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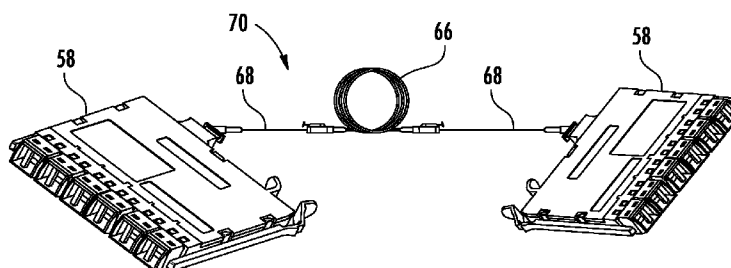


FIG. 7

(57) Abstract: Breakout assemblies for hybrid fiber optic cables are disclosed. The breakout assembly comprises a first multi-fiber connector, at least one multi-mode connector, and at least one single-mode connector. A plurality of multi-mode optical fibers is connected between the first multi-fiber connector and the at least one multi-mode connector, and a plurality of single-mode optical fibers is connected between the first multi-fiber connector and the at least one single-mode connector. One advantage of this arrangement is that transition back and forth between single-mode and multi-mode connectivity, or simultaneous use of both types of connectivity, is enabled through installation of a single hybrid cable having both multi-mode and single-mode optical fibers terminated in a common multi-fiber connector.



HYBRID FIBER OPTIC BREAKOUT ASSEMBLY HAVING MULTI-MODE AND SINGLE-MODE OPTICAL CONNECTIVITY, AND RELATED COMPONENTS, SYSTEMS, AND METHODS

PRIORITY APPLICATION

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application Serial No. 62/052,759, which was filed on September 19, 2014, the content of which is relied upon and incorporated herein by reference in its entirety.

FIELD

[0002] The present disclosure relates to optical fiber connection assemblies, and more particularly, to optical fiber connection assembly cable, hardware, and/or modules that support both single-mode and multi-mode optical connectivity.

BACKGROUND

[0003] The disclosure relates generally to fiber optic breakout assemblies and more particularly to hybrid fiber optic breakout assemblies having multi-mode and single-mode optical connectivity, which may be used for simultaneous connectivity of both types of connectivity at a common connection point. Related components, systems, and methods are also disclosed.

[0004] Benefits of utilizing optical fiber include extremely wide bandwidth and low noise operation. Because of these advantages, optical fiber is increasingly being used for a variety of applications, including but not limited to broadband voice, video, and data transmission. Fiber optic networks employing optical fiber are being developed for use in delivering voice, video, and data transmissions to subscribers over both private and public networks. These fiber optic networks often include separated connection points linking optical fibers to provide “live fiber” from one connection point to another. In this regard, fiber optic equipment is located in data distribution centers or central offices to support live fiber interconnections. For example, the fiber optic equipment can support interconnections between servers, storage area networks (SANs), and/or other equipment at data centers. Interconnections may be further supported by fiber optic patch panels or modules.

[0005] Different types of optical fiber may be used for different applications within a network. Multi-mode fiber, for example, refers to optical fiber that supports multiple

“modes” or cross-sectional areas for a laser light source. Multi-mode fiber has the advantage of being able to use larger, relatively inexpensive laser light sources because of its relatively large cross-sectional area. Single-mode fiber, on the other hand, refers to optical fiber that supports a single “mode” or cross-sectional area for a laser light source, and has a significantly smaller cross sectional area. Single-mode fiber has the advantage of being able to transmit data over relatively long distances, but requires more expensive light sources because of its relatively small cross sectional area. Thus, most applications favor less expensive multi-mode fiber solutions for spanning shorter distances, and favor single-mode fiber only when necessary for spanning longer distances.

SUMMARY

[0006] Embodiments of the disclosure include a breakout assembly for a hybrid fiber optic cable. The breakout assembly comprises a first multi-fiber connector, at least one multi-mode connector, and at least one single-mode connector. A plurality of multi-mode optical fibers is connected between the first multi-fiber connector and the at least one multi-mode connector, and a plurality of single-mode optical fibers is connected between the first multi-fiber connector and the at least one single-mode connector. One advantage of this arrangement is that transition back and forth between single-mode and multi-mode connectivity, or simultaneous use of both types of connectivity, is enabled through installation of a single hybrid cable having both multi-mode and single-mode optical fibers terminated in a common multi-fiber connector.

[0007] In one exemplary embodiment, without limitation, eight (8) multi-mode fibers are included, corresponding to port positions 1-4 and 9-12 of a conventional BASE-8 parallel optical connection scheme. Rather than leave port positions 5-8 of the multi-fiber connector unused, however, four (4) single-mode optical fibers may be disposed in the otherwise unused port positions 5-8, thereby enabling simultaneous connectivity with a pair of single-mode duplex connections, or other single-mode connectivity. In this manner, a single multi-fiber connection can support both parallel optical multi-mode connectivity and serial single-mode connectivity simultaneously, thereby allowing easy transition between the two connectivity solutions as requirements change over time.

[0008] One embodiment of the disclosure relates to a breakout assembly for a hybrid fiber optic cable. The breakout assembly comprises a first multi-fiber connector. The breakout assembly further comprises at least one multi-mode connector, and a plurality of multi-mode optical fibers connected between the first multi-fiber connector and the at least one multi-mode connector. The breakout assembly further comprises at least one single-mode connector, and a plurality of single-mode optical fibers connected between the first multi-fiber connector and the at least one single-mode connector.

[0009] An additional embodiment of the disclosure relates to a method of providing connectivity to a plurality of multi-mode optical fibers and a plurality of single-mode fibers. The method comprises connecting a hybrid fiber optic cable having a plurality of multi-mode optical fibers and a plurality of single-mode optical fibers terminated at a first multi-fiber connector to a breakout assembly. The method further comprises connecting at least one multi-mode fiber optic cable to at least one multi-mode connector of the breakout assembly optically connected to the plurality of multi-mode optical fibers via the first multi-fiber connector.

[0010] Additional features and advantages will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from the description or recognized by practicing the embodiments as described in the written description and claims hereof, as well as the appended drawings.

[0011] It is to be understood that both the foregoing general description and the following detailed description are merely exemplary, and are intended to provide an overview or framework to understand the nature and character of the claims.

[0012] The accompanying drawings are included to provide a further understanding, and are incorporated in and constitute a part of this specification. The drawings illustrate one or more embodiment(s), and together with the description serve to explain principles and operation of the various embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 illustrates a cross-sectional view of exemplary multi-mode and single-mode fibers;

[0014] FIG. 2 illustrates a multi-fiber connector having a multi-fiber ferrule that has a horizontal linear array of fiber positions for receiving a plurality of multi-mode and single-mode optical fibers;

[0015] FIGS. 3A-3C illustrate a plurality of fiber optic cables each having a plurality of single-mode and multi-mode optical fibers;

[0016] FIG. 4 illustrates a breakout module configured to convert between a hybrid multi-mode/single-mode configurations and separated multi-mode configurations and single-mode configurations;

[0017] FIG. 5 illustrates an alternative breakout module having a pair of single-mode LC duplex connectors and four (4) multi-mode LC duplex connectors;

[0018] FIG. 6 illustrates a portion of a fiber optic network including a hybrid multi-mode/single-mode fiber optic cable connected between a pair of fiber optic breakout modules;

[0019] FIG. 7 illustrates a portion of an alternative fiber optic network including a hybrid multi-mode/single-mode fiber optic cable connected between a different pair of fiber optic breakout modules;

[0020] FIG. 8 illustrates an alternative fiber optic network including a hybrid fiber optic cable connected between a pair of multi-fiber jumper cables each connected to a Quad Small Form-factor Pluggable (QSFP) transceiver; and

[0021] FIG. 9 illustrates an alternative fiber optic network including a fiber optic cable connected between a pair of multi-fiber to multi-fiber jumper cables, each connected to a BASE-8 multi-fiber to LC duplex breakout module.

DETAILED DESCRIPTION

[0022] Embodiments of the disclosure include a breakout assembly for a hybrid fiber optic cable. The breakout assembly comprises a first multi-fiber connector, at least one multi-mode connector, and at least one single-mode connector. A plurality of multi-mode optical fibers is connected between the first multi-fiber connector and the at least one multi-mode connector, and a plurality of single-mode optical fibers is connected between the first multi-fiber connector and the at least one single-mode connector. One advantage of this arrangement is that transition back and forth between single-mode and multi-mode connectivity, or simultaneous use of both types of connectivity, is enabled through

installation of a single hybrid cable having both multi-mode and single-mode optical fibers terminated in a common multi-fiber connector.

[0023] Various embodiments will be further clarified by the following examples. In this regard, FIG. 1 illustrates cross-sectional views of exemplary multi-mode and single-mode fibers. Multi-mode fiber 10 includes a multi-mode core 14 surrounded by protective cladding 16. In this embodiment, the multi-mode core 14 has a diameter DM of 50 μm , and the entire optical fiber has a diameter DF of 125 μm . Single-mode fiber 12, on the other hand, includes a core 18 having a diameter DS of 9 μm surrounded by a substantially thicker cladding 20 to achieve the same 125 μm diameter DF. In this manner, although the cores 14, 18 of the optical fibers 10, 12 have substantially different diameters, the overall diameter DF of both optical fibers 10, 12 are 125 μm , to ensure compatibility with standardized ferrule sizes. Both optical fibers 10, 12 are also typically enclosed within a protective coating to increase the diameter of the optical fiber 10, 12 to 250 μm .

[0024] Conventional fiber optic trunks and other cables generally use only multi-mode or only single-mode fibers. Because of the distance limitations with multi-mode fiber and the added expense of single-mode solutions, a large proportion of network design is devoted to selecting whether to use single-mode or multi-mode solutions for each leg of the network. In addition, as transceiver technology rapidly evolves, users are transitioning between parallel optical multi-mode solutions and duplex single-mode solutions as the network architecture changes over time.

[0025] In this regard, referring now to FIG. 2, a multi-fiber connector is illustrated having a form factor similar to and/or compatible with the standard multi-fiber connector such as a MTP and/or MPO connector. In this embodiment, the connector 22 includes a multi-fiber ferrule 24 that has a horizontal linear array of fiber positions 26 for receiving a plurality of optical fibers 10, 12. The multi-fiber ferrule 24 may also include one or more alignment features, such as alignment bores 28. As can be seen from FIG. 2, the linear array 26 of fiber positions includes 8 multi-mode optical fibers 10 at positions 1 through 4 and 9 through 12, and four single-mode optical fibers 12 at positions 5 through 8. In this manner, backwards compatibility is maintained with conventional BASE-8 multi-fiber connection schemes, while including additional single-mode functionality at otherwise unused fiber positions 5 through 8.

[0026] Referring now to FIGS. 3A through 3C, a plurality of fiber optic cables are illustrated. In FIG. 3A, a fiber optic cable subunit 30 is illustrated having a bundle of 8 multi-mode optical fibers 10(1) through 10(4) and 10(9) through 10(12), and 4 single-mode optical fibers 12(5) through 12(8). It should be understood that in FIG. 3A, as well as FIG. 2, fiber positions 1 through 12 correspond to the standard fiber positions 1 through 12 of a multi-fiber adapter array, with each corresponding single-mode or multi-mode optical fiber 10, 12 having a corresponding color. The bundle of optical fibers 10, 12 is surrounded by cable subunit covering 32. The cable subunit 30 may also include strength members 34 such as aramid yarn within the cable subunit covering 32.

[0027] In this embodiment, each of the optical fibers 10, 12 may include one or more indicia, such as color coding, to indicate to which fiber position the optical fiber 10, 12 corresponds. In this regard, the optical fibers 10, 12 may be color coded according to a standard 12-fiber multi-fiber array, according to the fiber positions of the optical fibers 10, 12 discussed above. In this embodiment for example, multi-mode optical fiber 10(1) may be blue, multi-mode optical fiber 10(2) may be orange, multi-mode optical fiber 10(3) may be green, and multi-mode optical fiber 10(4) may be brown. Meanwhile, single-mode optical fiber 12(5) may be slate, single-mode optical fiber 12(6) may be white, single-mode optical fiber 12(7) may be red, and single-mode optical fiber 12(8) may be black. Finally, multi-mode optical fiber 10(9) may be yellow, multi-mode optical fiber 10(10) may be violet, multi-mode optical fiber 10(11) may be rose, and multi-mode optical fiber 10(12) may be aqua.

[0028] In this manner, multi-mode optical fibers 10 are color coded such that they are assigned to the outside fiber positions 1-4 and 9-12 of a standard multi-fiber connector for a BASE-8 configuration, for example using a universal wiring polarity scheme. At the same time, the otherwise unused fiber positions 5-8 may be occupied by appropriately color coded single-mode optical fibers 12. Either set of optical fibers 10, 12 may be kept “dark” when not in use, or both sets of optical fibers 10, 12 can be used simultaneously.

[0029] Multiple cable subunits 30 can also be bundled together into a larger trunk cable. In this regard, FIG. 3B illustrates a 24-fiber trunk cable 36 having a pair of 12-fiber cable subunits 30 surrounded by a cable jacket 38. An additional layer of strength members 40, such as aramid yarn, may also be included. Likewise, FIG. 3C illustrates a 144-fiber trunk

cable 42 having 12, 12-fiber cable subunits 30 disposed therein. The cable subunits 30 are surrounded by a single cable jacket 44, and may include additional layers of strength members 46, such as aramid yarn. In alternate embodiments the trunk cable may not have a jacket and the subunits may be bound together with a binder or other appropriate covering.

[0030] An advantage of this hybrid MTP cable 30, 36, 42 is that the complexity in planning and cabling migration is reduced. Rather than plan out separate single-mode and multi-mode connections at the design phase, the hybrid MTP cables 30, 36, 42 can be used throughout an installation, and their use within the installation can be determined at any time, and can also be changed over time. For example, a user could plan to use only multi-mode fiber for an installation. If transmission distance issues arise at any stage, however, the installation will already have pre-terminated single-mode fiber installed and ready to use, which can be activated without running any new cable. This will allow users to save time and money on planning, and save labor cost on future planning, implementation, and upgrades.

[0031] Referring now to FIG. 4, a breakout module 48 configured to convert between hybrid multi-mode/single-mode configurations and separated multi-mode configurations and single-mode configurations is illustrated. In this embodiment, the breakout module 48 includes a module housing 50. A multi-fiber connector 52 is configured to optically connect to a hybrid multi-mode/single-mode multi-fiber configuration. Meanwhile, the other end of the breakout module 48 includes a pair of single-mode LC duplex connectors 54, for connecting to single-mode LC solutions, such as 40GB or 100GB connectivity, and also includes a BASE-8 multi-fiber connector 56, for connecting to conventional BASE-8 multi-mode solutions, such as 40GB or 100GB parallel optics solutions. In this embodiment, the single-mode LC duplex connectors 54 are optically connected to the single-mode fiber positions, i.e., fiber positions 5 through 8, of multi-fiber connector 52. Likewise, multi-mode multi-fiber connector 56 is optically connected to the multi-mode fiber positions, i.e., fiber positions 1 through 4 and 9 through 12, of multi-fiber connector 52. In this manner, a single connection to multi-fiber connector 52 can support a BASE-8 multi-mode multi-fiber connection, a pair of LC duplex single-mode connections, or both simultaneously. In addition, in this embodiment, it should be noted that the breakout module 48 is sized to be disposed in and backwards compatible with existing 4-slot Pretium EDGE Solutions, as

provided by Corning Optical Communications LLC, and may also be sized to be larger or more compact to accommodate alternative solutions, such as 6-slot BASE-8 solutions, for example.

[0032] Referring now to FIG. 5, an alternative breakout module 58 is illustrated. Similar to breakout module 48, breakout module 58 includes a module housing 60. Breakout module 58 includes a similar multi-fiber connector 52 at the rear of breakout module 58, for receiving a hybrid multi-mode/single-mode multi-fiber connection. At the front of breakout module 58, however, in addition to a pair of single-mode LC duplex connectors 54, additional 4 multi-mode LC duplex connectors 62 are disposed on the front of the breakout module 58 as well. In this manner, each of the single-mode and multi-mode fibers connected to multi-fiber connector 52 may be broken out into respective multi-duplex pairs. In addition, it should be understood that it may be desirable to visibly distinguish the multi-mode LC duplex connectors 62 from the single-mode LC duplex connectors 54. In this regard, it may be desirable to include indicia or a distinct coloring on one or both sets of single-mode LC duplex connectors 54, 62. Similar to breakout module 48 of FIG. 4 above, breakout module 58 is sized to be disposed in and backwards compatible with existing 4-slot EDGE-based solutions, and may also be resized as desired.

[0033] The above embodiments enable a wide variety of connection arrangements to be assembled, with a minimum of disassembly required, and while maximizing the available fiber density. In this regard, FIG. 6 illustrates a portion of a fiber optic network 64 including a hybrid multi-mode/single-mode fiber optic cable 66 connected between a pair of fiber optic breakout modules 48. The respective ends of fiber optic cable 66 are connected to breakout modules 48 by a respective multi-fiber to multi-fiber jumper cable 68. In this regard, two-way communication is enabled for both a pair of single-mode LC duplex connectors as well as a multi-mode BASE-8 multi-fiber connector.

[0034] Referring now to FIG. 7, an alternative fiber optic network 70 is illustrated, in which a pair of breakout modules 58 are connected via the hybrid fiber optic cable 66 and multi-fiber to multi-fiber jumper cable 68. In this manner, 2 single-mode LC duplex connection pairs are enabled, as well as 4 multi-mode LC duplex connections.

[0035] Referring now to FIG. 8, another connection scheme is illustrated in which a fiber optic network 72 includes a hybrid fiber optic cable 66 terminated with multi-fiber MTP

connector on each leg 74 containing one or more subunits 30 each MTP terminated leg 74 connected to an MTP adaptor panel 76. A multi-fiber MTP jumper 78 is connected between each MTP panel 76 and a Quad Small Form-factor Pluggable (QSFP) transceiver 80.

[0036] Referring now to FIG. 9, an alternative fiber optic network 82 includes fiber optic cable 66 connected between a pair of multi-fiber to multi-fiber jumper cables 68, each connected to a BASE-8 multi-fiber to LC duplex breakout module 84. In this embodiment, LC duplex breakout module 84 includes four (4) multi-mode LC duplex connectors 62 only. This permits the LC duplex breakout module 84 to have a smaller form factor than other modules sized to accommodate six (6) LC duplex connections for example. Thus, in this embodiment, only the multimode connections are employed, with the single-mode connections remaining unused. In this manner, the hybrid fiber optic cable 66 is backward compatible with BASE-8 LC duplex solutions.

[0037] Unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order. Accordingly, where a method claim does not actually recite an order to be followed by its steps or it is not otherwise specifically stated in the claims or descriptions that the steps are to be limited to a specific order, it is no way intended that any particular order be inferred.

[0038] It will be apparent to those skilled in the art that various modifications and variations can be made without departing from the spirit or scope of the disclosure. Since modifications combinations, sub-combinations and variations of the disclosed embodiments incorporating the spirit and substance of the disclosure may occur to persons skilled in the art, the disclosure should be construed to include everything within the scope of the appended claims and their equivalents.

What is claimed is:

1. A breakout assembly for a hybrid fiber optic cable comprising:
 - a first multi-fiber connector;
 - at least one multi-mode connector;
 - a plurality of multi-mode optical fibers connected between the first multi-fiber connector and the at least one multi-mode connector;
 - at least one single-mode connector; and
 - a plurality of single-mode optical fibers connected between the first multi-fiber connector and the at least one single-mode connector.
2. The breakout assembly of claim 1, wherein the at least one single-mode connector is at least one single-mode duplex connector.
3. The breakout assembly of claim 2, wherein the at least one multi-mode connector is a second multi-fiber connector.
4. The breakout assembly of claim 3, wherein the first multi-fiber connector is a twelve (12) fiber connector, and the at least one single-mode duplex connector is two (2) single-mode duplex connectors.
5. The breakout assembly of claim 4, wherein the at least one multi-mode connector is at least one multi-mode duplex connector.
6. The breakout assembly of claim 5, wherein the at least one multi-mode duplex connector is four (4) multi-mode duplex connectors, and the at least one single-mode duplex connector is two (2) single-mode duplex connectors.
7. The breakout assembly of claim 6, wherein the four (4) multi-mode duplex connectors have a first indicia, and the eight (8) multi-mode duplex connectors have a second indicia different from the first indicia.

8. The breakout assembly of claim 1, wherein the assembly is a fiber optic panel.
9. The breakout assembly of claim 1, wherein the assembly is a fiber optic module having an enclosure, wherein the first multi-fiber connector, the at least one multi-mode connector, and the at least one single-mode connector are carried by the enclosure, and the plurality of multi-mode optical fibers and the plurality of single-mode optical fibers are disposed in the enclosure.
10. The breakout assembly of claim 1, wherein the assembly is a fiber optic harness, further comprising at least one furcation surrounding the the plurality of multi-mode optical fibers and plurality of single-mode optical fibers.
11. The hybrid fiber optic cable of claim 1, wherein the plurality of single-mode optical fibers comprises four (4) single-mode optical fibers, and the plurality of multi-mode optical fibers comprises eight (8) multi-mode optical fibers.
12. The hybrid fiber optic cable of claim 11, wherein the eight (8) multi-mode optical fibers are color coded as blue, orange, green, brown, yellow, violet, rose, and aqua.
13. The hybrid fiber optic cable of claim 12, wherein the four (4) single-mode optical fibers are color coded as slate, white, red, and black.
14. The hybrid fiber optic cable of claim 11, wherein the eight (8) multi-mode optical fibers are terminated in the first multi-fiber ferrule at positions 1-4 and 9-12 of the linear array, and the four (4) single-mode optical fibers are terminated in the multi-fiber ferrule at positions 5-8 of the linear array.
15. The hybrid fiber optic cable of claim 1, wherein each of the plurality of multi-mode optical fibers and each of the plurality of single-mode optical fibers has a cross sectional diameter of two hundred fifty (250) microns.

16. The hybrid fiber optic cable of claim 1, wherein each of the plurality of multi-mode optical fibers comprises a multi-mode core surrounded by cladding, wherein the multi-mode core has a cross sectional diameter of fifty (50) microns.

17. The hybrid fiber optic cable of claim 16, wherein each of the plurality of single-mode optical fibers comprises a single-mode core surrounded by cladding, wherein the single-mode core has a cross sectional diameter of nine (9) microns.

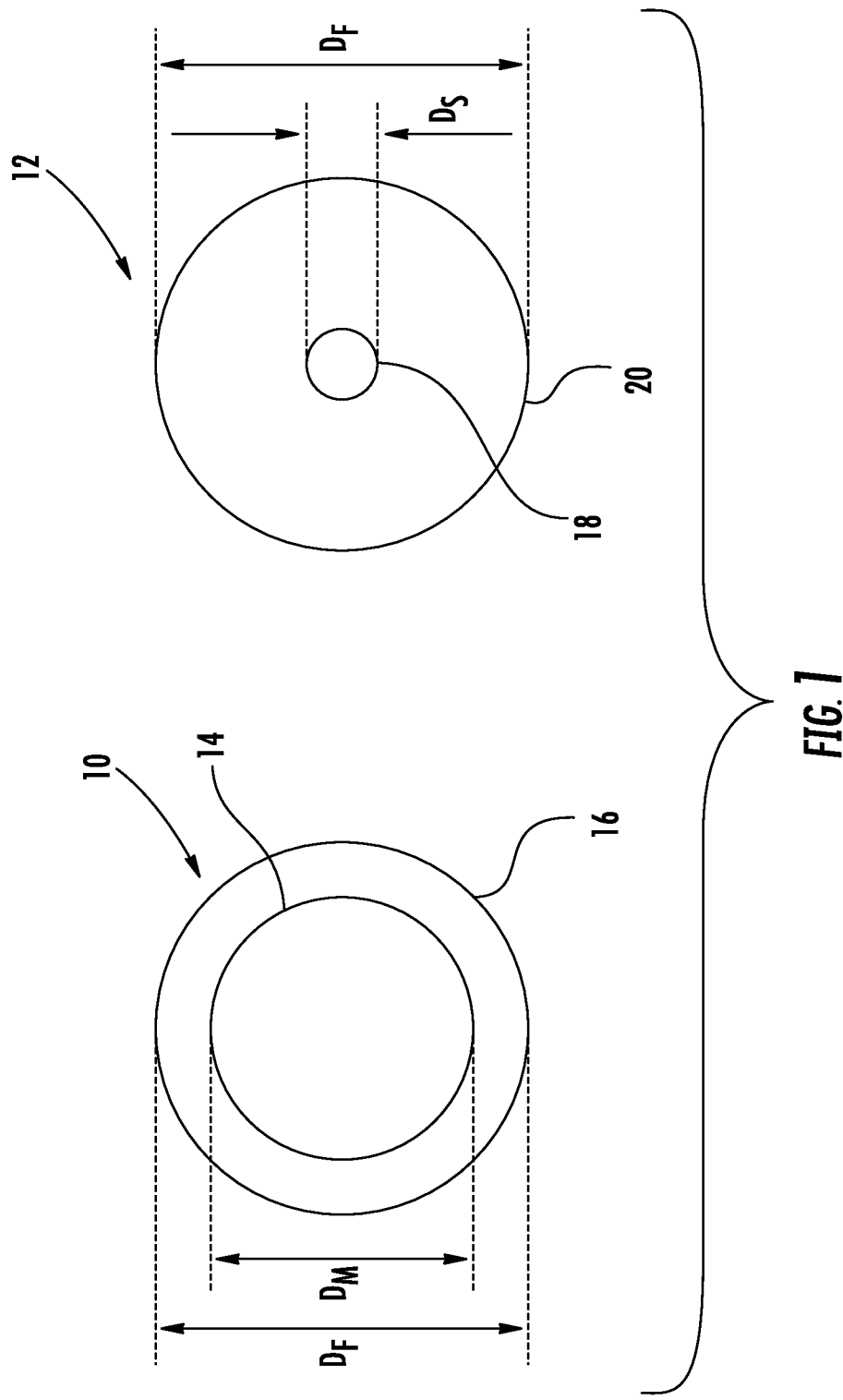
18. The hybrid fiber optic cable of claim 1, wherein each of the plurality of single-mode optical fibers comprises a single-mode core surrounded by cladding, wherein the single-mode core has a cross sectional diameter of nine (9) microns.

19. A method of providing connectivity to a plurality of multi-mode optical fibers and a plurality of single-mode fibers, the method comprising:

connecting a hybrid fiber optic cable having a plurality of multi-mode optical fibers and a plurality of single-mode optical fibers terminated at a first multi-fiber connector to a breakout assembly;

connecting at least one multi-mode fiber optic cable to at least one multi-mode connector of the breakout assembly optically connected to the plurality of multi-mode optical fibers via the first multi-fiber connector.

20. The method of claim 19, further comprising connecting at least one single-mode fiber optic cable to at least one single-mode connector of the breakout assembly optically connected to the plurality of single-mode optical fibers via the first multi-fiber connector.



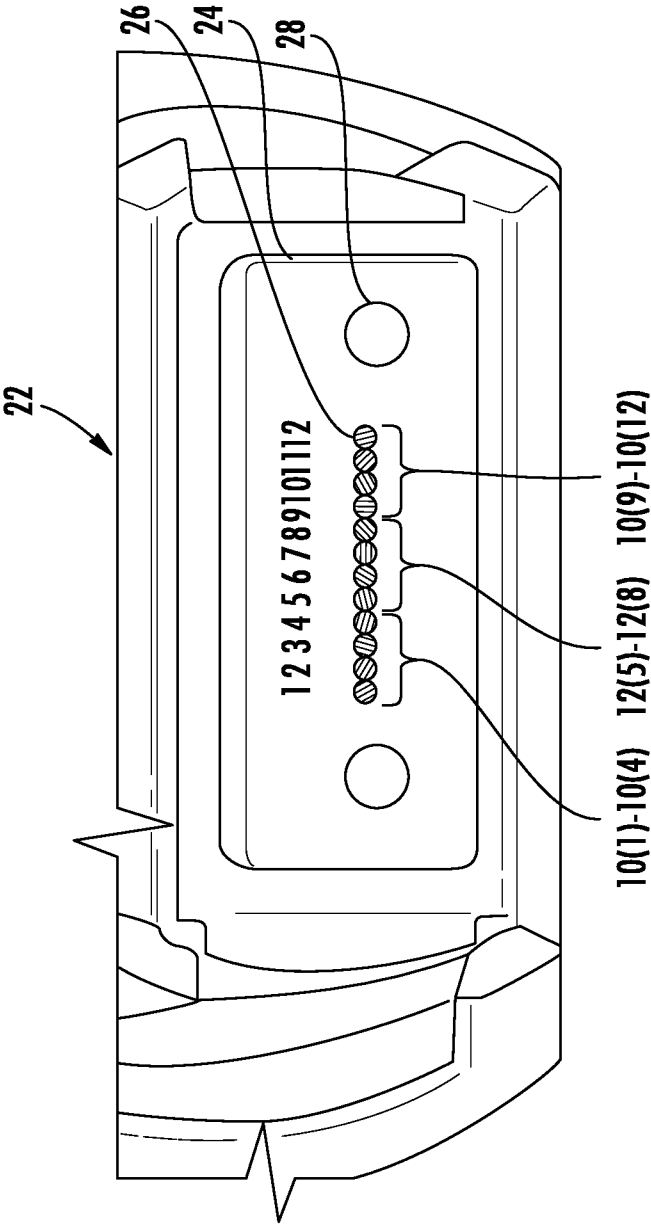


FIG. 2

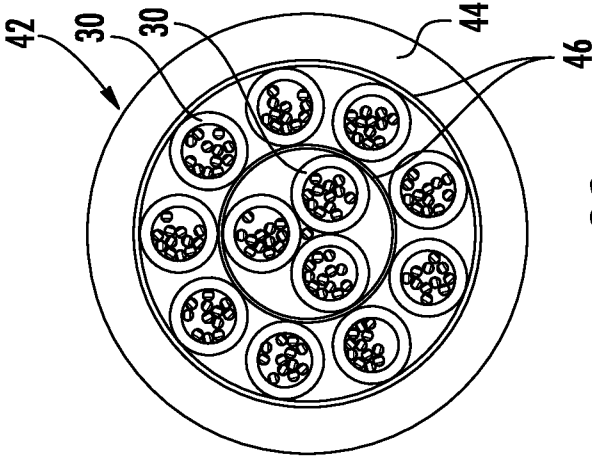


FIG. 3C

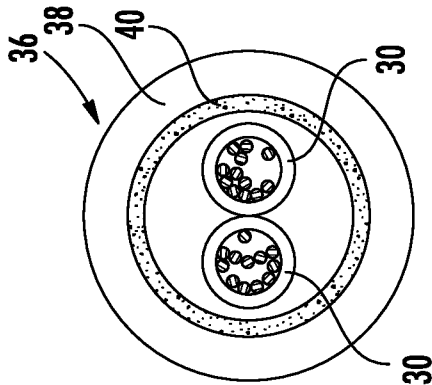


FIG. 3B

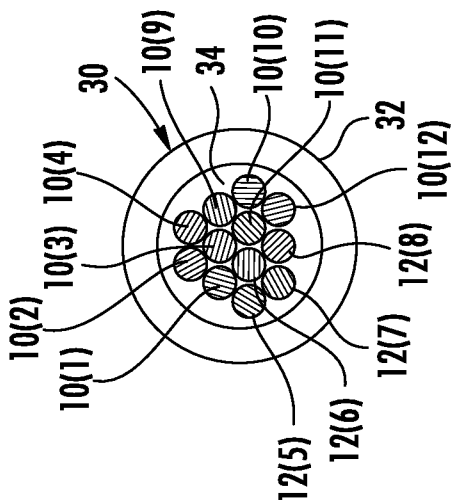
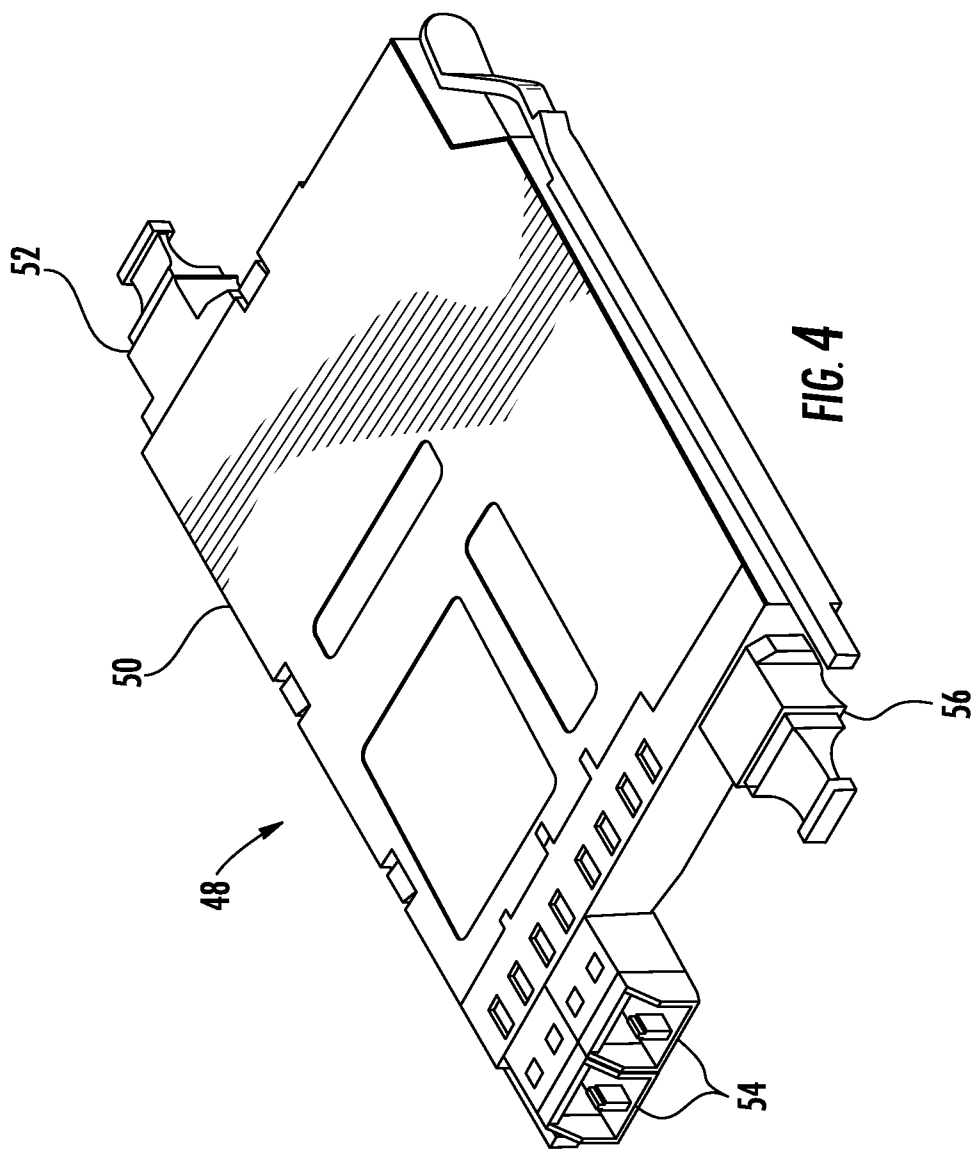


FIG. 3A



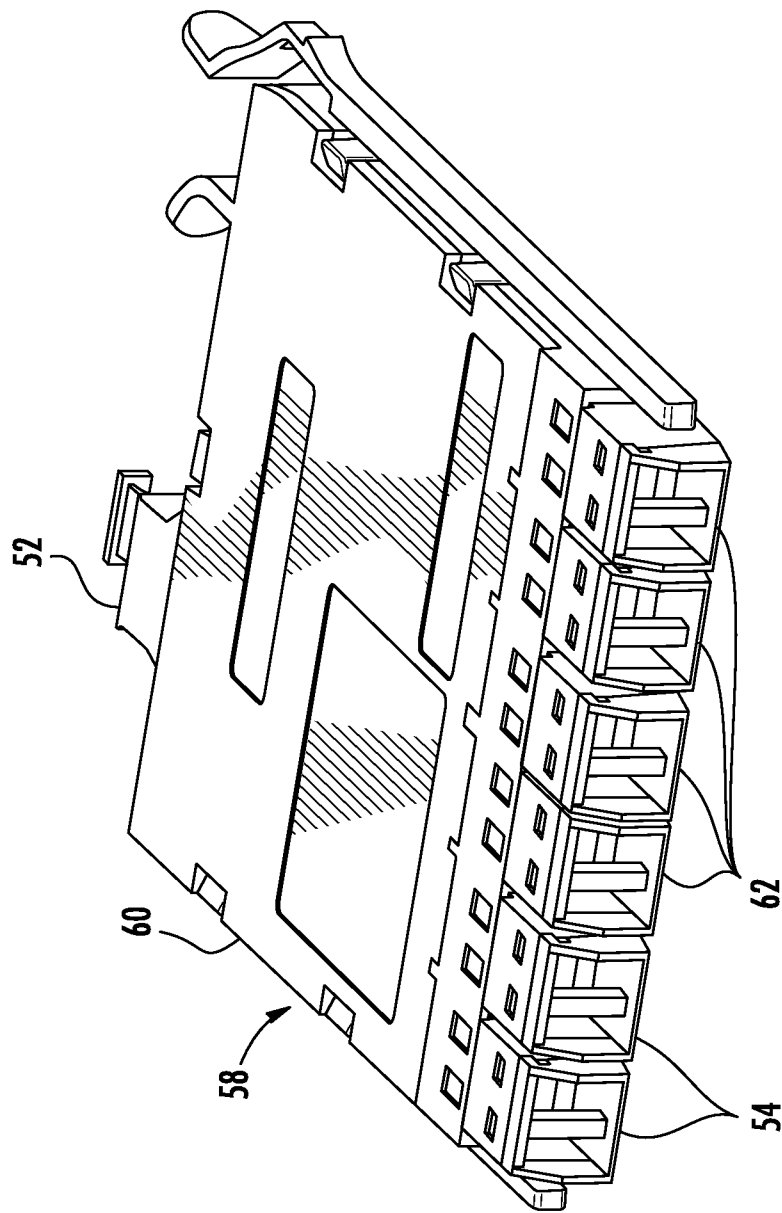


FIG. 5

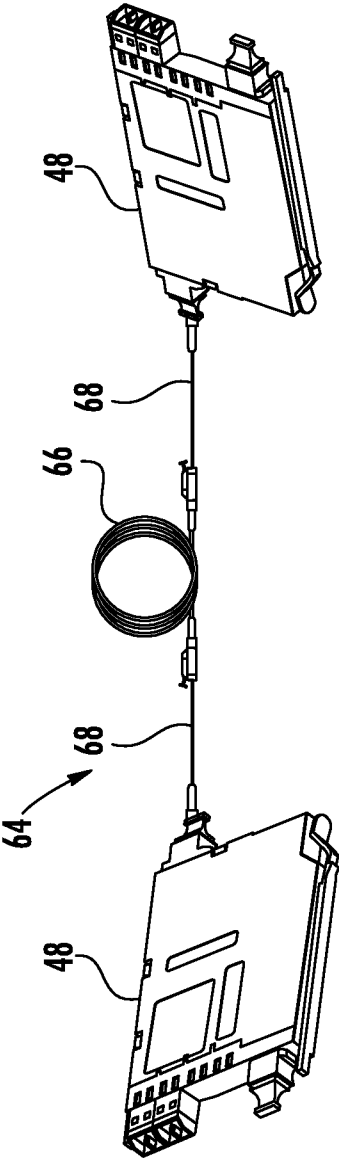


FIG. 6

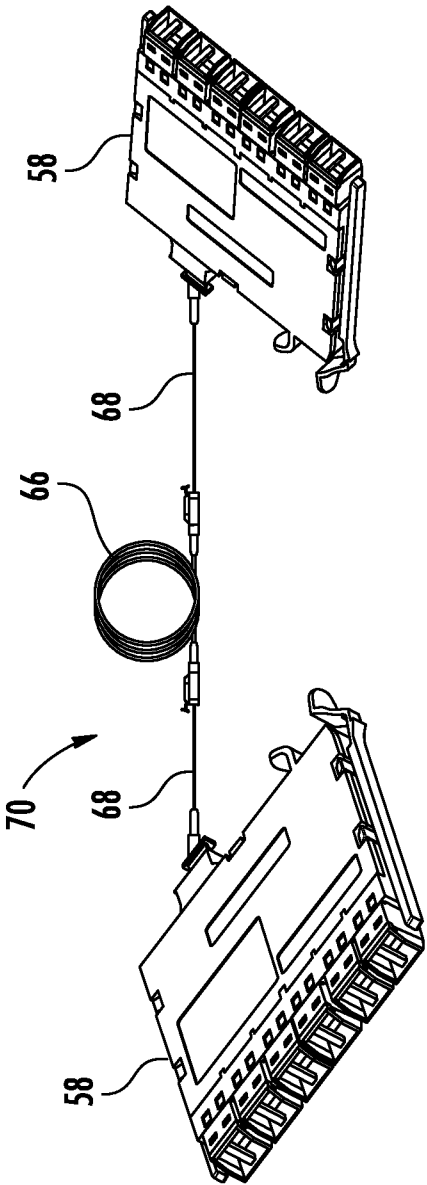
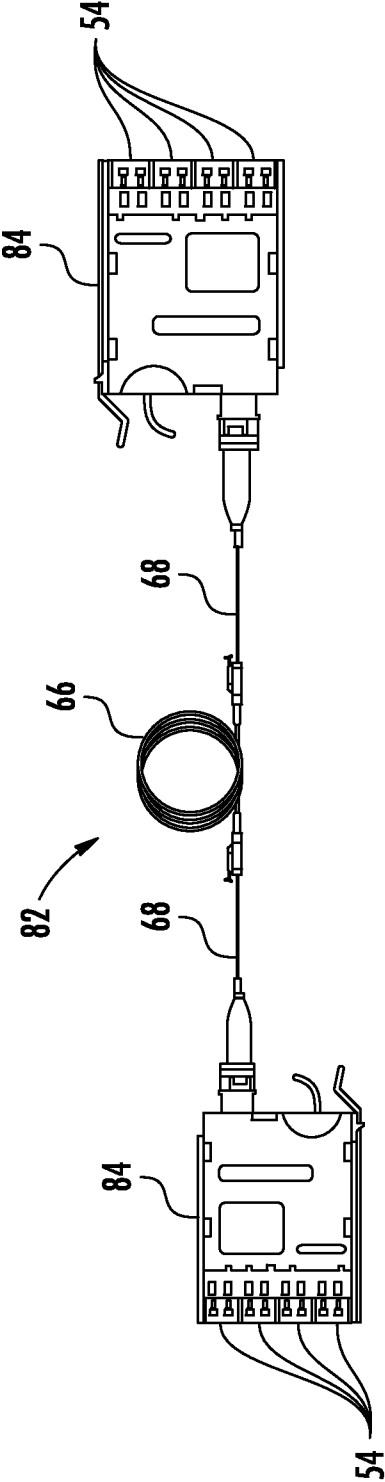
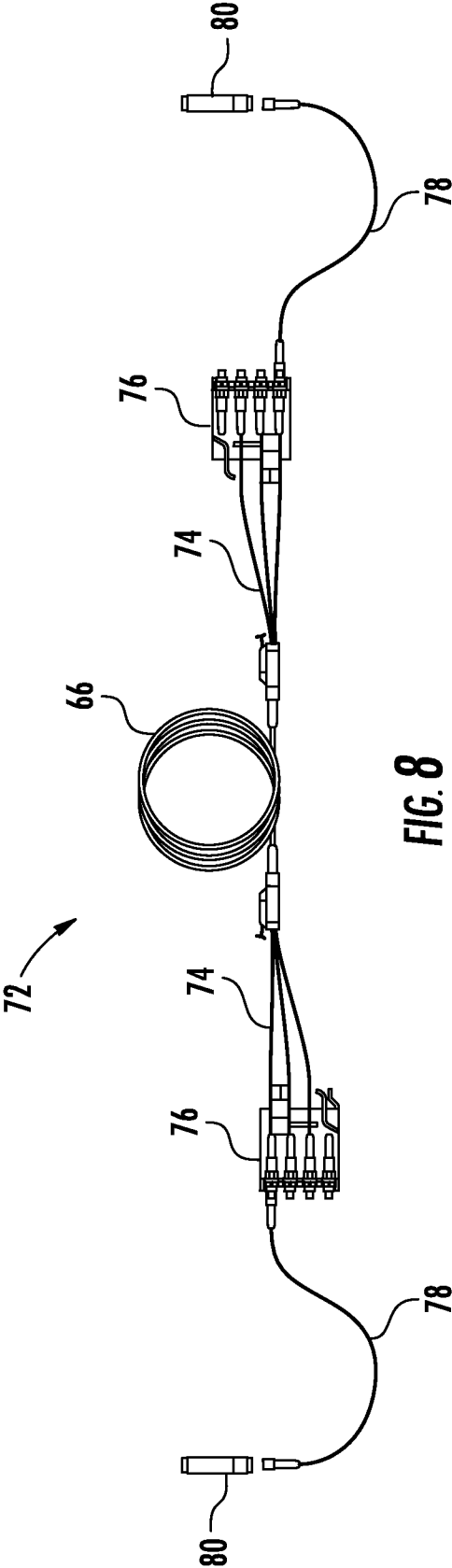


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/050646

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B6/38 G02B6/40 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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/308915 A1 (BUFF SCOTT EAKER [US] ET AL) 21 November 2013 (2013-11-21) paragraph [0047] - paragraph [0048] figures 1,4 paragraph [0045] - paragraph [0046] -----	1-20
A	US 5 659 655 A (PILATOS JOHN C [US]) 19 August 1997 (1997-08-19) -----	1-20
A	US 2005/084221 A1 (YANG LIZHANG [US] ET AL) 21 April 2005 (2005-04-21) -----	1-20
A	US 7 756 371 B1 (BURNHAM WILLIAM R [US] ET AL) 13 July 2010 (2010-07-13) -----	1-20
A	US 2008/175550 A1 (COBURN HUTCH [US] ET AL) 24 July 2008 (2008-07-24) ----- -/-	1-20



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

17 November 2015

Date of mailing of the international search report

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PCT/US2015/050646

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010/099059 A1 (CORNING CABLE SYS LLC [US]; COOKE TERRY L [US]; DEAN JR DAVID L [US];) 2 September 2010 (2010-09-02) -----	1-20
A	US 2010/183276 A1 (SMITH TREVOR D [US]) 22 July 2010 (2010-07-22) -----	1-20
A	US 2004/029437 A1 (CAVENEY JACK E [US]) 12 February 2004 (2004-02-12) -----	1-20
A	US 5 076 656 A (BRIGGS ROBERT C [US] ET AL) 31 December 1991 (1991-12-31) -----	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/050646

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013308915	A1	21-11-2013	CN 104471458 A 25-03-2015
			CN 104487880 A 01-04-2015
			EP 2850475 A1 25-03-2015
			EP 2850478 A1 25-03-2015
			US 2013308915 A1 21-11-2013
			US 2013308916 A1 21-11-2013
			WO 2013173534 A1 21-11-2013
			WO 2013173536 A1 21-11-2013
US 5659655	A	19-08-1997	AU 2927397 A 19-11-1997
			US 5659655 A 19-08-1997
			WO 9741475 A1 06-11-1997
US 2005084221	A1	21-04-2005	CN 1867850 A 22-11-2006
			EP 1673649 A1 28-06-2006
			US 2005084221 A1 21-04-2005
			WO 2005040884 A1 06-05-2005
US 7756371	B1	13-07-2010	AU 2010208579 A1 18-08-2011
			CA 2750528 A1 05-08-2010
			CN 102369468 A 07-03-2012
			EP 2384451 A1 09-11-2011
			JP 2012516470 A 19-07-2012
			JP 2014142659 A 07-08-2014
			US 7756371 B1 13-07-2010
			WO 2010088012 A1 05-08-2010
US 2008175550	A1	24-07-2008	US 2008175550 A1 24-07-2008
			US 2009214171 A1 27-08-2009
			US 2012321267 A1 20-12-2012
WO 2010099059	A1	02-09-2010	AU 2010218229 A1 22-09-2011
			CN 102414595 A 11-04-2012
			EP 2401643 A1 04-01-2012
			US 2010220967 A1 02-09-2010
			WO 2010099059 A1 02-09-2010
US 2010183276	A1	22-07-2010	NONE
US 2004029437	A1	12-02-2004	US 2004029437 A1 12-02-2004
			US 2005167140 A1 04-08-2005
			US 2006254817 A1 16-11-2006
US 5076656	A	31-12-1991	NONE