing portion;
- a first plurality of multifiber connectors disposed on the rear-facing portion, wherein the first plurality of multifiber connectors disposed on the rear-facing portion are aligned in a first column of the rear-facing portion; and
- wherein each connector of the first plurality of multifiber connectors disposed on the front-facing portion is optically connected to each connector of the first plurality of multifiber connectors disposed on the rear-facing portion by at least a pair of optical fibers.

11. The data center network environment of claim 10, wherein the high-capacity optical interconnect module further comprises:

- a second plurality of multifiber connectors disposed on the front-facing portion;
- a second plurality of multifiber connectors disposed on the rear-facing portion;
- wherein each connector of the second plurality of multifiber connectors disposed on the front-facing portion is optically connected to each connector of the second plurality of multifiber connectors disposed on the rear-facing portion by at least a pair of optical fibers.

12. The data center network environment of claim 11, wherein the first face of the front-facing portion being angled relative to the second face of the front-facing portion.

13. The data center network environment of claim 11, wherein the first face of the rear-facing portion being angled relative to the second face of the rear-facing portion.

14. The data center network environment of claim 11, wherein the high-capacity optical interconnect module further comprises the second plurality of multifiber connectors disposed on the front-facing portion are aligned in a second column of the front-facing portion.

15. The data center network environment of claim 11, wherein the high-capacity optical interconnect module further comprises the second plurality of multifiber connectors disposed on the rear-facing portion are aligned in a second column of the rear-facing portion.

16. The data center network environment of claim 11, wherein the housing further includes opposing brackets for mounting in a standard 1U telecommunications equipment rack and includes at least 72 multifiber connectors on each of the front-facing portion and the rear-facing portion.

17. The data center network environment of claim 16, wherein each of the multifiber connectors are at least 8-fiber multifiber connectors.

18. The data center network environment of claim 16, wherein each of the multifiber connectors are at least 12-fiber multifiber connectors.

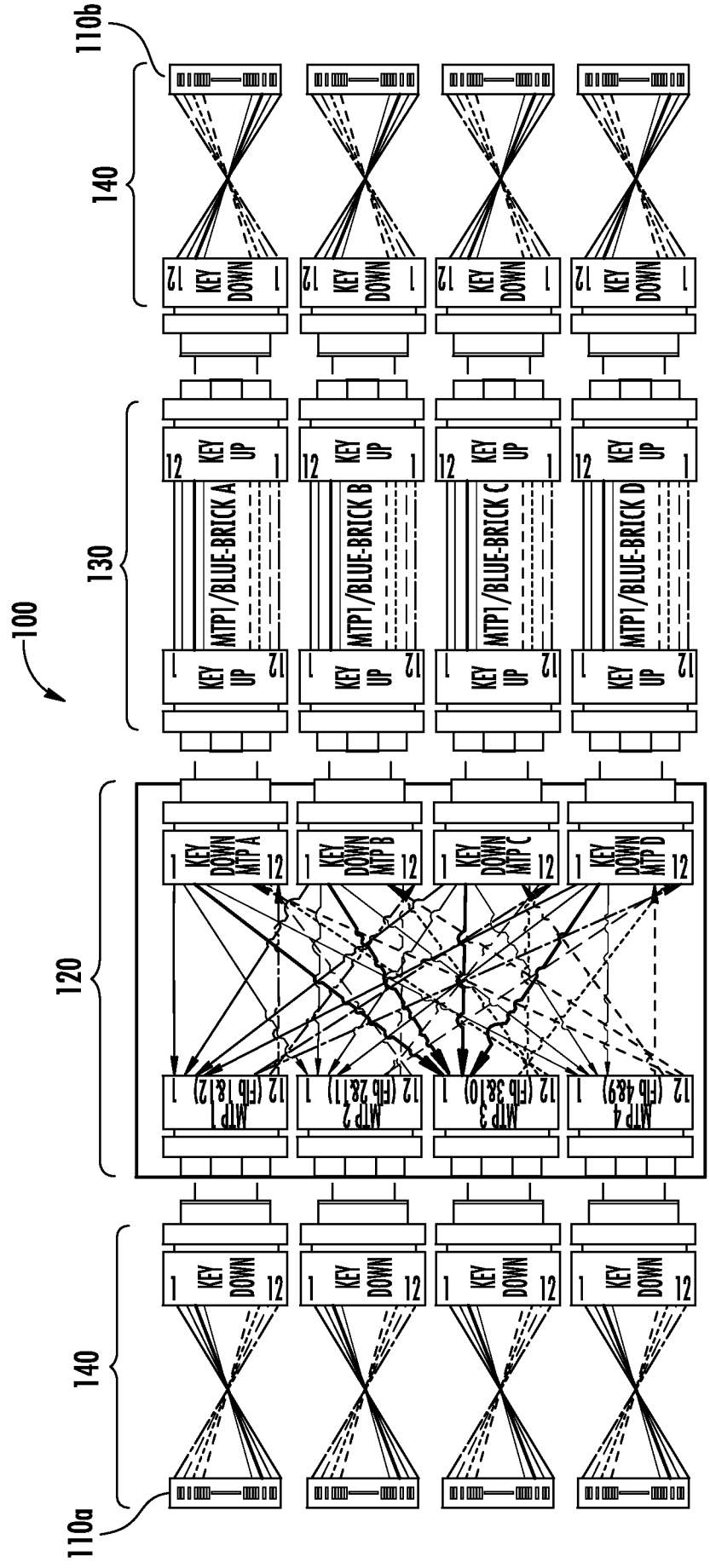


FIG. 1

2/11

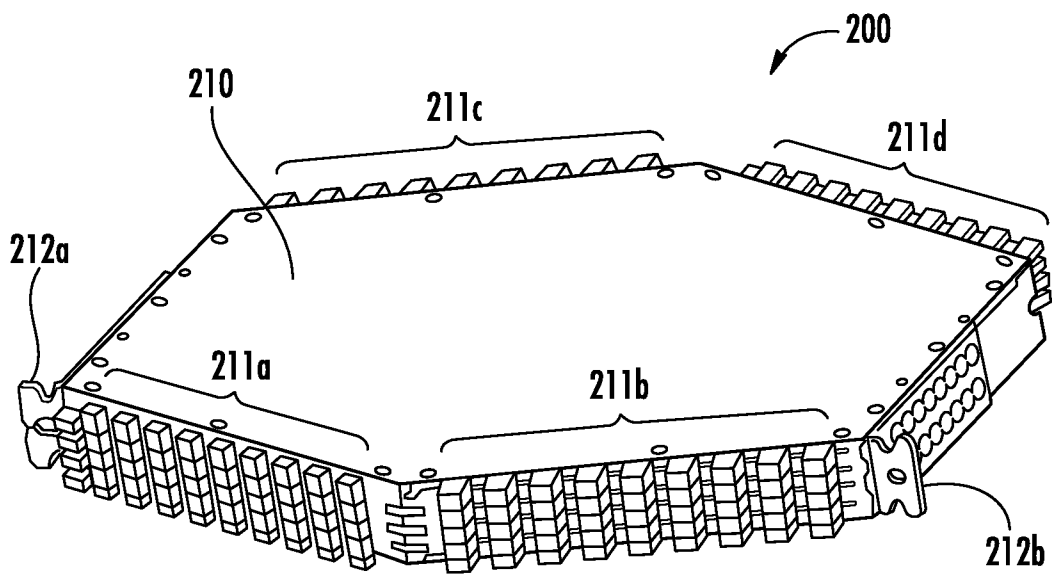


FIG. 2

3/11

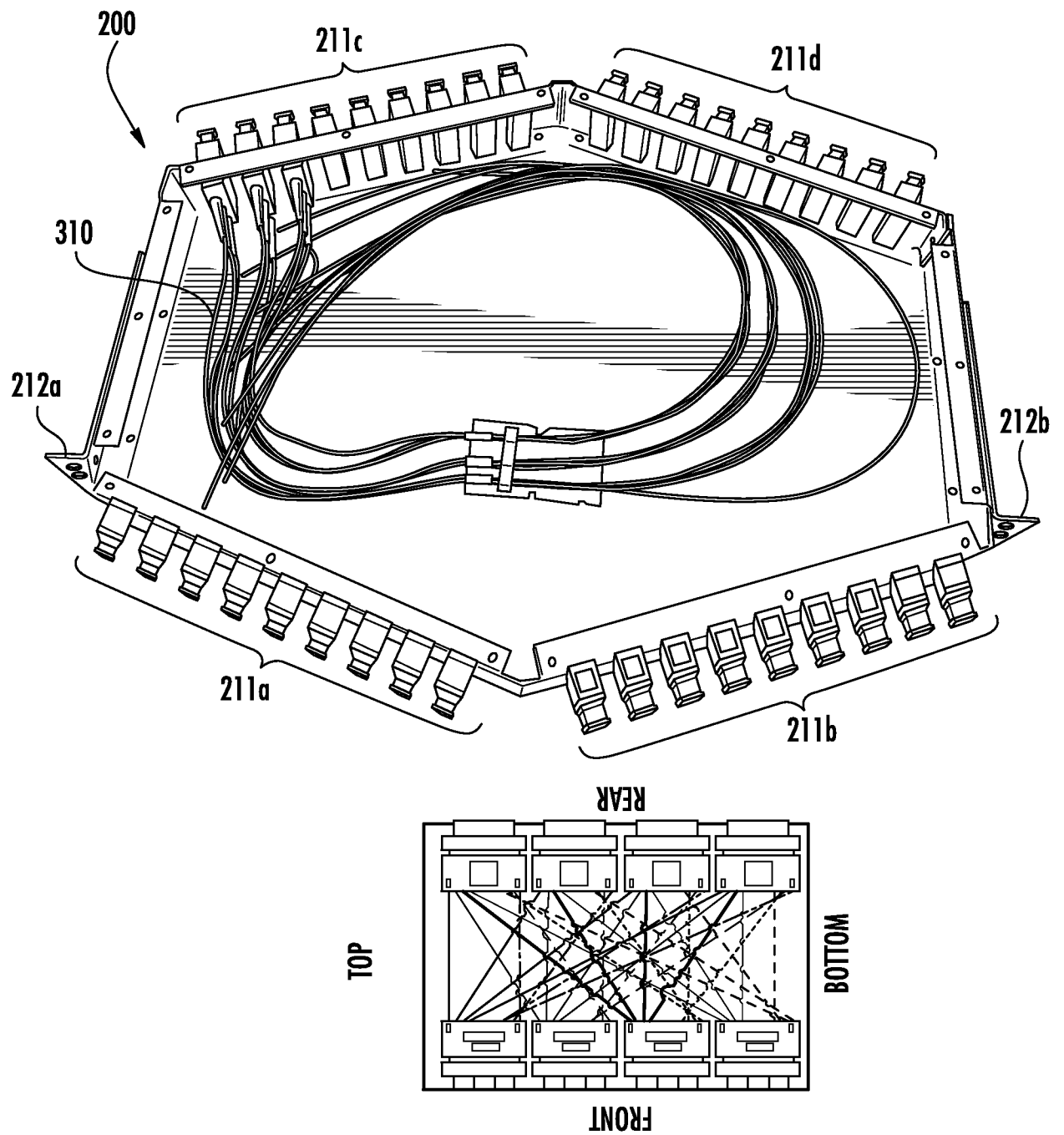


FIG. 3

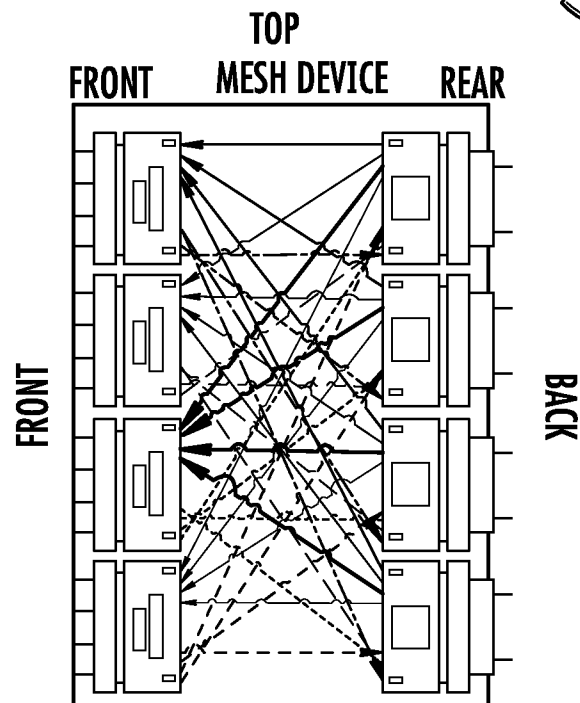
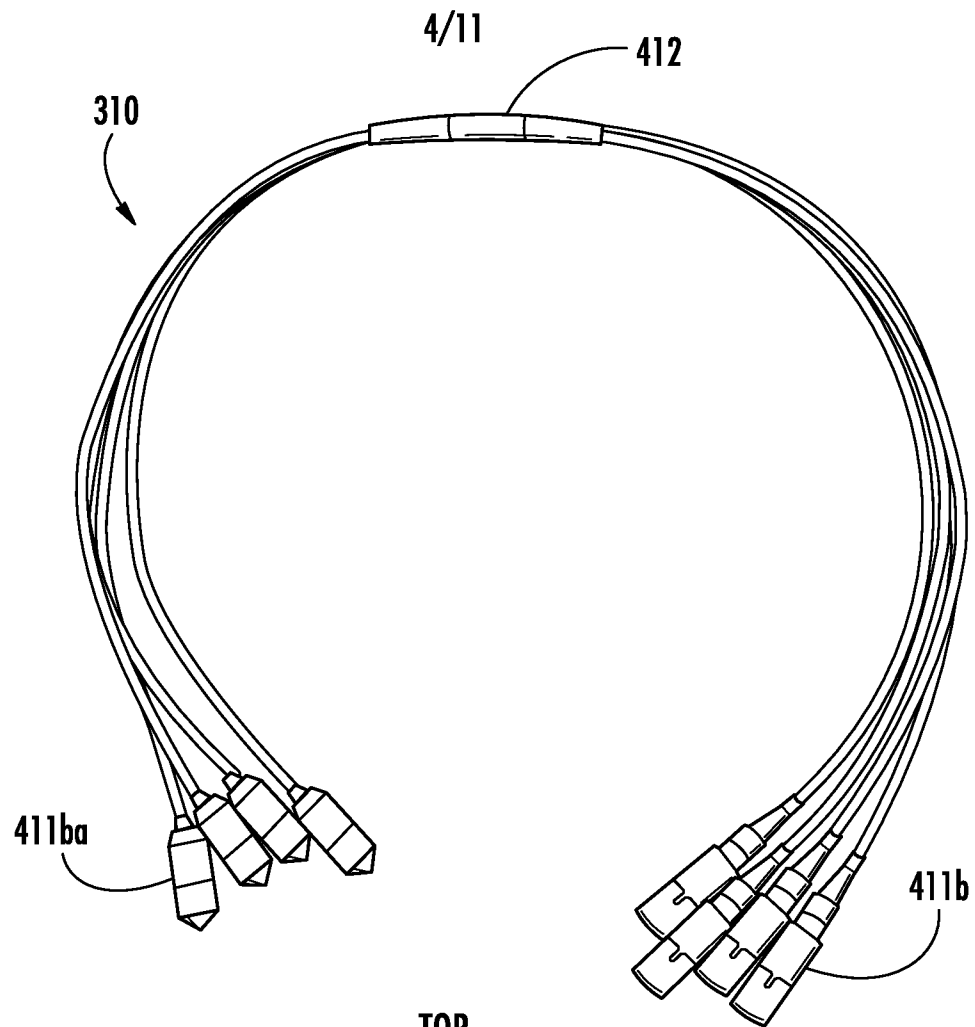


FIG. 4

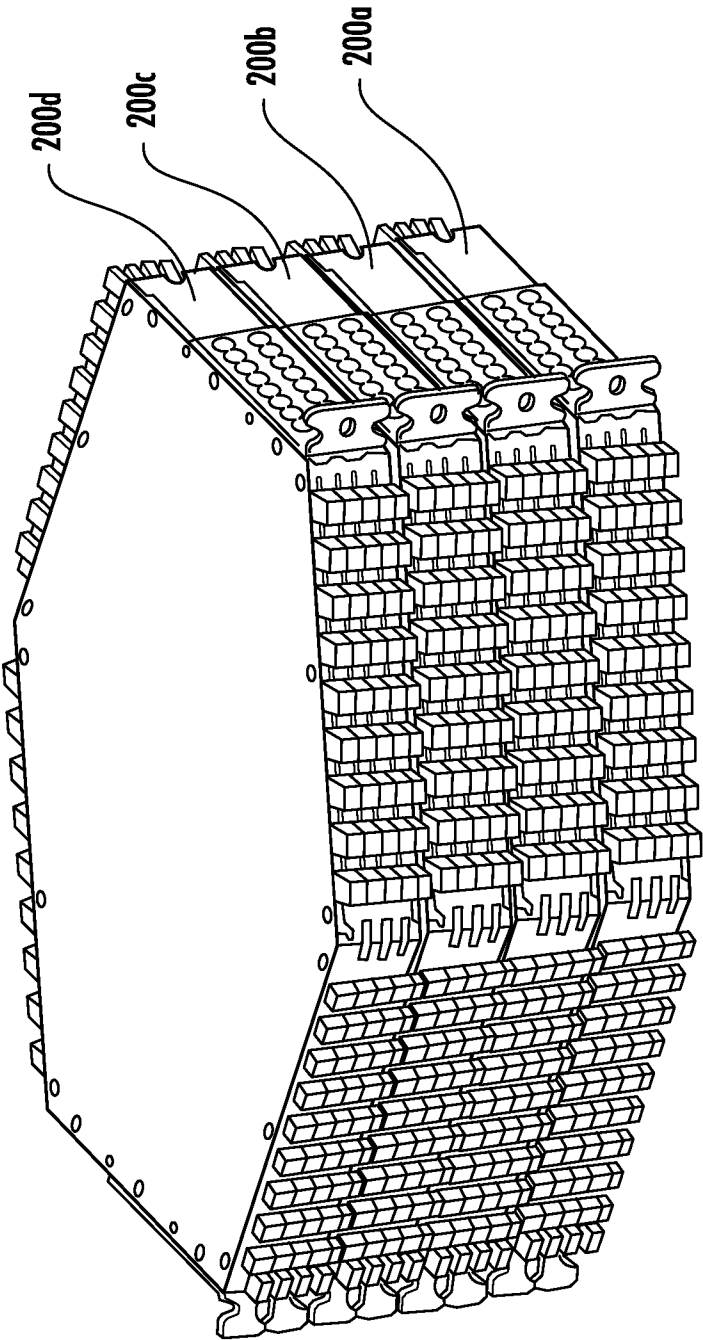
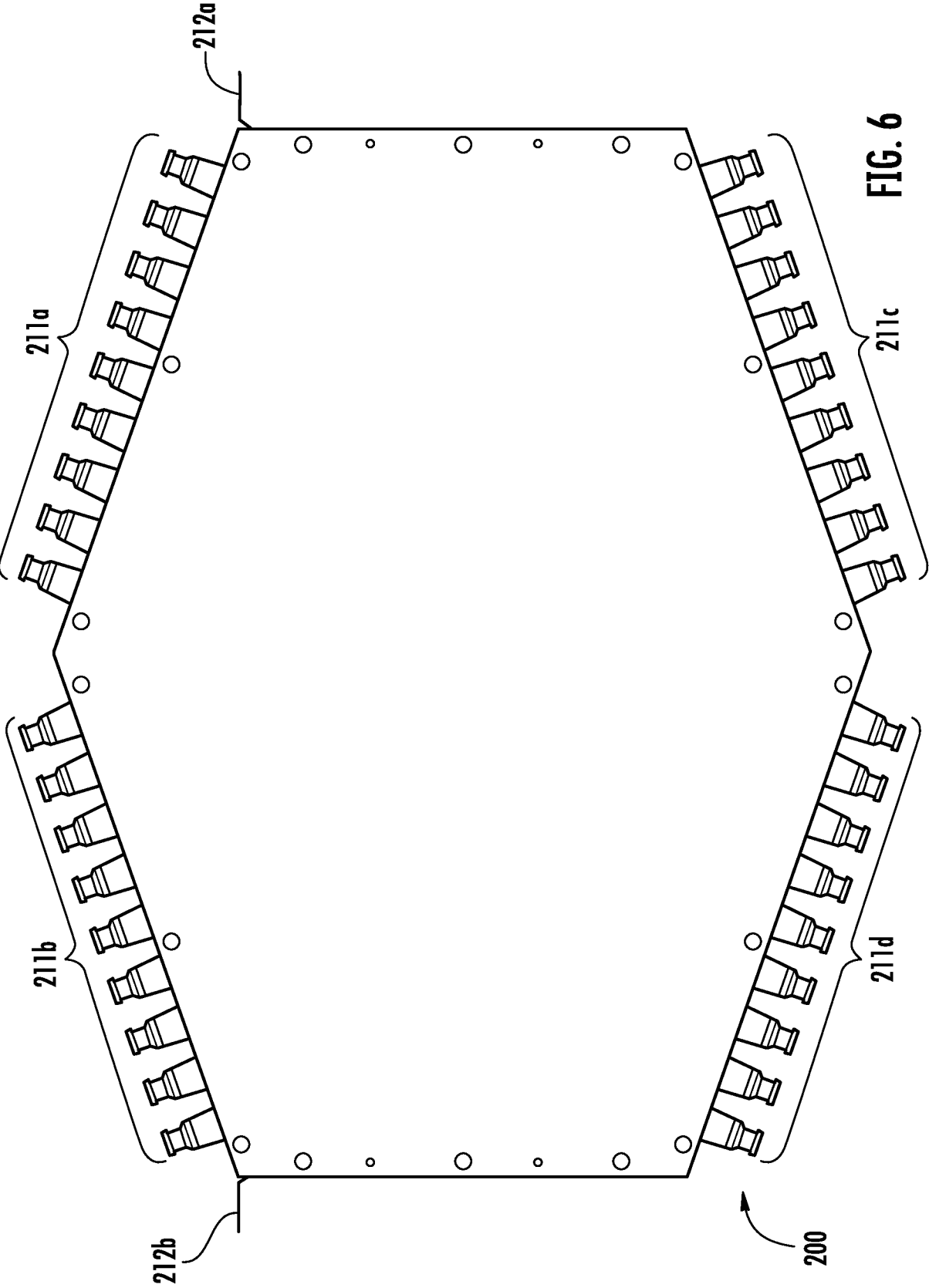


FIG. 5



7/11

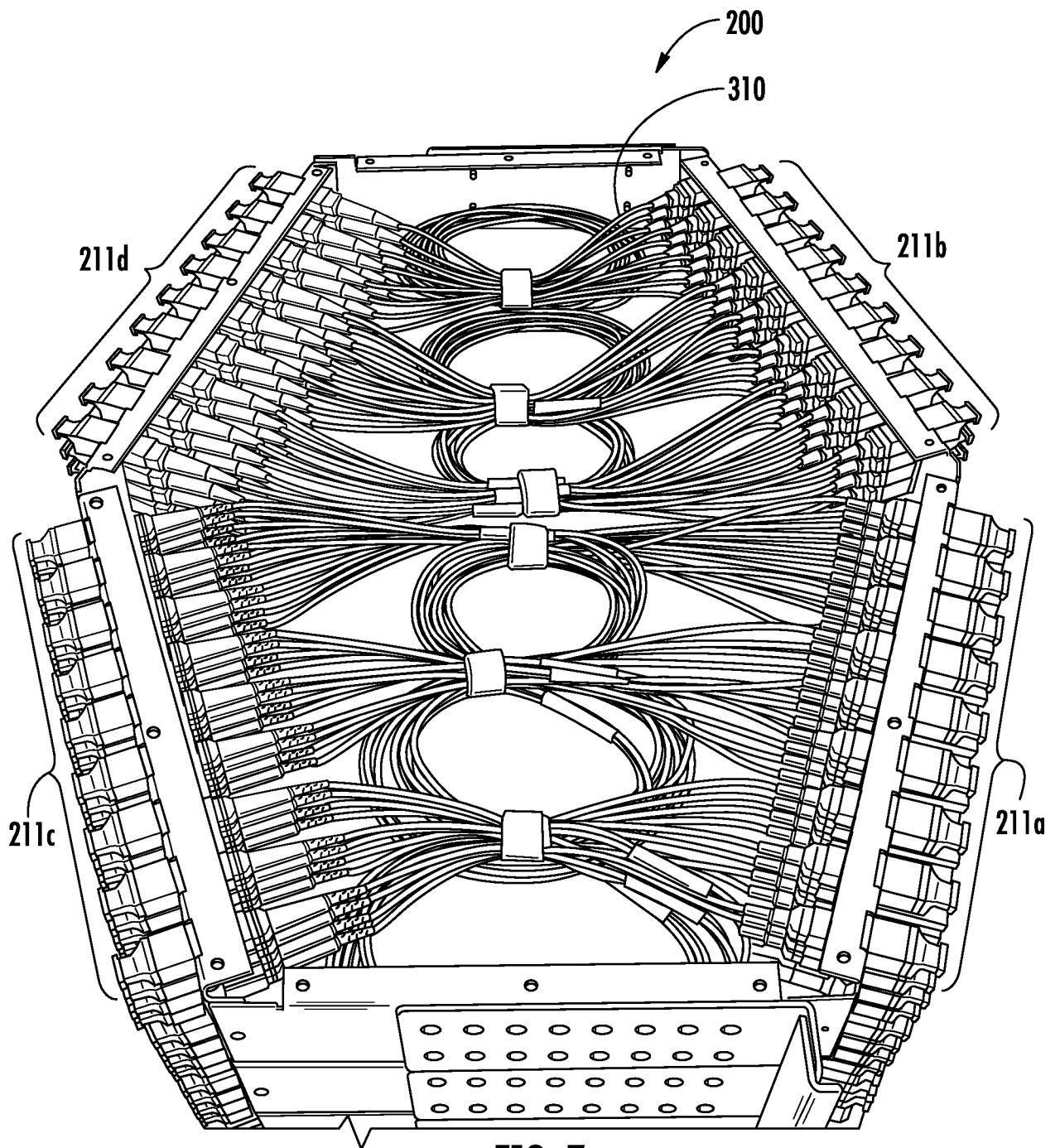
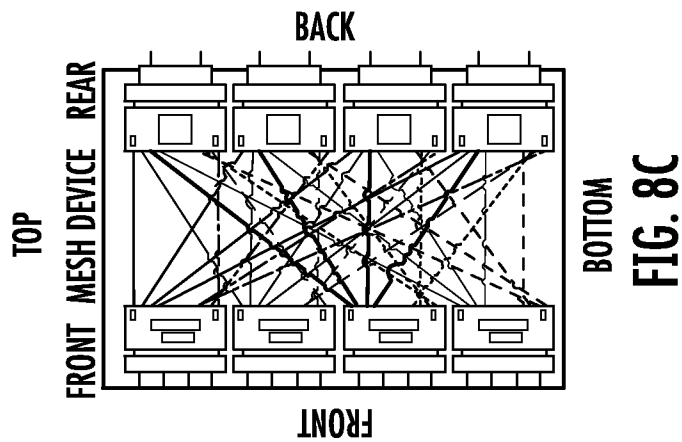
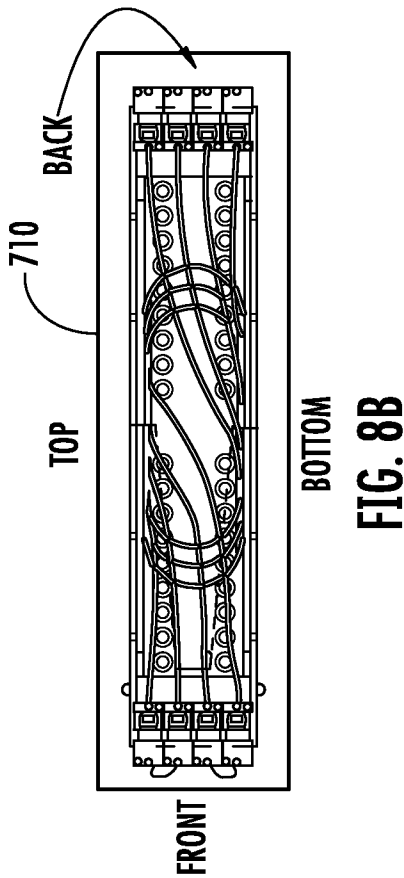
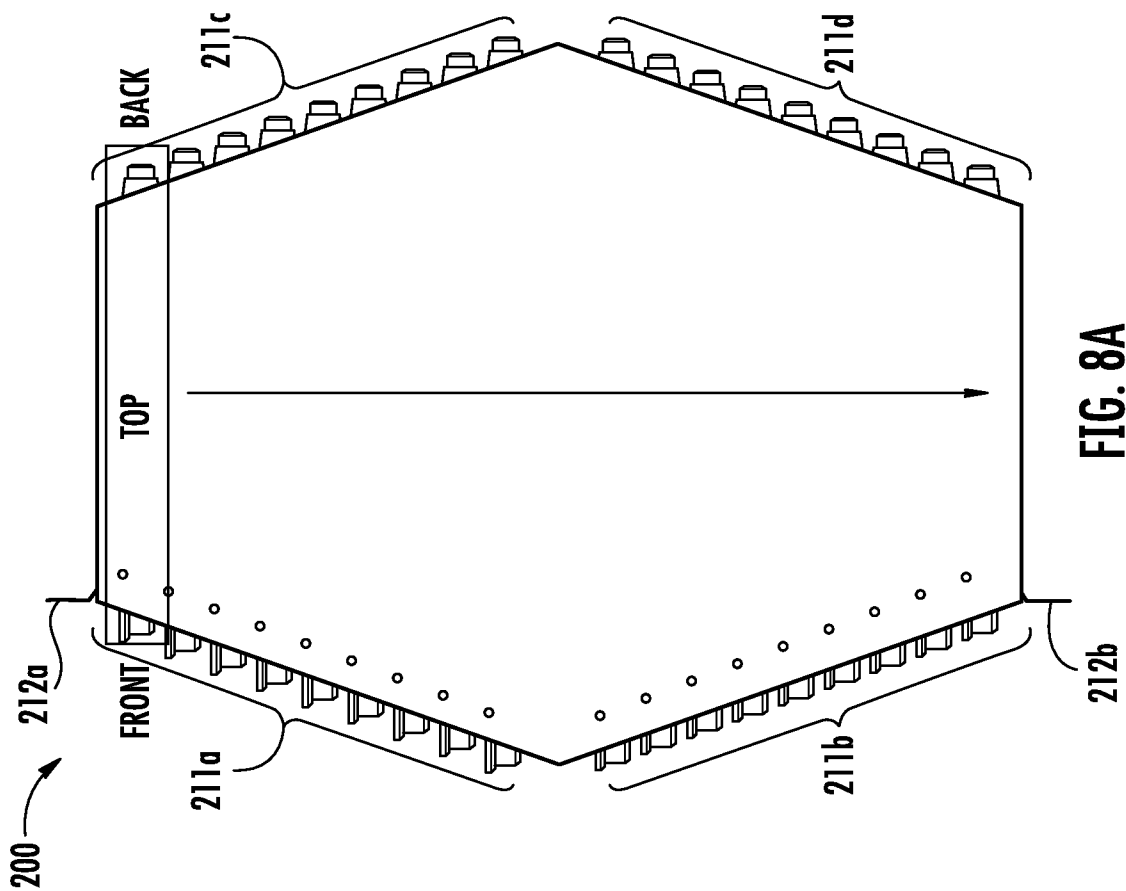


FIG. 7



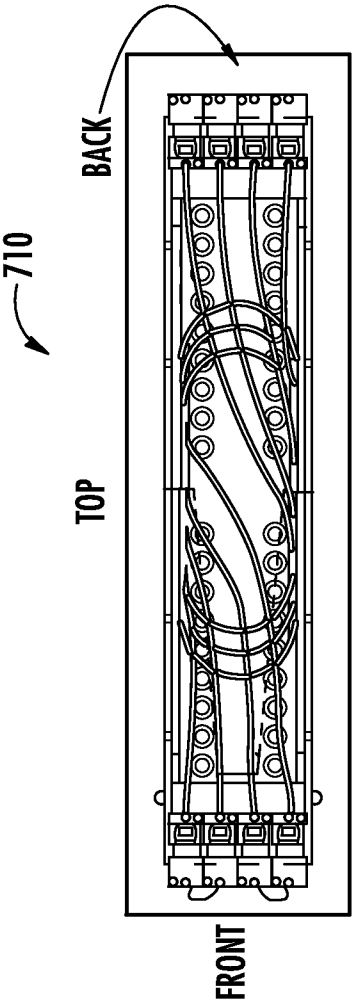


FIG. 9A

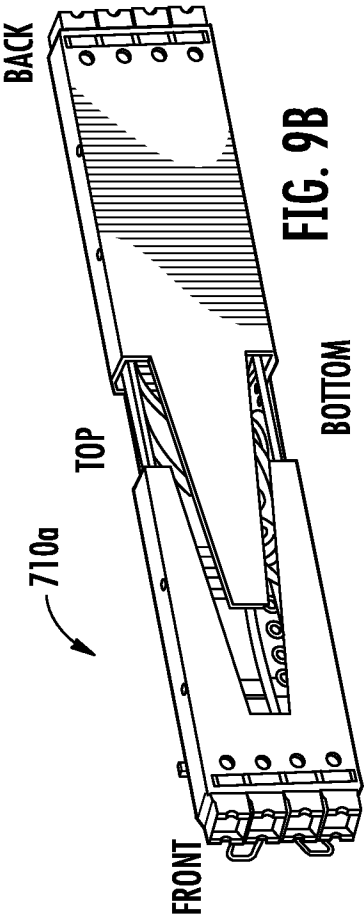


FIG. 9B

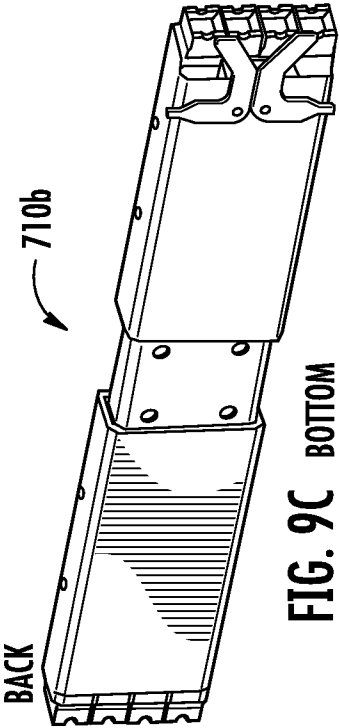


FIG. 9C

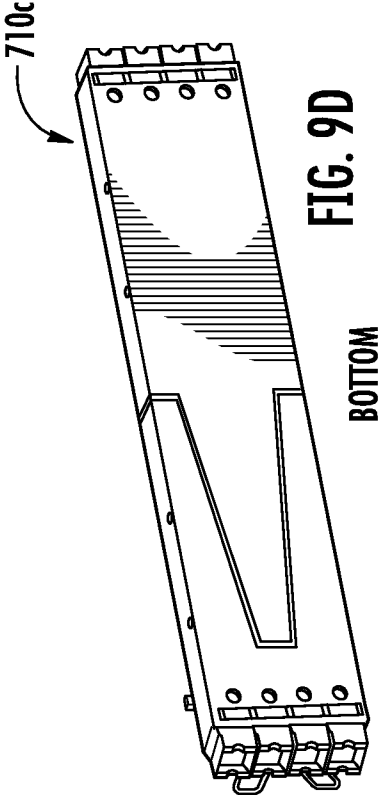


FIG. 9D

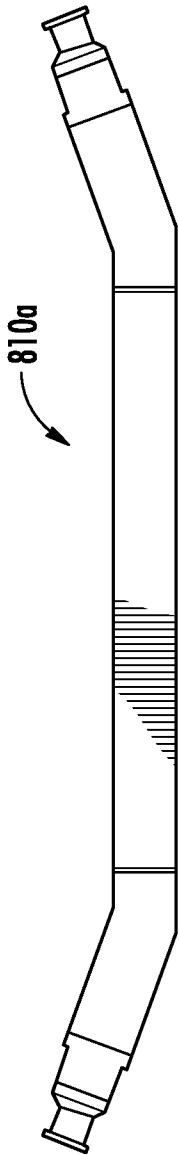


FIG. 10A

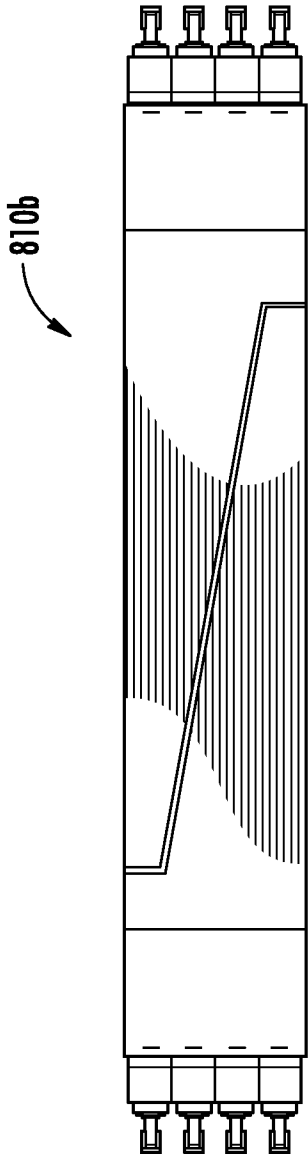


FIG. 10B

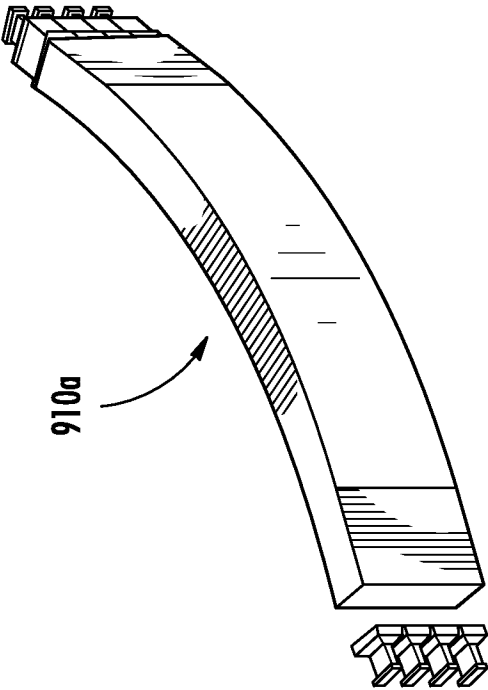


FIG. 11A

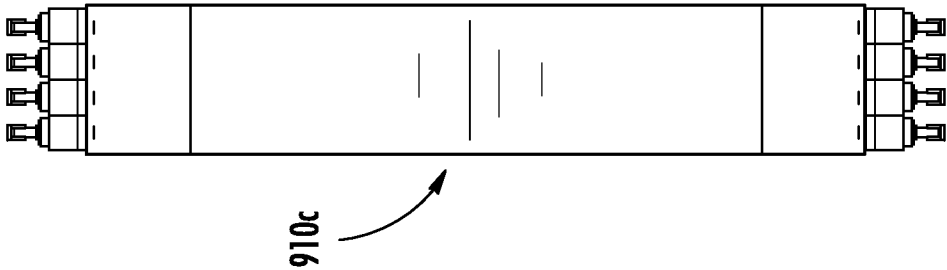


FIG. 11C

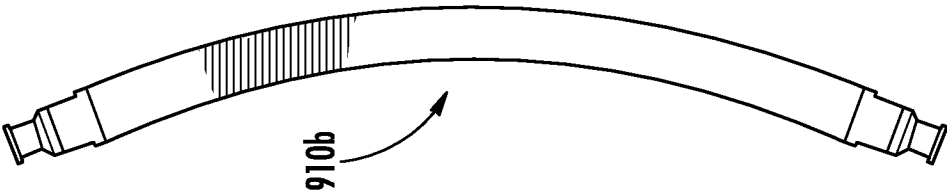


FIG. 11B

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 18/61179

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H04Q 11/00 (2018.01)

CPC - H04Q 2011/006

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- A	US 2015/0230007 A1 (CORNING OPTICAL COMMUNICATIONS LLC); 13 August 2015 (13.08.2015); entire document, especially Abstract, Figs. 3, 5A, para. [0032]-[0039].	10-11, 14-15 ----- 1-9, 12-13, 16-18
A	US 6,134,357 A (MACDONALD); 17 October 2000 (17.10.2000); entire document, especially Fig. 4; col. 2, ln 66- col. 3, ln 14.	1-9, 12-13
A	US 2016/0269229 A1 (INTERNATIONAL BUSINESS MACHINES CORPORATION); 15 September 2016 (15.09.2016) entire document, especially Abstract, para. [0079].	16-18
A	US 2010/0254703 A1 (KIRKPATRICK et al.); 7 October 2010 (07.10.2010); entire document.	1-18
A	US 2014/0270762 A1 (PLEXXI INC); 18 September 2014 (18.09.2014); entire document.	1-18

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

31 December 2018

Date of mailing of the international search report

24 JAN 2019

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer:

Lee W. Young

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774