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(54) **Title**: OPTICAL FIBER ARRAY CONNECTIVITY SYSTEM FOR MULTIPLE ROW TRUNK CABLES AND TERMINALS

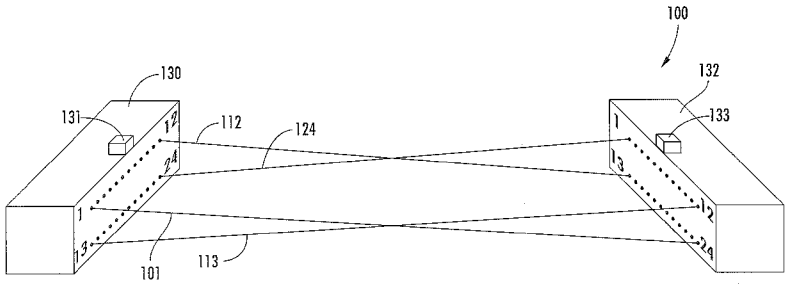


FIG. 1

(57) **Abstract**: A fiber optic trunk cable that can be used for connecting multi-channel transceivers includes: a plurality of optical fibers; and first and second terminals attached to opposite ends of the fibers, each of the terminals having an alignment key. The fibers enter the first terminal in an arrangement of 2N rows, wherein N is an integer, and enter the second terminal in an arrangement of 2N rows. Each fiber defines a position in the first terminal with respect to the alignment key that is laterally transposed and row-inverted to the position the fiber defines in the second terminal Such a cable can be employed with appropriate equipment cords and transceivers.

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OPTICAL FIBER ARRAY CONNECTIVITY SYSTEM FOR MULTIPLE ROW TRUNK CABLES AND TERMINALS

Related Application

[0001] This invention claims priority from U.S. Provisional Patent Application Serial No. 61/296,184, filed January 19, 2010, the disclosure of which is hereby incorporated herein in its entirety.

Field of the Invention

[0002] The present invention is directed generally to fiber optic multi-strand cables, connectors, adapters, fan-outs, and patching systems.

Background of the Invention

[0003] Optical fibers, both multi-mode and single mode, are commonly used for the transmission of signals of all sorts, including communication and data signals. Communications systems often transmit signals between transceivers (*i.e.*, devices that can both transmit and receive optical signals) via different fibers in each direction. More specifically, one or more fibers will transmit signals from the first transceiver to the second, and one or more of the other fibers will transmit signals from the second transceiver to the first. In this manner, optical signals are not traveling along the same fiber in different directions.

[0004] This arrangement would be fairly simple to organize for two transceiver devices that are permanently optically connected, but in practice transceivers are typically

connected through a much larger network of optical fibers, connectors and patch panels. For example, a common optical system includes multiple transceivers at one end, 2-fiber patch cords that are connected to the transceivers and to duplex adapters mounted on a patch panel, a fan-out transition device connected to the duplex adapters that connects to a multi-strand fiber optic trunk cable (12 fibers per cable is common, and the fiber strands may be in ribbon form) via an array adapter, a second fan-out transition device connected to the opposite end of the optic trunk cable via a second array adapter, and corresponding transceivers connected via 2-fiber patch cords to the second fan-out transition device through duplex adapters. Thus, it is important to be able to track individual optical fibers in the various devices and cables between the transceivers in order to ensure that the individual transceivers are connected as desired.

[0005] To ensure intermateability of cabling components and signal polarity, standards have been created to define arrangements of fibers, cables, adapters and connectors. For example, one such standard for array connectors, TIA-604-5B, is directed to multi-fiber push-on (MPO) fiber optic connector intermateability. Another standard, TIA 568-B.3 with addendum No. 7 written by committee TR-42, is directed to maintaining optical fiber polarity with systems using array connectors and adapters, including MPOs. Systems built using these methods utilize fiber optic cables, adapters, transition devices and patch cords that are typically partially or completely unique to one of these methods.

[0006] In some instances, transceivers may utilize less than all of the fibers of the trunk cable. For example, a transceiver may have only four channels, each of which has a "transmit" fiber and a "receive" fiber. Commonly, two such transceivers would utilize the outer four fibers on either end of a 12-fiber trunk cable; *i.e.*, the transmit fibers would use fibers 1-4 of the trunk cable, and the receive fibers would use fibers 9-12 of the trunk cable. Thus, the devices would occupy only eight of the 12 fibers of a 12-fiber trunk cable, which would result in inefficient use of the trunk cable. However, adding more transceivers onto the trunk cable in order to utilize all of the trunk cable fibers may complicate the connection scheme. One approach to this problem is proposed in co-assigned and co-pending U.S. Patent Application Serial No. 12/608,230, which provides schemes and accompanying devices that enable multiple transceivers having fewer than 12 fibers to connect with proper polarity via an available 12-fiber trunk cable.

[0007] A different situation may also arise when a transceiver has more than 6 channels (12 fibers); for example, each of a pair of transceivers may have 12, 18 or even 24 channels. It may also be desirable to provide schemes and devices that enable such transceiver to utilize 12-fiber trunk cables.

Summary of the Invention

[0008] As a first aspect, embodiments of the present invention are directed to a fiber optic trunk cable that can be used for connecting multi-channel transceivers. The trunk cable comprises: a plurality of optical fibers; and first and second terminals attached to opposite ends of the fibers, each of the terminals having an alignment key. The fibers enter the first terminal in an arrangement of 2N rows, wherein N is an integer, and enter the second terminal in an arrangement of 2N rows. Each fiber defines a position in the first terminal with respect to the alignment key that is laterally transposed and row-inverted to the position the fiber defines in the second terminal.

[0009] As a second aspect, embodiments of the present invention are directed to a fiber optic fan-out, comprising: a plurality of optical fibers; a first terminal attached to one end of the fibers, wherein the fibers are arranged in 2N rows, wherein N is an integer; and a plurality of second terminals attached to the opposite ends of the fibers, the fibers being attached in pairs, said pairs being formed by association of adjacent fibers within each row of the first terminal, and said pairs arranged in succession along the rows.

[0010] As a third aspect, embodiments of the present invention are directed to a fiber optic fan-out, comprising: a plurality of optical fibers; a first terminal attached to one end of the fibers, wherein the fibers are arranged in 2N rows, wherein N is an integer, the terminal having an alignment key; and 2N second terminals each with an alignment key, said second terminals attached to the opposite end of the fiber rows, the fibers being attached to the second terminals in single rows, the order of the second terminals being in succession to the rows of the first terminal, the alignment keys all facing in the same direction.

[0011] As a fourth aspect, embodiments of the present invention are directed to a fiber optic fan-out, comprising: a plurality of optical fibers; a first terminal attached to one end of the fibers, wherein the fibers are arranged in 2N rows, wherein N is an integer, said terminal having an alignment key; and N second terminals each with an alignment key, said second terminals attached to the opposite end of the fiber rows, the fibers being attached to

the second terminals in two rows and retaining their consecutive relationship established at the first terminal, the order of the second terminals being in succession to the rows of the first terminal, the alignment keys of the second terminals all facing the same direction.

[0012] As a fifth aspect, embodiments of the present invention are directed to a fiber optic system, comprising first and second fan-outs, a trunk cable, and connector-mating adapters. The first and second fan-outs comprise, respectively, first and second transceiver-side terminals with optional adapters. The first fan-out further comprises a first plurality of optical fibers attached to the first terminal, and the second fan-out comprises a second plurality of optical fibers attached to the second terminal. The first and second fan-outs further comprise first and second trunk cable-mating terminals, each of said terminals having an alignment key. The trunk cable comprises: a third plurality of optical fibers; and first and second trunk cable terminals attached to opposite ends of the third plurality of fibers, each of the first and second trunk cable terminals having an alignment key. The third fibers enter the first trunk cable terminal in an arrangement of 2N rows, wherein N is an integer. The third fibers enter the second trunk cable terminal in an arrangement of 2N rows. Each third fiber defines a position in the first trunk cable terminal with respect to the key that is laterally transposed and row-inverted (relative to a line parallel to and bisecting the rows) to the position the third fiber defines in the second trunk cable terminal. The first trunk cable terminal is connected with the first trunk cable-mating terminal, and wherein the second trunk cable terminal is connected with the second trunk cable-mating terminal, each connection mated with an adapter having aligned keyways.

Brief Description of the Figures

[0013] **Figure 1** is a schematic view of a 24-fiber trunk cable having fibers arranged in two rows according to embodiments of the present invention, wherein only the endmost fibers in the upper and lower rows are shown for clarity.

[0014] **Figure 2** is a schematic view of a system employing the trunk cable of **Figure 1**, wherein the transceivers employ fewer than 7 channels.

[0015] **Figure 3** is a schematic view of a system employing the trunk cable of **Figure 1**, wherein the transceivers employ more than 6 channels, and wherein the receive and transmit portions of the transceivers are separated in side-by-side relationship and receive separate terminals from the equipment cords.

[0016] **Figure 4** is a schematic view of a system employing the trunk cable of **Figure 1**, wherein the transceivers employ more than 6 channels, and wherein the receive and transmit portions of the transceivers are arranged in two rows within a single terminal.

[0017] **Figure 5** is a schematic view of a portion of a system employing two trunk cables of **Figure 1** as well as an inverted-row patch cord.

[0018] **Figure 6** is an enlarged view of multi-2-fiber fan-out and associated adapters for one or more transceivers in which the transmit and receive ports are arranged in individual pairs, and wherein the fibers are arranged in two rows at the terminal mating with a trunk cable. In **Figure 6**, the fan-out is shown in an "alpha" orientation.

[0019] **Figure 7** is an enlarged view of the fan-out of **Figure 6** shown in a "beta" orientation.

[0020] **Figure 8** is a schematic view of a system employing the trunk cable of **Figure 1** and the fan-outs of **Figures 6** and **7**.

[0021] **Figure 9** is a schematic view of a system employing the trunk cable of **Figure 1** similar to that shown in **Figure 4**, but wherein the equipment cords are row-inverted.

[0022] **Figure 10** is a schematic side view of a system having a trunk cable with fibers arranged in four rows, wherein each row serves a separate transceiver and the adapters between terminals are not shown.

[0023] **Figure 11** is a schematic perspective view of the system of the system of **Figure 10**, wherein only the endmost fibers in each row are shown for clarity, adapters are shown, and the trunk extension cable is not shown.

[0024] **Figure 12** is a schematic side view of a system similar to that shown in **Figure 10**, but with the key orientations of the trunk-side terminals of the fan-outs reversed.

[0025] **Figure 13** is a schematic perspective view of the system of **Figure 12**, wherein only the endmost fibers in each row are shown for clarity, adapters are shown, and the trunk extension cable is not shown.

[0026] **Figure 14** is a schematic side view of a system like that of **Figure 10**, wherein two rows of fibers serve each of the transceivers.

Detailed Description

[0027] The present invention will now be described more fully hereinafter, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, like numbers refer to like elements throughout, and the thickness of lines, layers and regions may be exaggerated for clarity.

[0028] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0029] It will be understood that when an element is referred to as being "coupled" or "connected" to another element, it can be directly coupled or connected to the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly coupled" or "directly connected" to another element, there are no intervening elements present. As used herein the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0030] In addition, spatially relative terms, such as "under", "below", "lower", "over", "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "under" or "beneath" other elements or features would then be oriented "over" the other elements or features. Thus, the exemplary term "under" can encompass both an orientation of over and under. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0031] Well-known functions or constructions may not be described in detail for brevity and/or clarity.

[0032] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0033] Referring now to the drawings, an exemplary 24-fiber trunk cable, designated broadly at **100**, is illustrated in **Figure 1**. The trunk cable **100** includes twenty-four optical fibers (four of which, fibers **101, 112, 113** and **124**, are shown in **Figure 1**), a terminal **130** at one end of the fibers **101-124**, and a terminal **132** at the opposite end of the fibers. Each of the terminals has a respective projection, or "key" **131, 133** on one side thereof to enable the trunk cable **100** to be aligned and oriented properly with another cable, cord or component. As can be seen in **Figure 1**, the fibers are arranged such that they form two rows of twelve fibers each at each terminal **130, 132**, with the fibers entering one terminal **130, 132** in the top row entering the other terminal **132, 130** in the bottom row at laterally transposed positions relative to a vertical plane that bisects the terminals **130, 132**. For example, using the convention that the top row has positions 1-12 from left to right, as viewed from the direction the fibers enter the terminal, and that the bottom row has positions 13-24 from left to right from the same vantage point, the fiber **101** extends between position 1 of terminal **130** (the leftmost position of the top row) and position 24 of terminal **132** (the rightmost position of the bottom row). Similarly, fiber **113** extends between position 13 of terminal **130** (the leftmost position of the bottom row) and position 12 of terminal **132** (the rightmost position of the top row). On the opposite side of the cable **100**, fiber **112** extends between position 12 of terminal **130** and position 13 of terminal **132**, and fiber **124** extends between position 24 of terminal **130** and position 1 of terminal **132**.

The fibers that are not shown follow the pattern established by the illustrated fibers. The keys **131, 133** shown on the top surface establish the orientation of the terminals **130, 132**. Fibers attached to the upper row of the terminal **130** are also attached to the lower row of the terminal **132**. For fibers routed as shown, the oppositely facing terminals produce a lateral transposition of the fiber locations, such that fibers attached to the leftmost positions on one

terminal are attached to the rightmost positions on the other terminal (the "right" and "left" positions being from a vantage point of the fibers as they enter the terminal). The result is that the group of fibers forms mirror images about a vertical plane extending normal to the rows formed by the fibers in the terminals **130, 132** extending through the keys **131, 133**.

[0034] As can be seen from this explanation and illustration, the cable **100** is "row-inverted", in that each fiber occupies a position at one terminal in one row (*i.e.*, top or bottom row) and at the other terminal occupies the position in the opposite row (*i.e.*, bottom or top) that is laterally transposed (*e.g.* leftmost to rightmost) as seen when viewed from the direction where the fibers enter the terminals. This pattern can be extended to terminals with arbitrary even numbers of rows. For the 2-row, 24-fiber cable **100**, **Table 1** shows the routing arrangement.

Table 1

Fiber No.	Position at Terminal 130	Position at Terminal 132	Fiber No.	Position at Terminal 130	Position at Terminal 132
101	1	24	113	13	12
102	2	23	114	14	11
103	3	22	115	15	10
104	4	21	116	16	9
105	5	20	117	17	8
106	6	19	118	18	7
107	7	18	119	19	6
108	8	17	120	20	5
109	9	16	121	21	4
110	10	15	122	22	3
111	11	14	123	23	2
112	12	13	124	24	1

[0035] The trunk cable **100** can be used in fiber optic systems for connecting transceivers. One exemplary system is shown in **Figure 2** and designated **200**. A transceiver **252** having separate receive and transmit portions **Rx, Tx** of six ports each on each side thereof is located at one end of the system **200**, and a similarly configured transceiver **254** is located at the opposite side of the system **200**. This configuration denotes a transceiver with six or fewer lanes (channels). Two identical equipment cords **256, 256'** are interconnected with the transceivers **252, 254**. The equipment cords **256, 256'** each include a terminal **262**

that receives twenty-four fibers arranged in two rows, with the fibers of the upper row being routed to a terminal **258** and the fibers of the lower row being routed to a terminal **260**. An "aligned-keyway" adapter **264** connects the terminal **262** of the equipment cord **256** to the terminal **130** of the trunk cable **100**. The opposite terminal **132** of the trunk cable **100** is connected with another adapter **264'**, which is attached to one end of an optional twenty-four fiber extension cable **268**. The opposite end of the extension cable **268** is connected to a third adapter **264''**, which is connected with the terminal **262** of the equipment cord **256'**. Notably, the "keys" for each of the equipment cords **256, 256'**, the trunk cable **100** and the equipment cable **268** are oriented to be "up" for alignment with the aligned keyways of the adapters.

[0036] The connectivity of the system can be demonstrated by following a signal from a transmitter **Tx** of the transceiver **252** to a receiver **Rx** of the transceiver **254**. Beginning on the left side of **Figure 2**, a signal (represented by a bold line) is transmitted from the left endmost port of the transmitter **Tx** to the endmost fiber **201** of terminal **260** of the equipment cord **256**. The signal proceeds to the endmost port of the bottom row of the terminal **262** of the equipment cord **256**, then through the endmost port of the bottom row of the terminal **130** and to the fiber **113** of the trunk cable **100** (corresponding to position 13 of **Figure 1**). The fiber **113** rises to the upper row of the terminal **132** (*i.e.*, to position 12 of **Figure 1**), where it then passes to the extension cable **268** and into the right endmost fiber of the upper row of the equipment cord **256'**. From there the signal passes through the right endmost port of the terminal **258** of the equipment cord **256'** and into the right endmost port of the receiver **Rx** of the transceiver **254**. Similar paths can be traced for the other fibers connecting the transceivers **252, 254**. Thus, it can be seen that the equipment cords **256. 256'** can be identical and can be used to interconnect the transceivers **252, 254** in a "key-up to key-up" manner and retain functional polarity.

[0037] Referring now to **Figure 3**, a system **300** is shown therein that includes two transceivers **350, 352** that have more than six channels, such that each transceiver **350, 352** has one transmitter portion **Tx** and one receiver portion **Rx** having twelve ports each. The system also includes equipment cords **256, 256'**, a trunk cable **100**, and an extension cable **268**. A signal sent through fiber **301** can be traced from transmitter **Tx** in transceiver **350** to receiver **Rx** in transceiver **352** by following the same path through the equipment cord

256, the trunk cable **100**, the extension cable **268**, and the equipment cord **256'** as described above for a signal through fiber **201**.

[0038] **Figure 4** illustrates a system **400** in which transceivers **450, 452** are arranged with their twelve ports for receivers **Rx** positioned in a row above their twelve ports for transmitters **Tx** as a single unit, thereby requiring only a single terminal for connection. In this instance each of two equipment cords **456, 456'** has only one terminal **458** that connects with its respective transceiver **450, 452**, with the two rows of fibers each being routed directly from the terminal **460** to the terminal **458** and remaining in their respective (upper or lower) positions. In this arrangement, a signal traveling through fiber **401** can be traced from lower row of fibers (connected to a transmitter **Tx**) of the transceiver **450** to the upper row of fibers (connected to a receiver **Rx**) of the transceiver **452** by passing through the equipment cord **456**, the trunk cable **100** (where the signal passes from the bottom row to the top row), the extension cord **268** and the equipment cord **456'**.

[0039] **Figure 5** demonstrates that, in a system **500** in which multiple trunk cables **100** are employed in a cross-connected arrangement, row-inverted patch cords **556** with fiber routing identical to that of the trunk cables can be used to maintain proper polarity.

[0040] **Figures 6** and **7** are enlarged views of a multi-2-fiber fan-out and associated adapters **656**, which includes a terminal **662**, twenty-four fibers **601-624** arranged in upper and lower rows, and twelve 2-fiber terminals **681-692** that mate each with optional 2-fiber adapters **631 – 642** (note that **Figure 6** shows the "alpha" orientation of the cord **656** and **Figure 7** shows the inverted "beta" orientation **656'**). Notably, fibers **613-624** of the upper row (wherein the "upper" row is designated based on the alpha orientation of **Figure 6**, wherein the key is "down") are routed directly from the ports 13-24 of the terminal **662** to the ports numbered 12 – 1 of terminals **687-692** that face adapter ports numbered 24 – 13 respectively. However, the fibers **601-612** of the lower row are routed such that each fiber crosses over an adjacent paired fiber to accommodate the keyway-down orientation of the adapters **631-636**. (The adapters are oriented with keyways down to facilitate finger access to terminal latch features that are not shown.) For example, fiber **601** crosses over fiber **602**, such that fiber **601** is routed from port 1 of the terminal **662** to port 12 of the terminal **686** that faces port 11 of adapter **636**, and fiber **602** is routed from port 2 of the terminal **662** to port 11 of the terminal **686** that faces port 12 of adapter **636**. The same crossing over of adjacent paired fibers is followed for all of the fibers of the lower row as they are routed to

the terminals **681-685**. **Figure 7** shows that the same arrangement is maintained when the fan-out **656** is inverted to the beta orientation. It should be noted that while the assemblies shown in **Figures 6** and 7 depict fan-outs mating to adapters, they also illustrate the connectivity of equipment cords in the case where the 2-fiber adapters are instead transceivers. Thus the term "fan-out" is meant to apply to both transition assemblies contained within cassettes as well as equipment cords.

[0041] **Figure 8** shows a system **600** that utilizes two fan-outs **656, 656'**. A trunk cable **100** is connected between each fan-out **656**, one of which (fan-out **656**, on the left side of **Figure 8**) is shown in the alpha orientation and the other of which (fan-out **656'**, on the right side of **Figure 8**) is shown in the beta orientation. For clarity, the trunk cable **100** is shown in a twisted configuration such that the key of terminal **130** faces down. Each of the alpha-side adapters **631-642** is assigned a transmit port **Tx** and a receive port **Rx**, as are the beta-side adapters **631'-642'**, as they would be associated with 2-fiber transceivers via 2-fiber patch cords both of which are not shown.

[0042] Connectivity of the system **600** can be verified by tracking a signal from the alpha-side port 13 of adapter **637**, which travels on fiber **624** of the alpha fan-out **656** to the endmost port 24 of the upper row of the terminal **662**. The signal then travels in the fiber **113** from port 13 of the terminal **130** of the trunk cable **100** to port 12 of the terminal **132** (which is shown in as the endmost port of the upper row in **Figure 8**). The signal then travels in fiber **601'** of the beta fan-out **656'** to the port 14 of the beta-side adapter **636'**, where it is received in the proper **Rx** port. As another example, a signal transmitted from the **Tx** port 23 of the adapter **642** is routed in fiber **614** of the cord **656** to the second nearest upper port 14 of terminal **662**, then to the second farthest upper port of terminal **662'** of fan-out **656'**, then to the endmost port 24 (an **Rx** port) of the adapter **631'**. Similar tracking can be performed for the other fibers of the system **600**.

[0043] **Figure 9** illustrates a system **700** which is like that of the system **400** of **Figure 4**, but which utilizes equipment cords **756, 756'** that are row-inverted. In other words, a fiber is routed from the upper row of one terminal **758** to the lower row of the other terminal **762** and vice versa. Notably, in the system **700**, each of the trunk cable **100** and the two equipment cords **756, 756'** are row-inverted, which may render it simpler for the installer/customer to keep track of connectivity (because both the equipment cords and the trunk cable are row-inverted).

[0044] **Figures 10** and **11** illustrate a system **1000** that demonstrates that the principles discussed above can be applied to systems in which more than two rows of fibers are employed. For simplicity in **Figure 10** each row of fibers is represented by a single line and the adapters are not shown. For simplicity in **Figure 11** the extension cable **1110** is not shown to provide space to show the adapters and all ports on the terminals. In the description that follows, extension cable **1110** is ignored. A trunk cable **1100** has four rows of fibers that are row-inverted between terminal **1130** and **1132**. Array fan-outs **1056, 1056'** each include four terminals **1058, 1060, 1062, 1064** on one end, each of which has a single row of fibers, and a single terminal **1066** that has four rows of twelve fibers each and connects to one end of the trunk cable **1100**. For simplicity in **Figures 10** and **11**, both fan-outs **1056, 1056'** are shown in an alpha orientation, in which the terminals **1058, 1060, 1062, 1064** have key features on top. As can be seen in **Figure 11**, a signal from alpha port 1 connected to terminal **1064** of fan-out **1056** is routed to the terminal **1058** and beta port 1 of fan-out **1056'**; similarly, a signal from alpha port 4 connected to terminal **1058** of fan-out **1056** is routed to the terminal **1064** and beta port 4 of fan-out **1056'**. Thus port numbers on the left connect to like port numbers on the right.

[0045] **Figures 12** and **13** illustrate a system **1200** that is similar to the system **1000**, with the exception that the orientation of the keys of the terminals **1266** of the fan-outs **1256, 1256'** is reversed (i.e. shown on top of terminals **1266**) to the key orientation shown for analogous terminals **1066** of **Figures 10** and **11**.

[0046] **Figure 14** illustrates a system **1400** in which fan-outs **1456, 1456'** each have two terminals **1458, 1460** that each receive two rows of fibers from the terminal **1462**. Tracking of signals through the fibers of the system **1400** shows that a signal originating in the top row of the terminal **1458** of fan-out **1456** (i.e. alpha port number 02) is received in the bottom row of the terminal **1460** of fan-out **1456'** (i.e. beta port number 02).

[0047] Those skilled in this art will appreciate that systems other than those illustrated herein may be employed. For example, extension cables may be added or omitted. The numbers of fibers and/or rows of fibers within trunk cables and equipment cords may vary. For example, a trunk cable, equipment cord or fan-out may have 2N rows of fibers in its terminals, wherein N is an integer (*e.g.*, 1, 2, 3, 4, etc.). The style and type of MPO connector may vary. Other modifications will be apparent to those of skill in this art.

[0048] The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.

That Which is Claimed is:

1. A fiber optic trunk cable, comprising:

a plurality of optical fibers;

first and second terminals attached to opposite ends of the fibers, each of the terminals having an alignment key;

wherein the fibers enter the first terminal in an arrangement of 2N rows, wherein N is an integer;

wherein the fibers enter the second terminal in an arrangement of 2N rows;

each fiber defining a position in the first terminal with respect to the alignment key that is laterally transposed and row-inverted to the position the fiber defines in the second terminal.

2. The cable defined in Claim 1, wherein N=1 or 2.

3. The cable defined in Claim 2, wherein 12 fibers occupy each row.

4. A fiber optic fan-out, comprising:

An even number of optical fibers;

a first terminal attached to one end of the fibers, wherein the fibers are arranged in 2N rows, wherein N is an integer;

a plurality of second terminals attached to the opposite ends of the fibers, the fibers being attached in pairs, said pairs formed by association of adjacent fibers within each row of the first terminal, said pairs arranged in succession along the rows.

5. The fan-out defined in Claim 4, wherein N=1.

6. The fan-out defined in Claim 5, wherein the plurality of fibers is 24 fibers.

7. A fiber optic fan-out, comprising:

a plurality of optical fibers;

a first terminal attached to one end of the fibers, wherein the fibers are arranged in 2N rows, wherein N is an integer, said terminal having an alignment key;

and 2N second terminals each with an alignment key, said second terminals attached to the opposite end of the fiber rows, the fibers being attached to the second terminals in single rows and retaining their consecutive relationship established at the first terminal, the order of the second terminals being in succession to the rows of the first terminal, the alignment keys of the second terminals all facing the same direction..

8. The fan-out defined in Claim 7, wherein N=1 or 2.

9. The fan-out defined in Claim 8, wherein the plurality of fibers is either 24 or 48 fibers.

10. A fiber optic fan-out, comprising:

a plurality of optical fibers;

a first terminal attached to one end of the fibers, wherein the fibers are arranged in 2N rows, wherein N is an integer, said terminal having an alignment key;

and N second terminals each with an alignment key, said second terminals attached to the opposite end of the fiber rows, the fibers being attached to the second terminals in two rows and retaining their consecutive relationship established at the first terminal, the order of the second terminals being in succession to the rows of the first terminal, the alignment keys of the second terminals all facing the same direction.

11. The fan-out defined in Claim 10, wherein N=1 or 2.

12. A fiber optic system, comprising:

first and second fan-outs comprising, respectively, first and second transceiver-side mating terminals, the first fan-out further comprising a first plurality of optical fibers attached to the first transceiver-side terminal(s), the second fan-out comprising a second plurality of optical fibers attached to the second transceiver-side terminal(s), the first and second fan-outs further comprising first and second trunk cable-mating terminals; and

a trunk cable comprising:

a third plurality of optical fibers;

first and second trunk cable terminals attached to opposite ends of the third plurality of fibers, each of the first and second trunk cable terminals having an alignment key;

wherein the third fibers enter the first trunk cable terminal in an arrangement of 2N rows, wherein N is an integer;

wherein the third fibers enter the second trunk cable terminal in an arrangement of 2N rows;

each third fiber defining a position in the first trunk cable terminal with respect to the alignment key that is laterally transposed and row-inverted (relative to a line parallel to and bisecting the rows) to the position the third fiber defines in the second trunk cable terminal;

wherein the first trunk cable terminal is connected with the first trunk cable-mating terminal, and wherein the second trunk cable terminal is connected with the second trunk cable-mating terminal, each connection mated with an adapter having aligned keyways.

13. The system defined in Claim 12, wherein N=1 or 2.

14. The system defined in Claim 13, wherein N=1 and the plurality of fibers is 24 fibers, such that 12 fibers occupy each row.

15. The system defined in Claim 13, wherein N=2 and the plurality of fibers is 48 fibers, such that 12 fibers occupy each row.

16. The system defined in Claim 12, wherein the first fan-out comprises 2N first transceiver-side mating terminals and the second fan-out comprises 2N second transceiver-side mating terminals.

17. The system defined in Claim 12, wherein the first fan-out comprises N first transceiver-side mating terminals and the second fan-out comprises N second transceiver-side mating terminals.

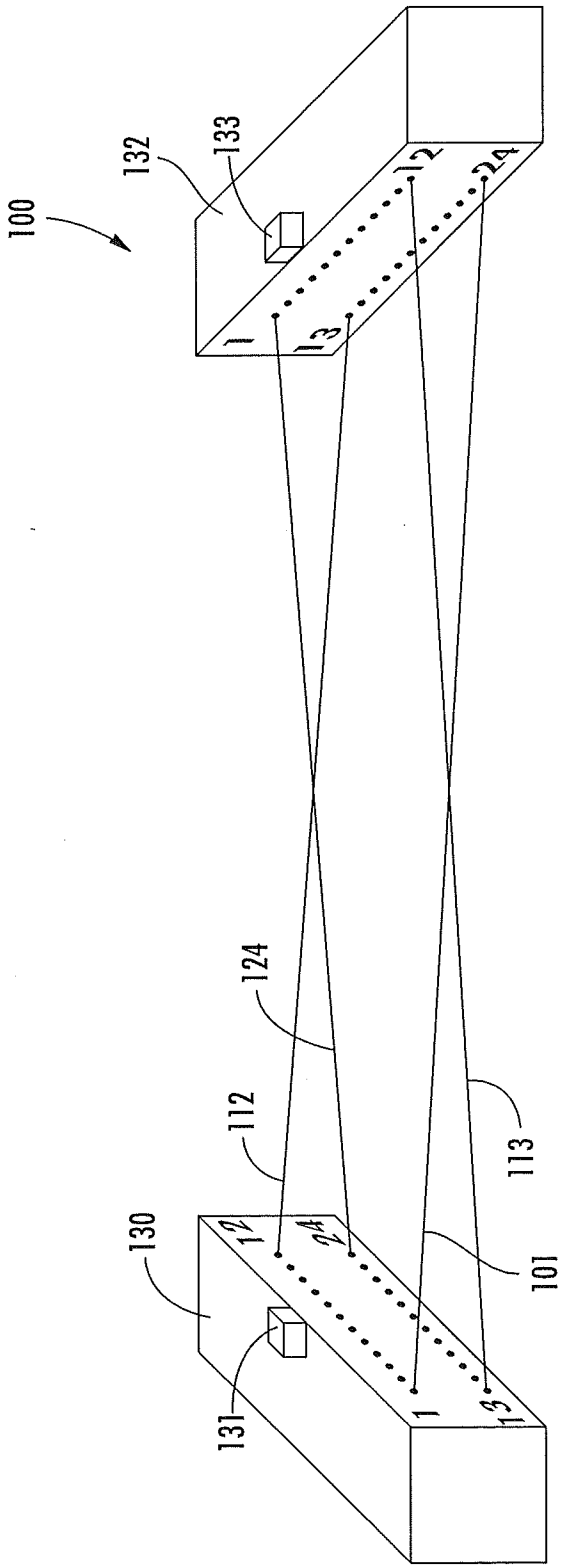


FIG. 1

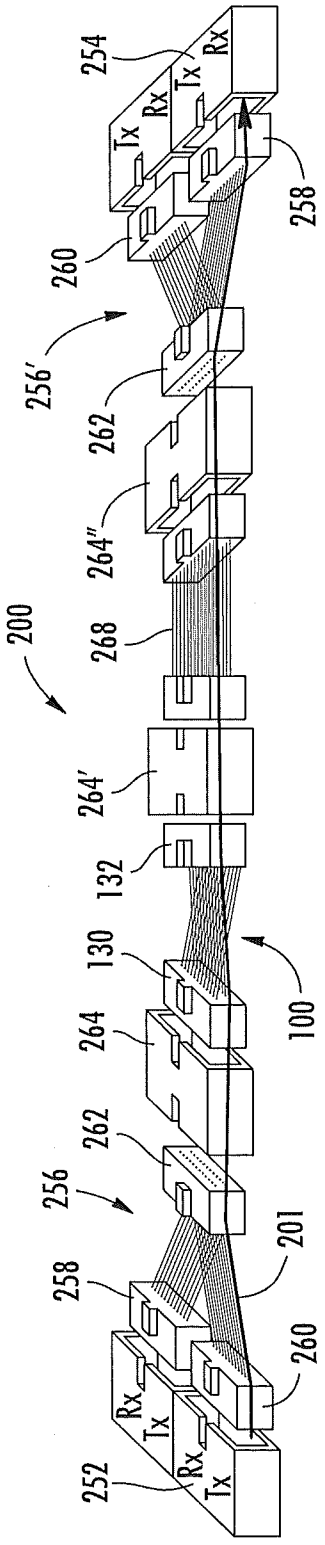


FIG. 2

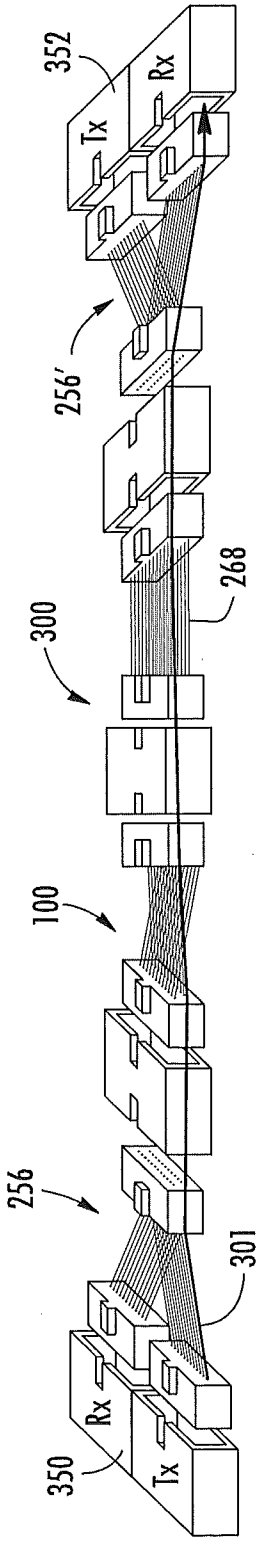


FIG. 3

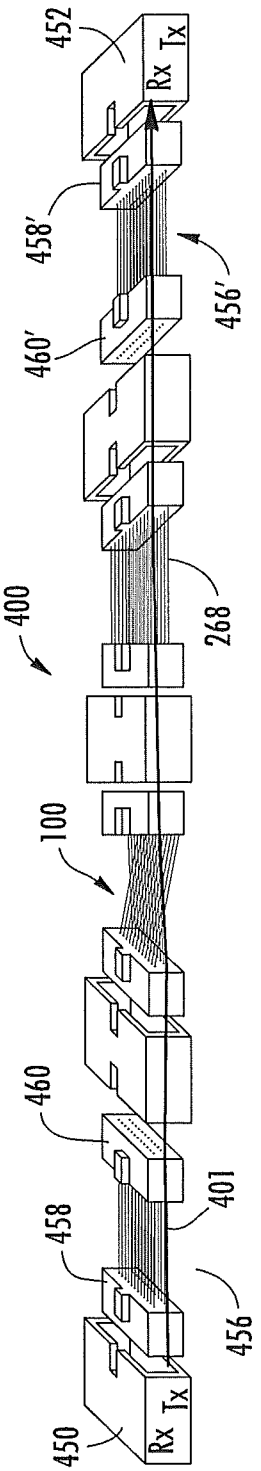


FIG. 4

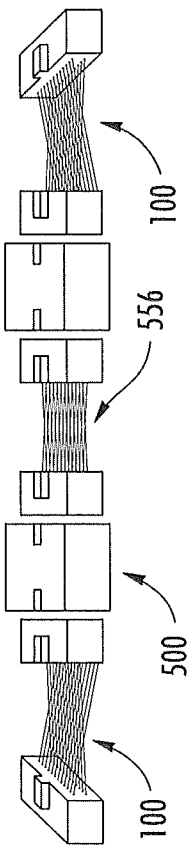


FIG. 5

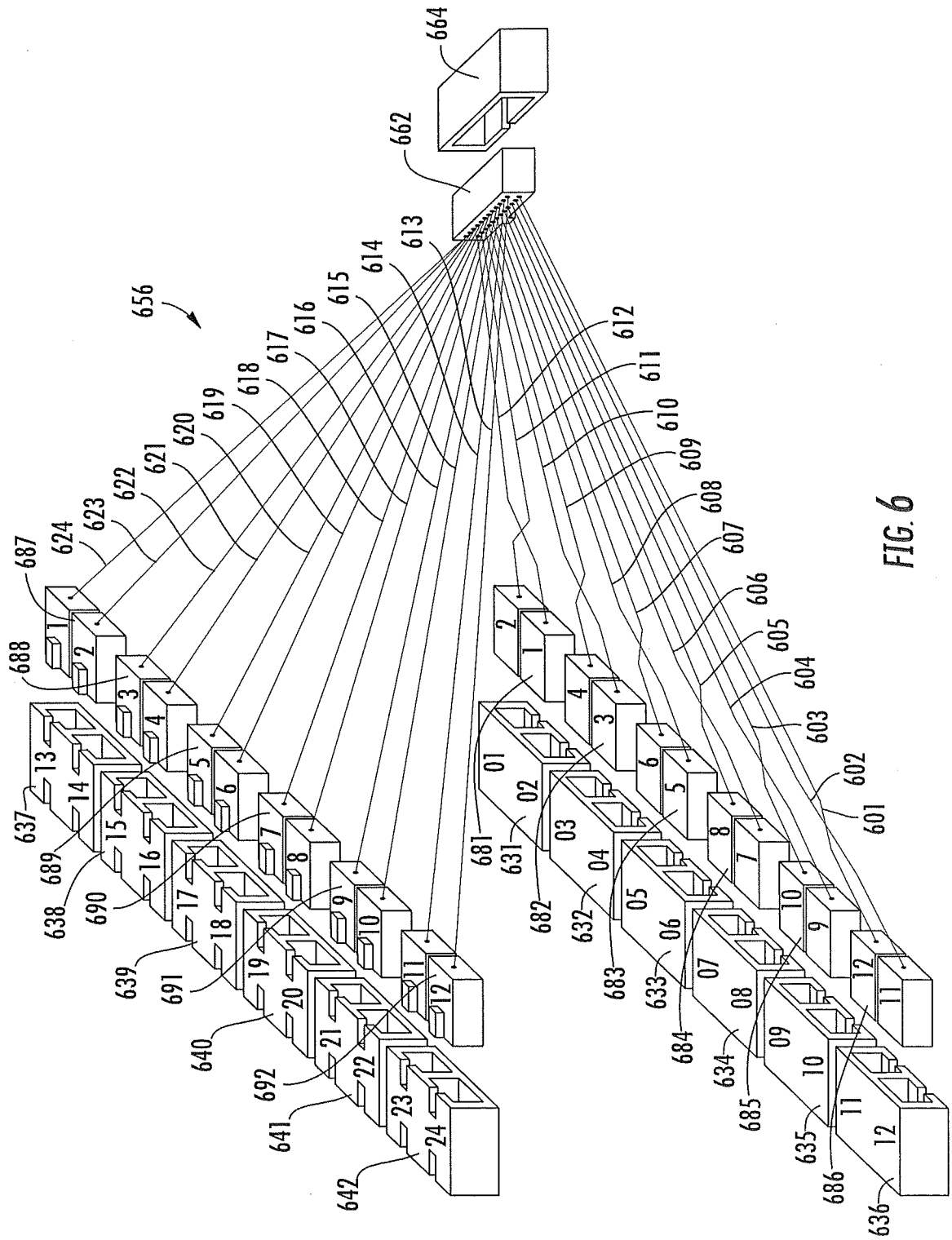

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FIG. 6

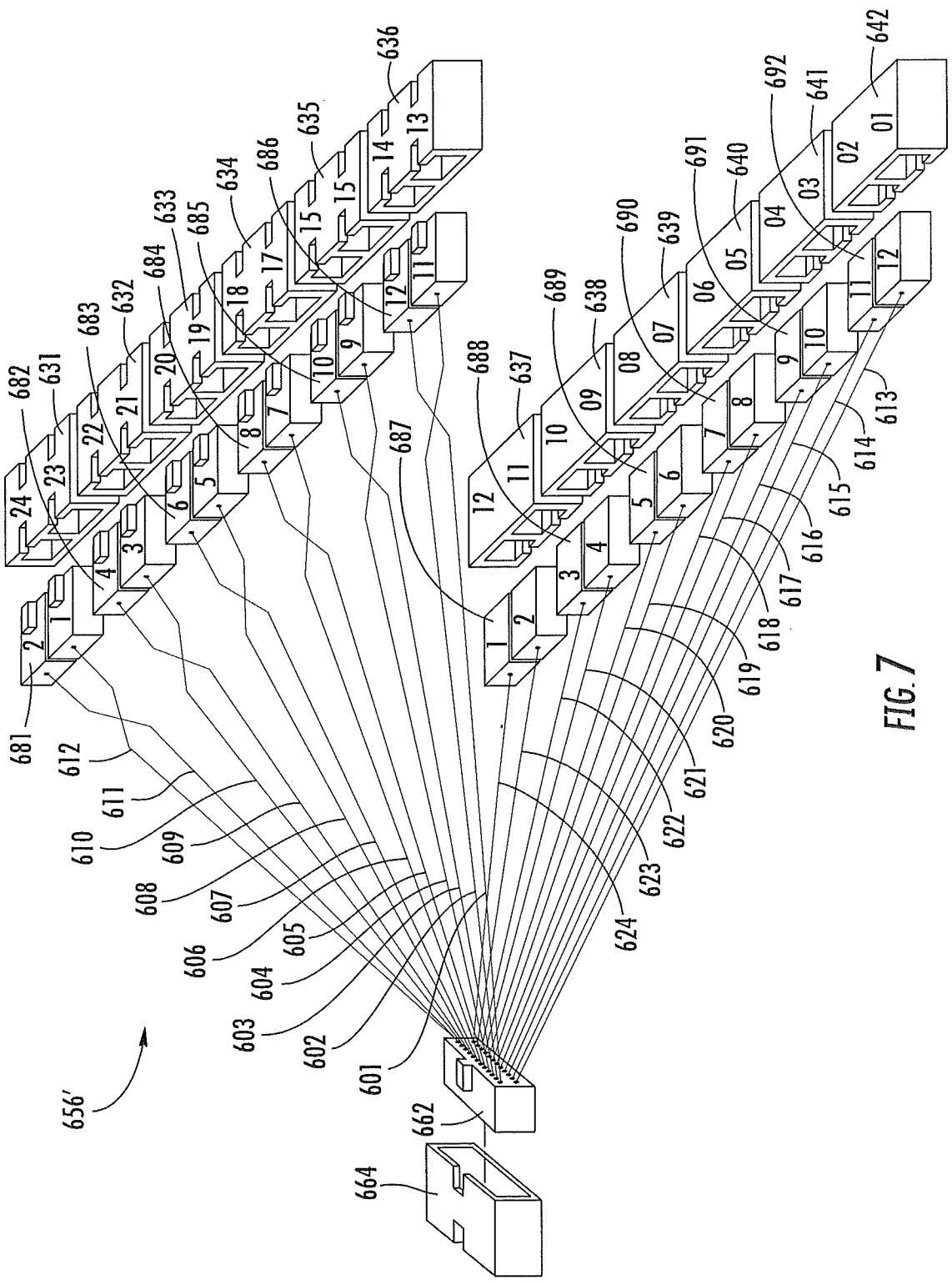

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FIG. 7

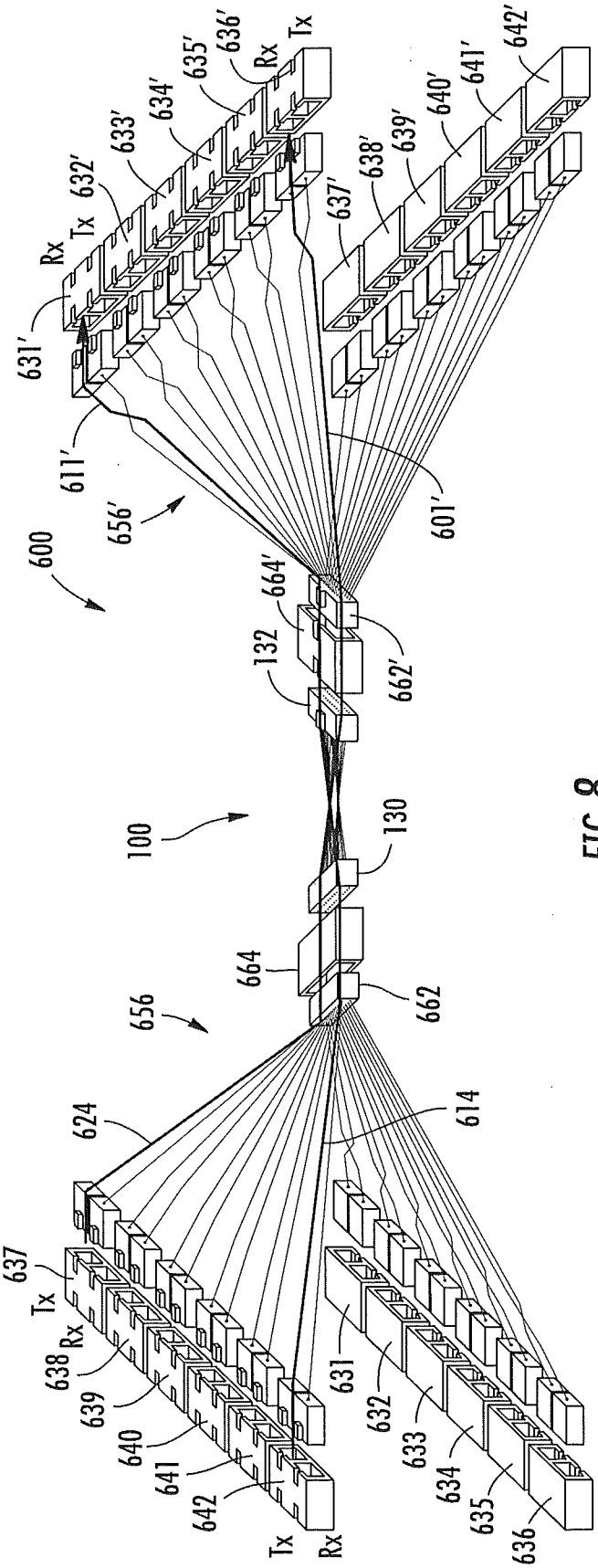

600
100
656
656'
611'
631'
Rx
Tx
632'
633'
634'
635'
636'
Tx
Rx
637'
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641'
642'
601'
664'
132
662'
130
664
662
624
614
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Tx
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636

FIG. 8

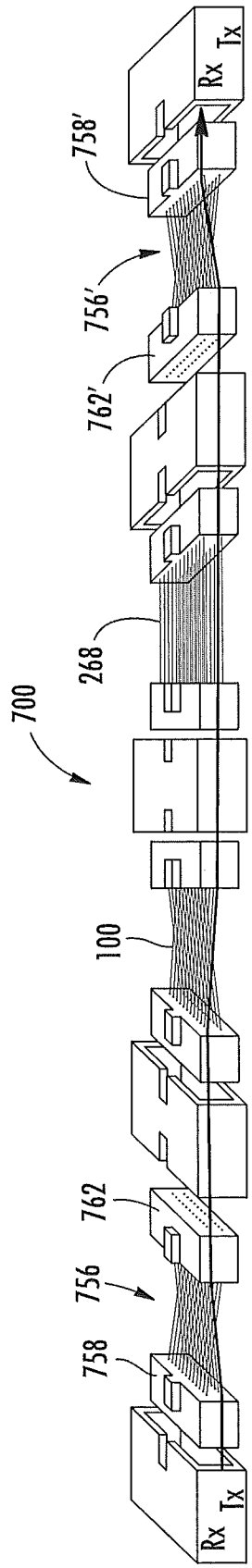

700
268
100
762
762'
756
756'
758
758'
Rx
Tx
Rx
Tx

FIG. 9

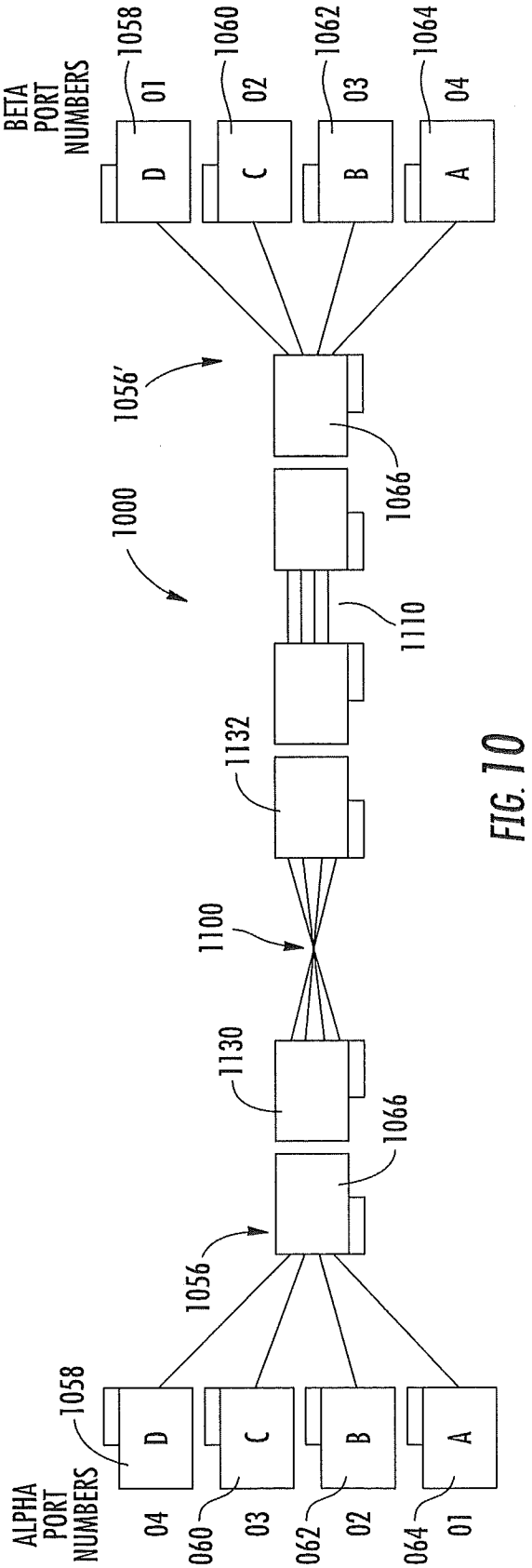

BETA PORT NUMBERS
1058
1060
1062
1064
01
02
03
04
D
C
B
A
1056'
1066
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1110
1132
1100
1130
1066
1056
ALPHA PORT NUMBERS
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D
C
B
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04
03
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1060
1062
1064

FIG. 10

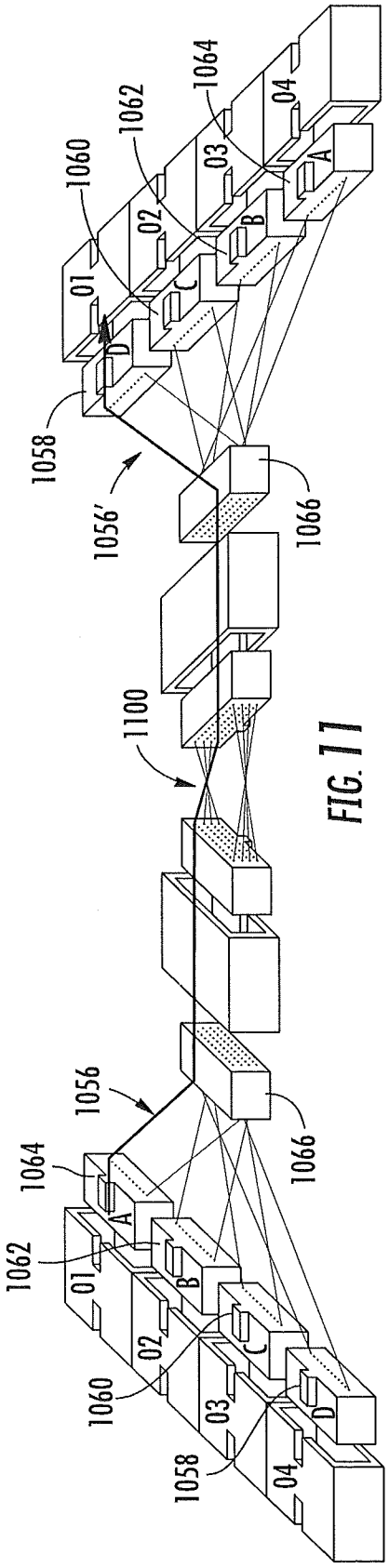

1058
1060
1062
1064
1056'
1066
1100
1056
1066
1064
1062
1060
1058
01
02
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04
A
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C
D

FIG. 11

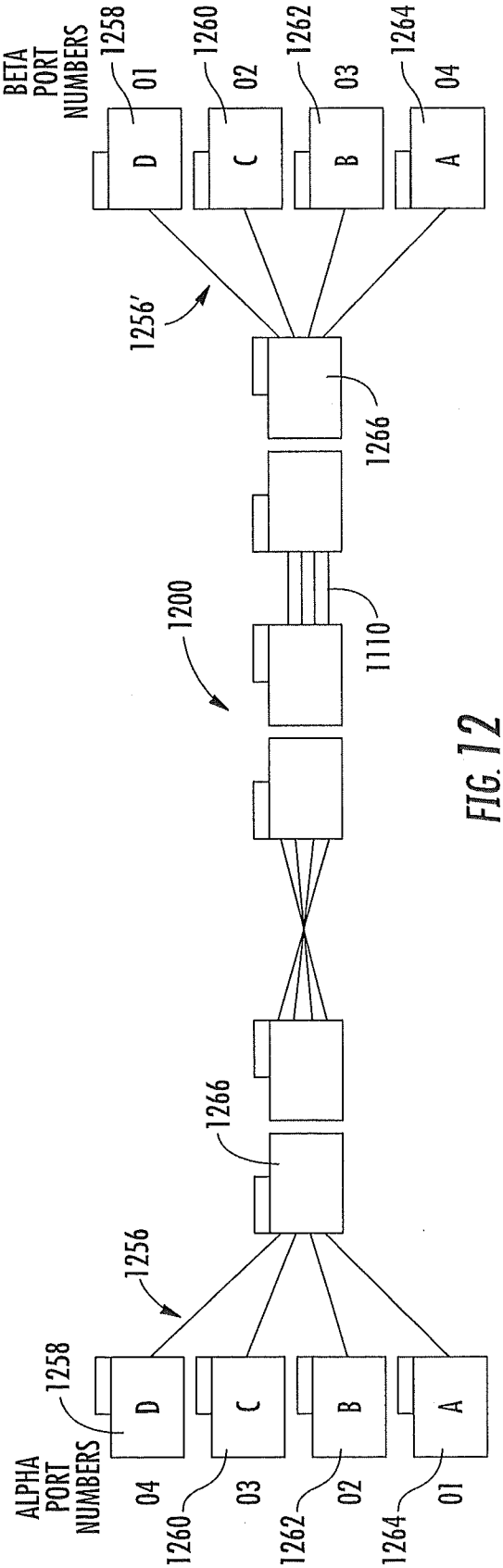

BETA PORT NUMBERS
1258
1260
1262
1264
01
02
03
04
D
C
B
A
1256'
1266
1200
1110
1266
1256
1258
ALPHA PORT NUMBERS
04
03
02
01
1260
1262
1264

FIG. 12

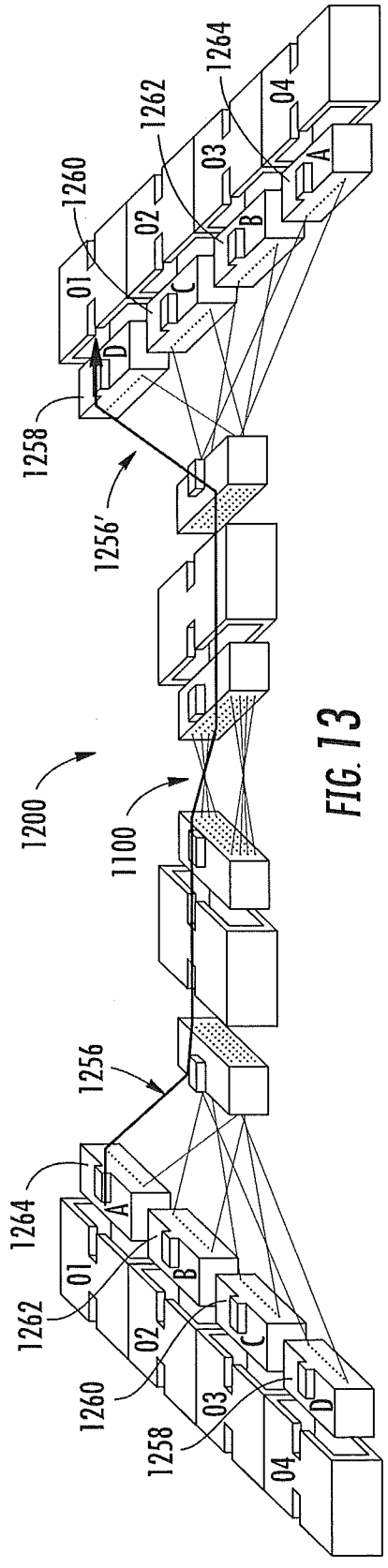

1200
1100
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1256'
1258
1260
1262
1264
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A
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FIG. 13

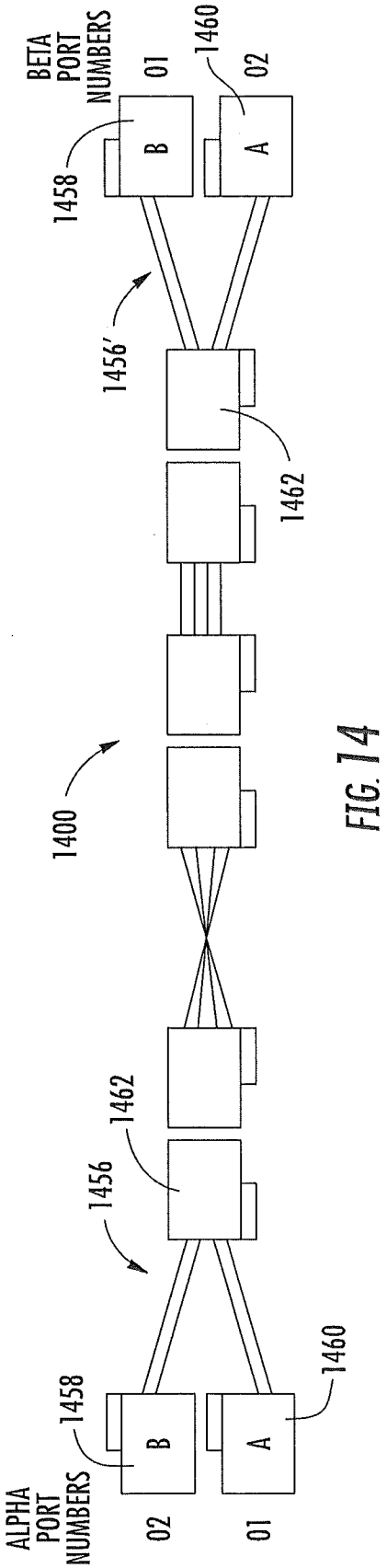

1400
1456
1456'
1458
1460
1462
BETA PORT NUMBERS
ALPHA PORT NUMBERS
01
02
A
B

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/021489

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B6/44
ADD.

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)
G02B

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 180 708 A2 (FRAMATOME CONNECTORS INT [FR]) 20 February 2002 (2002-02-20) figure 1 paragraph [0010] -----	1-3, 12-15
X	US 2004/062498 A1 (DEL GROSSO STEVEN C [US] ET AL) 1 April 2004 (2004-04-01) figure 1 paragraph [0004] -----	4-6

☐ 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 document 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	Date of mailing of the international search report
26 May 2011	07/06/2011

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Orignac, Xavier

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2011/021489

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1180708 A2	20-02-2002	CA 2354802 A1	15-02-2002
		CN 1338647 A	06-03-2002
		JP 2002116360 A	19-04-2002
		KR 20020013806 A	21-02-2002
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		CA 2495693 A1	08-04-2004
		CN 1682140 A	12-10-2005
		CN 101482635 A	15-07-2009
		DE 20321843 U1	05-01-2011
		EP 1546780 A2	29-06-2005
		EP 2259118 A2	08-12-2010
		JP 4248495 B2	02-04-2009
		JP 2006500637 T	05-01-2006
		WO 2004029670 A2	08-04-2004
		US 2004184741 A1	23-09-2004

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/021489

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

1-6, 12-17

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-3, 12-17

   a fibre optic trunk cable comprising fibres in an arrangement of 2N rows, the fibres linking two terminals, wherein the positions of the fibres in the first terminal is laterally transposed and row-inverted to the position of the fibres defined in the second terminal.

   ---

2. claims: 4-6

   a fibre optic fan-out comprising fibres in an arrangement of 2N rows, the fibres linking a first terminal to a plurality of second terminals, the fibres being attached in pairs, said pairs being formed by association of adjacent fibres within each row of the first terminal, said pairs arranged in succession along the rows.

   ---

3. claims: 7-9

   a fibre optic fan-out comprising fibres in an arrangement of 2N rows, the fibres linking a first terminal to N second terminals, the fibres being attached to the second terminals in two rows and retaining their constitutive relationship established at the first terminal.

   ---

4. claims: 10, 11

   a fibre optic fan-out comprising fibres in an arrangement of 2N rows, the fibres linking a first terminal to 2N second terminals, the fibres being attached to the second terminals in single rows and retaining their constitutive relationship established at the first terminal.
