(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 September 2011 (22.09.2011)

PCT

(10) International Publication Number
WO 2011/116167 A1

(51) International Patent Classification:
G02B 6/38 (2006.01)

(21) International Application Number:
PCT/US2011/028781

(22) International Filing Date:
17 March 2011 (17.03.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/315,418 19 March 2010 (19.03.2010) US

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(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, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, 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, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, 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, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: FIBER OPTIC INTERFACE DEVICE WITH TRANSLATABLE FERRULE

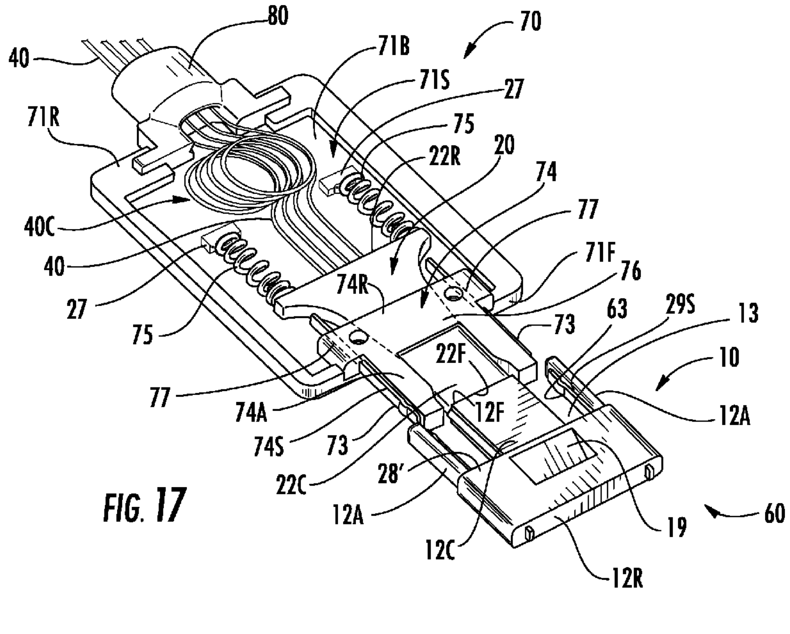


FIG. 17

(57) Abstract: Optical fiber ferrules (10, 20) for making optical or optical and electrical connections are disclosed, along with receptacle and plug fiber optic interface devices (60, 70) using the ferrules, and cable assemblies (6, 7) using the fiber optic interface devices. The optical fiber ferrules support optical pathways (14) and have front ends (12F, 22F) with mating geometries that facilitate a relatively high number of mating/unmating cycles. The ferrule is translatable within the enclosure (62e, 72e). Resilient members (75) provide the ferrule with forward-bias and rear-bias positions when the fiber optic interface device is un-mated and mated, respectively.

WO 2011/116167 A1

Published:

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

FIBER OPTIC INTERFACE DEVICE WITH TRANSLATABLE FERRULE

CLAIM OF PRIORITY

[0001] This application claims the benefit of priority under 35 U.S.C. § 119(e) of U.S. Provisional Application Serial No. 61/315,418, entitled "Ferruled Optical USB Connector," filed on March 19, 2010.

FIELD

[0002] The disclosure is directed to any optical interface in which easy access for cleaning is accomplished by including retractable elements in one or both of the mating components, for example plugs, adapters, and fiber optic interface devices. More specifically, the disclosure is directed to fiber optic interface devices with complementary mating geometries, including fiber optic interface devices having either optical or electrical and optical connection capability, wherein the fiber optic interface device ferrule is translatable.

BACKGROUND

[0003] Optical fiber is increasingly being used for a variety of applications, including but not limited to broadband voice, video, and data transmission. As consumer devices are steadily using more bandwidth, fiber optic interface devices for these devices will likely move away from electrical connections and toward using optical connections for increased bandwidth. Generally speaking, conventional fiber optic interface devices used for telecommunication networks and the like are not suitable for consumer electronic devices.

[0004] For instance, conventional fiber optic interface devices are relatively large compared with the consumer devices and their interfaces. Additionally, conventional fiber optic interface devices are deployed with great care into relatively clean environments and/or cleaned by the craft before connecting the same. Further, even though fiber optic interface devices are reconfigurable (i.e., suitable for mating/unmating), they are not intended for a relatively large number of mating cycles.

Instead, conventional fiber optic interface devices are high-precision connectors designed for reducing insertion loss between mating fiber optic interface devices in the optical network.

[0005] On the other hand, the consumer electronic devices are expected to have a relatively large number of mating/unmating cycles during ordinary operation. The consumer electronic devices will be operated in a multitude of environments where dirt, dust, and other debris are encountered on a regular basis. Further, consumer electronic devices typically have size and space constraints for making connections. Consequently, there is an unresolved need for fiber optic interface devices suitable for consumer electronic devices.

SUMMARY

[0006] The disclosure is directed to optical fiber interfaces having ferruled fiber optic plugs, adapters, interconnections, or fiber optic interface devices having a ferrule that is translatable. More specifically, the disclosure is directed to ferruled fiber optic interface devices with complementary mating geometries - including fiber optic interface devices having both electrical and optical connection capability - where the fiber optic interface device ferrule is translatable so that it can be in a retracted (rear-biased) position or an unretracted (forward-biased) position. The unretracted position allows for the front end of the ferrule to be readily cleaned, while the retracted position serves to reduce the chances of the ferrule front end from being contaminated with environmental contaminants, e.g., dirt, debris, dust, liquid, etc.

[0007] One disclosed embodiment is directed to a first fiber optic ferrule having a body with a plurality of optical pathways and a mating geometry having at least one slot monolithically formed in the body. The slot of the first fiber optic ferrule permits a relatively high number of mating/unmating cycles without generating excessive wear and debris, thereby making it suitable for consumer electronic devices or the like.

[0008] The disclosure is also directed to fiber optic interface devices and cable assemblies using the first fiber optic ferrule.

[0009] Another embodiment is directed to a second fiber optic ferrule having a complementary mating geometry for the first fiber optic ferrule. The second fiber optic ferrule includes a body having a plurality of optical pathways and a mating geometry that has at least one guide pin that is monolithically formed in the body and at least one spring retention feature disposed on a rear portion of the fiber optic ferrule. The second fiber optic ferrule reduces the number of parts required for a fiber optic interface device and allows for quick and easy assembly.

[0010] The disclosure is also directed to fiber optic interface devices and cable assemblies using the fiber optic ferrule. The disclosure can include a retractable alignment structure, for example retractable pins.

[0011] An aspect of the disclosure includes a fiber optic interface device having a ferrule body that has front and rear ends connected by one or more optical pathways configured to respectively operably support the one or more optical waveguides. The device also includes one or more optical waveguides respectively supported by the one or more optical pathways. The device has an enclosure with front and rear ends and an interior in which the ferrule body is translatably supported. The interior has a storage region adjacent the ferrule body that is configured to loosely store one or more excess portions of the one or more optical waveguides. The device also includes at least one resilient member operably configured relative to the ferrule to provide a forward-bias position of the ferrule when the fiber optic interface device is unmated and a rear-bias position of the ferrule when the fiber optic interface device is mated.

[0012] In various examples, the optical fiber connects described herein are configured to mate and unmate with a reasonable amount of force, e.g., with a gram-force of between 25 gf and 1,500 gf, and more preferably between 500 gf and 1,000 gf.

[0013] 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 that description or recognized by practicing the same as described herein, including the detailed description that follows, the claims, as well as the appended drawings.

[0014] It is to be understood that both the foregoing general description and the following detailed description present embodiments that are intended to provide an overview or framework for understanding the nature and character of the claims. The accompanying drawings are included to provide a further understanding of the disclosure, and are incorporated into and constitute a part of this specification. The drawings illustrate various embodiments and together with the description serve to explain the principles and operation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] **FIG. 1A** is isometric end view of a fiber optic interface device having a close-up view of a first fiber optic ferrule with complementary mating geometry for mating with the fiber optic ferrule shown in **FIG. 2** and **FIG. 3**;

[0016] **FIG. 1B** is a schematic representation of the cooperation of the mating geometry of the ferrule of **FIG. 1A** and the ferrule of **FIG. 2**;

[0017] **FIGS. 2** and **3** respectively are front and rear isometric views of a second fiber optic ferrule having mating geometry suitable for mating with the first ferrule of **FIG. 1**;

[0018] **FIGS. 4** and **5** respectively are elevated isometric and exploded views of mating fiber optic interface devices using another style of complementary mating fiber optic ferrules with mating geometry similar to the fiber optic ferrules shown in **FIGS. 1** through **3**;

[0019] **FIGS. 6** and **7** are elevated isometric views that respectively depict exemplary receptacle and plug fiber optic interface devices that respectively use the first and second example ferrules depicted in **FIG. 1A, FIG. 2** and **FIG. 3** and form a portion of a cable assembly;

[0020] **FIG. 8** is a front-end isometric view of the plug fiber optic interface device of **FIG. 7** along with a close-up view showing the details of the plug fiber optic interface device;

[0021] **FIG. 9** is a elevated isometric view of the plug fiber optic interface device of **FIGS. 7** and **8** with the shroud removed along with a close-up view showing details of the plug fiber optic interface device;

[0022] **FIG. 10** is an elevated rear isometric view of the receptacle of **FIG. 6** showing the electrical connections;

[0023] **FIG. 11** is an isometric end view of another fiber optic ferrule having both female and male mating geometry according to the concepts disclosed herein;

[0024] **FIG. 12** is a schematic representation showing the different shapes for the mating geometry;

[0025] **FIG. 13** is a top-down isometric view of an example hand-held consumer electronic device to which is operably connected an example plug fiber optic interface device;

[0026] **FIG. 14** is similar to **FIG. 13** and shows the plug fiber optic interface device disconnected from the consumer electronic device, which includes a receptacle fiber optic interface device that resides within the consumer electronic device;

[0027] **FIG. 15** and **FIG. 16** are respective front elevation views of the example receptacle and plug fiber optic interface devices of **FIG. 14**;

[0028] **FIG. 17** is a cut-away, elevated isometric view of example USB-based receptacle and plug fiber optic interface devices in the process of being mated, with just the plug ferrule shown for plug fiber optic interface device for ease of illustration;

[0029] **FIG. 18** is a close-up view of the receptacle and plug ferrules of **FIG. 17**, with the receptacle and plug fiber optic interface devices in the mated state;

[0030] **FIGS. 19** and **20** are close-up, cut-away elevated isometric views of the ferrule guide and ferrule of the receptacle fiber optic interface device in the unretracted and retracted states, respectively;

[0031] **FIG. 21** is a close-up cross-sectional view of portions of the mated receptacle and plug fiber optic interface devices, illustrating an example where the gradient-index (GRIN) lens elements supported in the respective optical pathways are separated by a small gap when the receptacle and plug fiber optic interface devices are mated;

[0032] **FIG. 22** is similar to **FIG. 17** and illustrates another example embodiment of a USB-based receptacle fiber optic interface device;

[0033] **FIG. 23** that shows the receptacle fiber optic interface device of **FIG. 22** engaged with a plug fiber optic interface device;

[0034] **FIGS. 24A** through **24C** are top-down isometric views of the receptacle and plug fiber optic interface devices illustrating different phases of the receptacle-plug mating operation;

[0035] **FIG. 25** is a front elevated isometric view of an example plug that illustrates an example guide pin configuration that includes recesses configured to mitigate contamination;

[0036] **FIG. 26** is a partial cross-sectional close-up view of the plug ferrule of the plug of **FIG. 25**, showing the guide pin and surrounding trench recess;

[0037] **FIG. 27A** and **FIG. 27B** are front elevated isometric views of an example plug that has extendable pins, with **FIG. 27A** illustrating the retracted pin position and **FIG. 27B** illustrating the unretracted (extended) pin position; and

[0038] **FIGS. 28A** and **28B** are a top-down views of an example plug **70** having retractable guide pins, illustrating two different guide pin configurations.

DETAILED DESCRIPTION

[0039] Reference is now be made in detail to the preferred embodiments of the disclosure, examples of which are illustrated in the accompanying drawings. Whenever possible, like reference numbers are used to refer to like components or parts.

[0040] The ferrules, fiber optic interface devices and/or cable assemblies described herein are suitable for making optical or optical and electrical connections for a variety of devices, and are particularly well suited for consumer electronic devices. The concepts of the disclosure advantageously allow the simple, quick, and economical connection and disconnection of the fiber optic interface devices for a relatively large number of mating cycles.

[0041] In the discussion below, the term "electronic device" means a device that has either electronic or optical and electronic components and functionality, including a fiber optic interface device and associated hardware configured to receive, transmit or both transmit and receive optical signals and also communicate electrical power. Also in the discussion below and in the claims, the terms “ferrule” and “ferrule body” can be used interchangeably.

Example ferrules with complementary mating geometries

[0042] **FIGS. 1A, 2** and **3** are isometric views that depict examples of a first fiber optic ferrule **10** (**FIG. 1A**) and a second fiber optic ferrule **20** (**FIG. 2** and **FIG. 3**). First and second fiber optic ferrules **10** and **20** have complementary mating geometries for use in suitable complementary structures for making fiber optic interface devices including for example, fiber optic plugs, adapters, interconnections, and fiber optic interface devices. Specifically, **FIG. 1A** is an isometric view of a first fiber optic ferrule **10** (hereinafter, ferrule) that is a portion of a first fiber optic interface device **60**. **FIGS. 2** and **3** are isometric views of a second ferrule **20**. As shown, first ferrule **10** includes a body **12** with a front end **12F** that is configured in a mating geometry for interfacing and making an optical connection with second ferrule **20** having a body **22** with a front end **22F** and a rear end **22R**.

[0043] First ferrule body **12** also includes a plurality of optical pathways **14** with ends **14E** at ferrule body front end **12F**. As used herein, “optical pathways” mean any suitable structure or component of the ferrule for permitting the transmission of optical signals. By way of example, optical pathway(s) **14** may include optical fiber bores for receiving and supporting therein respective optical waveguides such as optical fibers, an optical lens (lens elements), an active device such as a vertical-cavity surface-emitting laser (VCSEL), a photodiode, a photodetector other active device, or other structure or component of, or attached to, the ferrule for transmitting or receiving optical signals.

[0044] The mating geometry of first ferrule **10** includes a slot **15** for receiving a guide pin **25** of second ferrule **20** when the ferrules are mated together. In this embodiment, the mating geometry of first ferrule **10** also includes a second female portion such as a hole **16** that cooperates with slot **15** when mating with a complementary ferrule. In other words, slot **15** and hole **16** each receive a respective guide pin **25** of the second ferrule. Slot **15** and hole **16** are sized and spaced for cooperating with guide pins **25** of second ferrule **20**.

[0045] As used herein, slot means that the mating geometry is sufficiently oversized with respect to its complementary mating geometry in the direction that passes through both centerlines of the mating geometry (i.e., the X-axis), thereby allowing a larger alignment tolerance between the slot and its corresponding mating geometry such as the pin. Ferrules with mating geometry that includes one or more slots allow for a large number of mating cycles since they do not generate a high level of debris with a relatively large number of mating cycles as do conventional ferrules having tight-tolerance bore and guide pin mating geometry for creating an interference fit.

[0046] Additionally, slot **15** allows for a larger tolerance between the complementary mating geometry such as guide pins of a mating ferrule. In other words, the tolerance of the mating geometry of the second ferrule may have a larger variance while still providing suitable alignment and optical performance.

[0047] **FIG. 1B** is a schematic representation of the mating geometry between first ferrule **10** and second ferrule **20**. Specifically, the mating geometry of first ferrule **10** is represented by the shaded area and the mating geometry of second ferrule **20** is represented by the dashed lines. Although the mating geometry is schematically depicted as round shape or a slot shape with rounded ends, any suitable shape(s) may be used for the mating geometry (i.e., slot, holes, and/or pins) such as square, rectangular, hexagonal etc. As shown, the left-side of the mating geometry between the first ferrule **10** and the second ferrule **20** have a relatively snug fit using the same shape, thereby creating an alignment reference datum. On the other hand, the right-side of the mating geometry between the first ferrule **10** and the second ferrule **20** do not have the same shape. In other words, the slot **15** of the first ferrule **10** is larger than the mating feature (e.g. the guide pin **25**) of second ferrule **20**, and thus provides a tolerance about a centerline distance **L** between the left-side and right-side mating geometry as shown. Additionally, the mating geometry may include a chamfer or the like at the edges to aid in alignment and/or reduce wear and debris with repeated matings.

[0048] **FIGS. 2** and **3** depict an example embodiment of a second ferrule **20** in a form suitable for mating with first ferrule **10**. Second ferrule **20** includes a body **22** with the aforementioned plurality of optical pathways **14** in the form of multiple bores for receiving and supporting respective optical waveguides such as optical fibers **40** (not shown in **FIG. 2** and **FIG. 3**; see **FIG. 9**). Second ferrule **20** includes a mating geometry having at least one guide pin **25** sized and configured for being received by the mating geometry of first ferrule **10**, thereby aligning the optical waveguides of the two mating ferrules. As shown, guide pins **25** are monolithically formed with the body **22** of the second ferrule **20**. In other words, guide pins **25** are made from the same material and are integral with body **22** of ferrule **20**.

[0049] In the embodiment shown, second ferrule **20** has two guide pins **25** that are monolithically formed in the body of the second ferrule **20** on opposite sides of the plurality of optical pathways **14**. Unlike conventional fiber optic ferrules using precision-machined guide pins that are received into guide pin bores of the ferrule and held in place with a pin retainer, the guide pins **25** of second ferrule **20** are molded into body **22**, machined, or otherwise monolithically formed. Further, guide pins **25** of ferrule **20** protrude a sufficient distance to engage the mating geometry (e.g., slot **15** and hole **16**) of first ferrule **10**, thereby aligning the optical waveguides (e.g., optical fibers **40**; see **FIG. 9**) mounted within the respective optical pathways **14** (e.g. bores) of the mated ferrules **10** and **20**. However, first ferrule **10** may be mated with a complementary ferrule using a conventional type ferrule where one or more conventional guide pins are received in guide pin bores of the ferrule.

[0050] The mating geometry of the first and second ferrules **10** and **20** disclosed herein provides an advantage over conventional mating geometry for numerous reasons. Conventional mating geometry uses a dedicated guide pin that fits into a guide pin bore of the conventional ferrule and typically results in an interference fit between the guide pins and guide pin bores due to variance in guide pin bore spacing. This interference fit used with conventional ferrules causes wear and debris when subject to a relatively high number of mating cycles.

[0051] On the other hand, using a first ferrule **10** with at least one slot **15** reduces wear and the amount of debris generated with a large number of mating cycles. Additionally, forming guide pins **25** monolithically with the body **22** of second ferrule **20** provides a reliable and low-cost solution that is suitable for relatively high-mating cycles such as experienced with consumer electronic devices. Stated another way, the mating geometry is advantageous since it allows a large number of mating/unmating cycles such as typical with consumer electronic devices. Moreover, the mating geometry of the first ferrule **10** with at least one slot **15** reduces the wear between the mating geometry of the ferrules compared with the conventional mating geometry.

[0052] Second ferrule **20** may optionally include other features. As shown, second ferrule **20** has at least one retention feature **27** disposed on a rear end **22R** of body **22**. More specifically, second ferrule **20** has at least two retention features **27** disposed at rear end **22R** of the ferrule and disposed on opposite sides of the plurality of optical pathways **14**. Retention features **27** are configured to retain respective resilient members **75** (introduced and discussed below; see e.g., **FIG. 9**), such as springs. Although retention features **27** are shown as protrusions, other structures are possible such as blind holes, recesses, snap-on structures, or the like.

[0053] Further, second ferrule **20** may optionally include one or more stops **28'** (see **FIG. 2**). Specifically, second ferrule **20** includes two stops **28** that are recessed from the ferrule body front end **22F** and disposed on opposite sides of the plurality of optical pathways **14**, but the stop(s) maybe be flush or extend beyond ferrule body front end **22F**. Other areas of second ferrule **20** may also have recessed areas. By way of example, second ferrule **20** optionally includes a recessed area **26** about guide pins **25**, both of which are monolithically formed in ferrule body **22**, as best shown in **FIG. 2**.

[0054] Another type of recess **26** that mitigates adverse effects from contaminants is in the form of a trench such as shown in **FIG. 11** and as discussed below in connection with **FIG. 26**. Additionally, the ferrules disclosed herein may also provide electrical connections in addition to optical connections, thereby providing a hybrid connection. Example ferrules that support both optical and electrical connections are described below. The fiber optic interface devices disclosed herein may thus have either optical connection capability or both optical and electrical connection capability, and both types of fiber optic interface devices are referred to herein as optical fiber optic interface devices for ease of explanation.

[0055] First and second ferrules **10** and **20** may also include an angled portion **19** adjacent optical pathways **14**. Angled portion **19** allows for laser processing of the optical fibers **40** supported by first and second ferrules **10** and **20** in optical pathways **14**. Specifically, angled portion **19** aids manufacturing by providing a relief that inhibits marking and/or damage to the front end of the ferrule during laser processing of optical fibers **40** supported by optical pathways **14**. Angled portion **19** is thus configured to inhibit the interaction between a laser beam **LB** and/or debris during cutting and/or polishing of the optical fibers **40** with the laser beam, thereby inhibiting marking and/or damage to the front end **12F** of ferrule **10** (see **FIG. 1A**).

[0056] As shown in **FIG. 1A** and **FIG. 2**, angled portions **19** can include a surface that is angled with respect to the longitudinal axis of the ferrules **10** and **20**. Angled portion **19** can have any suitable angle and/or geometry such as between 30 to 45 degrees from the front face, but other suitable angles/geometry are possible. Further, angled portion **19** can start at any suitable distance from optical pathways **14**, so long as the dimensions and the structural integrity of the ferrule are preserved.

[0057] In other variations, angled portion **19** can also be optionally recessed rearward from the front surface of the ferrule having the optical pathways **14**. By way of example, a shoulder can be formed adjacent to angled surface **19**, thereby permitting the angled surface to be recessed rearward from the front surface of the ferrules. For instance, the shoulder can have a depth of about 2 microns or greater from the front surface of the ferrule (e.g., ferrule body front end **22F**).

[0058] Since ferrules **10** and **20** include angled portion **19**, processing the plurality of optical fibers **40** supported by the ferrule may include cutting and/or polishing the plurality of optical fibers with laser beam **LB** in one or more steps (see **FIG. 1A**). For instance, separate steps may be used for cutting and polishing optical fibers **40** with laser beam **LB**, but cutting and polishing may also occur in one step with the laser beam. Any suitable type of laser and/or mode of operation for generating laser beam **LB** can be used.

[0059] By way of example, the laser for generating laser beam **LB** may be a CO_2 laser operating in the pulse, continuous, or other suitable mode. The angle between laser beam **LB** and optical fibers **40** may also be adjusted to produce the desired angle on the ends of optical fibers **40**, such as 12 degrees, 8 degrees, or flat. Due to the distance between the portion of ferrule body front end **12F** that includes the bores and the outboard portions of the front end, laser beam **LB** substantially avoid interaction with the ferrules **10** and **20** during cutting and polishing of the plurality of optical fibers **40**.

[0060] Optional angled portion **19** is provided to further reduce the probability of interaction between refracted portions of laser beam **LB**, any debris and the ferrules. For instance, laser beam **LB** may be aligned to cut and/or polish the plurality of optical fibers **40** in a general direction from the bottom of the ferrule **10** and **20** toward angled portion **19**.

[0061] By way of example, suitable complementary structures that use first and second ferrules **10** and **20** include first and second fiber optic interface devices respectively configured in one example as a receptacle fiber optic interface device ("receptacle") **60** (see **FIG. 6**) and a plug fiber optic interface device ("plug") **70** (see **FIG. 7**) that allow the user to make a quick and reliable optical and/or hybrid connection (i.e., optical/electrical connection) therebetween. More specifically, first ferrule **10** and second ferrule **20** form portions of respective USB fiber optic interface device types that may optionally include respective electrical contacts **63** and **73** (see **FIG. 6** and **FIG. 7**), or that alternatively may form a portion of optical USB fiber optic interface devices. In other words, in an example, plug **70** is configured as a USB plug fiber optic interface device and receptacle **60** is configured as a USB receptacle fiber optic interface device as shown.

[0062] Other details of first and second ferrules **10** and **20** are discussed below in combination with the receptacle **60** and plug **70** shown in **FIGS. 6** through **10**. The concepts of first and second ferrules are useful with other types of ferrule, fiber optic interface devices, and mating devices.

Example MTP-based fiber optic interface devices

[0063] **FIGS. 4** and **5** are respective elevated isometric and exploded views of respective examples of fiber optic interface devices **100** and **101** using another set of example first and second ferrules **110** and **120** having complementary MTP-based mating geometries. First ferrule **110** includes mating geometry having at least one slot **115** formed in a body **112** similar to ferrule **10** as part of the mating geometry. Likewise, second ferrule **120** includes mating geometry having at least one guide pin **125** monolithically formed with the body similar to ferrule **20** as part of the mating geometry. Mating first and second ferrules **110** and **120** are configured as a MPO type fiber optic interface device such as a MT fiber optic interface device that mate together using an adapter (not shown), but other fiber optic interface device configurations are possible using the concepts disclosed. Further, fiber optic interface devices **100** and **101** are part of a cable assembly having one or more optical waveguides such as optical fibers **40** (not shown for clarity) inserted into the bores of ferrules. The fiber optic interface devices **100** and **101** are just examples of fiber optic interface devices and cable assemblies that can incorporate ferrules in accordance with the disclosed concepts.

[0064] More specifically, **FIG. 4** illustrates an isometric view of an assembled fiber optic interface device **100,** while **FIG. 5** illustrates an exploded view of a similar fiber optic interface device **101**. Like parts in fiber optic interface devices **100** and **101** are represented by like reference numbers. Fiber optic interface device **100** may optionally comprise a spring seat **104**, a coil spring **105**, a spring push **118**, a lead-in tube **130** and a generally hollow fiber optic interface device housing **102**. The optional spring seat **104** of the example embodiment shown in **FIG. 4**, can be positioned adjacent the rear face of the rear end of ferrule **110**, adjacent the ferrule and the coil spring **105**. An opening **106** extending lengthwise through the spring seat **104** can be configured to permit the lead-in tube **130** and the end portions of the optical waveguides (not shown) to pass through the spring push **118** to the rear face of ferrule **110**. The lead-in tube **130** can be positioned within an opening **122** of the spring push **118**, an opening **112** of the coil spring **110** and the opening **106** of the spring seat **104**. An opening **132** extending lengthwise through the lead-in tube **130** receives and guides the end portions of the optical fibers of the fiber optic cable in respective bores of the respective ferrule.

[0065] Fiber optic interface device **100** can include alignment and/or attachment structure for mating and securing the same within an adapter (not numbered). As shown, the ferrule **110**, the spring seat **104**, the coil spring **105**, a forward portion **124** of the spring push **118** and the lead-in tube **130** can be positioned at least partially within the fiber optic interface device housing **102**. In one example, a flexible latch, e.g., a latch with projection in the form of arms **126** provided on spring push **118**, can extend lengthwise from the forward portion **124** to engage openings **103** formed in the fiber optic interface device housing **102** for securing the spring push **122** with the fiber optic interface device housing **102**. A forward mechanical stop (not visible) can be provided on the interior surface of the fiber optic interface device housing **102** so that the ferrule **110** is movable when the disposed within the fiber optic interface device housing **102**, but retained therein. The ferrule **110** is biased in the forward direction by the coil spring **105** and the spring seat **104**.

[0066] Fiber optic interface device **101** of **FIG. 5** has a similar construction to fiber optic interface device **100**, but includes ferrule **120** instead of ferrule **110**, thereby providing a cable assembly suitable for mating with fiber optic interface device **100**.

First examples of USB-based fiber optic interface devices

[0067] **FIGS. 6** through **10** are elevated isometric views that respectively depict first examples of USB-based fiber optic interface devices that respectively use the first ferrules **10** as depicted in **FIG. 1A** and the second ferrule **20** as depicted in **FIG. 2** and **FIG. 3**. Specifically, **FIGS. 6** and **10** depict a receptacle **60,** and **FIG. 7** through **FIG. 9** depict a plug **70**. Receptacle **60** is attached to a cable **69** thereby forming a receptacle cable assembly **6**, while plug **70** is connected to a cable **79**, thereby forming a plug cable assembly 7. Receptacle **60** and plug **70** mate directly together in one relative orientation and by being urged together, form an optical connection or an optical and electrical connections therebetween. Although, ferrules **10** and **20** are depicted as portions of receptacle **60** and plug **70**, the ferrules or variations thereof may be used with other types of fiber optic interface devices, such as fiber optic interface devices that are solely optical.

[0068] Receptacle **60** includes first ferrule **10** at least partially disposed within an interior **62i** of an enclosure **61e**, which in an example is in the form of a shroud **62**, as shown in **FIGS. 6** and **10**. In an example, shroud **62** is a cylindrical metal shell with a substantially rectangular cross-section. Receptacle **60** is configured as USB fiber optic interface device. Specifically, receptacle **60** in the instant example is backward compatible with USB plugs that only have electrical connections and may be used with suitable USB plugs that have optical connections or both optical and electrical connections.

[0069] Specifically, receptacle **60** also includes a plurality of electrical contacts **63** for making electrical connections with electrical contacts **73** of plug **70**. Electrical contacts **63** may be molded with ferrule **10** so that they are slightly protruding or relatively flush with a wiping surface of the ferrule (i.e., the horizontal surface of the ferrule that includes the electrical contacts) or have other suitable attachment means. Receptacle **60** has transmission elements **69** (e.g., both electrical wire and optical fibers) that are routed to the rear of the fiber optic interface device for making electrical connections with the electrical contacts **63** or routed to the plurality of optical pathways **14** of ferrule **10**. In an example, transmission elements **69** collectively constitute a cable and so are also referred to herein as cable **69**.

[0070] Shroud **62** also includes tabs **65** for securing and/or grounding receptacle **60** to a circuit board or the like. As best shown in **FIG. 10**, shroud **62** includes a plurality of latching arms **62a** for securing the plug with the receptacle **60** when mated together. Although not visible, a second set of latching arms **62a** is disposed on the lower surface of shroud **62**. As shown, latching arms **62a** are cantilevered but can have other suitable constructions or can be omitted altogether. Further, as illustrated in **FIG. 10**, an example shroud **62** is formed from two halves, and locking tabs **62b** are used to secure the two halves at a seam **62s**.

[0071] **FIG. 7** through **FIG. 9** are front-end elevated isometric views of an example plug **70** suitable for mating with receptacle **60**. Plug **70** includes an enclosure **71e** comprising a housing **71** and a shroud **72** operably connected to an end of the housing. Enclosure **71e** defines an interior **72i**. Plug **70** also includes the aforementioned second ferrule **20** being at least partially disposed within the portion of interior **72i** defined by shroud **72**. Shroud **72** is similar to but fits within receptacle shroud **62**. **FIG. 8** includes a close-up view showing ferrule **20** disposed within a plug ferrule guide **74**, and **FIG. 9** shows plug **70** with the shroud **72** removed to show ferrule **20** in cooperation within ferrule guide **74**.

[0072] Thus, example plug **70** includes ferrule **20**, enclosure **71e** comprising a housing **71** and a shroud **72**, electrical contacts **73**, ferrule guide **74**, a pair of resilient members **75** for biasing ferrule **20** forward. Like receptacle **60**, the example plug **70** is configured as USB fiber optic interface device, but other types of fiber optic interface devices are possible with the concepts disclosed herein. Specifically, the example plug **70** is backward compatible with USB receptacles that only have electrical connections and may be used with suitable USB receptacles that have optical connections, or both optical and electrical connections. Specifically, plug **70** includes the aforementioned plurality of electrical contacts **73** for making electrical connection between the receptacle **60** and plug **70** (i.e., electrical connection with the corresponding electrical contacts **63** of receptacle **60**).

[0073] As with receptacle **60**, electrical contacts **73** may be molded with ferrule **20** so that they are relatively flush with a wiping surface of the ferrule (i.e., the horizontal surface of the ferrule that includes the electrical contacts) or have other suitable attachment means. Plug **70** has transmission elements **79** (i.e., both electrical wire and optical waveguides) that are routed to the rear of the fiber optic interface device for making electrical connection with the electrical contacts **73** or routed to the plurality of optical pathways **14** of ferrule **20** as shown. In an example, transmission elements **79** collectively constitute a cable and so are also referred to herein as cable **79**.

[0074] The close-up view of **FIG. 9** depicts ferrule **20** disposed within an opening **76** of plug ferrule guide **74** and biased to a forward position by one or more resilient members **75**. As shown, ferrule guide **74** includes a channel **78** connected to opening **76** that leads to ferrule body rear end **22R** to provide a passageway for routing optical waveguides (i.e., transmission elements) of cable **79** to ferrule **20**. In this embodiment, resilient members **75** are coil springs, but other suitable resilient members such as leaf springs or the like are possible.

[0075] As best shown in **FIG. 2**, ferrule **20** includes retention features **27** on opposite sides of the plurality of optical pathways **14**. As depicted, retention features **27** are protrusions that seat resilient members **75** to ferrule body rear end **22R**. Additionally, plug ferrule guide **74** includes protrusions or the like (not shown) for seating the second end of resilient members **75**. Plug ferrule guide **74** also includes ferrule stops **74a** for limiting the travel of ferrule **20** within ferrule guide opening **76**. Ferrule stops **74a** have a shape and position that is complementary to stops **28'** on ferrule **20** (see **FIG. 2**). Additionally, ferrule stops **74a** and stops **28** have complementary angled surfaces to help center the ferrule **20** with opening **76** of plug ferrule guide **74** and inhibit undue sideways displacement.

[0076] When shroud **72** is installed, ferrule **20** is trapped between plug ferrule guide **74** and shroud **72** as shown in **FIGS. 7** and **8**. Shroud **72** also includes a plurality of windows **72a** for cooperating with latching arms **62a** of receptacle **60** for securing the plug **70** to receptacle **60** when mated. Further, the opposite side of plug ferrule guide **74** is used for mounting electrical contacts **73** thereto as depicted.

[0077] Additionally, first ferrule **10** can have other mating geometries while still using the slot configuration is disclosed herein. By way of example, **FIG. 11** depicts an example receptacle **60** having a ferrule **10** similar to that described above but that includes a mating geometry with slot **15** and a guide pin **25** disposed on opposite sides of optical pathways **14.** In other words, the example ferrule **10** of **FIG. 11** has a female portion and a male portion rather than two female portions. The concept of using a female slot portion and a male pin on the same ferrule may be used with any suitable ferrule and/or fiber optic interface device design. **FIG. 11** also illustrates optical fiber ends **40E** residing at optical pathway ends **14E**.

[0078] Moreover, as stated above, the mating geometry can have shapes other than round. Illustratively, **FIG. 12** is a schematic representation showing a non-round complementary mating geometry with a slot **15** and a rectangular shaped hole **16** for the first ferrule. Second ferrule **20** has a complementary mating geometry configured as rectangular guide pins sized and shaped for mating with slot **15** and hole **16**. Using a mating geometry with flat surfaces may reduce forces between the mating geometries of the two confronting ferrules. In other words, the force is spread over a larger surface with the flat surfaces (i.e., squares and rectangles) compared with a line contact created by round geometry. Thus, the use of flat surfaces may reduce wear and debris formation. Moreover, the use of flat surfaces can increase the stability along a weak axis between the ferrules. Stated differently, the connection stability may be improved because a greater volume of material must be deformed with the flat surfaces before inducing an angle between the ferrules along the weak axis (i.e., bending about the centerline of the pin).

Examples of USB-based fiber optic interface devices

[0079] As discussed above, there is an increasing need for fiber optic interface devices suitable for use with electronic devices such as consumer electronic devices, which are often operated in a multitude of environments where contaminants in the form of dirt, dust, and other debris are encountered on a regular basis. Such contaminants can adversely affect the ability of fiber optic interface devices to optically or optically and electrically communicate with the electronic device. Thus, it advantageous to have optical fiber optic interface devices that are resistant to the adverse effects of contaminants and that can also be readily cleaned to maintain a substantially contaminant-free connection.

[0080] **FIG. 13** is a top-down isometric view of an example hand-held electronic device **200** to which is operably connected an example plug fiber optic interface device **70** at a receptacle **60**. **FIG. 14** is similar to **FIG. 13** and shows plug fiber optic interface device (plug) **70** disconnected from electronic device **200**. Electronic device **200** includes an example receptacle fiber optic interface device (fiber optic interface device) **60,** which resides within the consumer electronic device, as best seen in the inset of **FIG. 14**.

[0081] **FIG. 15** and **FIG. 16** are respective front elevation views of plug **70** and receptacle **60**. Plug **70** includes the aforementioned enclosure **71e** comprising housing **71** and a shroud **72**. Plug ferrule **20** is movably supported by a plug ferrule guide **74**. Electrical contacts **73** are disposed on respective outer sides **74S** of each of two arms **74A** of plug ferrule guide **74**. In an example, optical pathways **14** include gradient-index (GRIN) lens elements **210** disposed therein and supported at ferrule body front end **22F**.

[0082] Receptacle fiber optic interface device **60** includes ferrule **10,** wherein ferrule body **12** of ferrule **10** has arms **12A**, a central body portion **12C** and stops **28’** configured to receive ferrule guide arms **74A**. Arms **12A** and central ferrule body portion **12C** define slots **13**, with the arms each having inner sides **29S** on which are disposed electrical contacts **63**. Receptacle and plug fiber optic interface devices **60** and **70** are configured to mate so that the plug and receptacle optical pathways **14** are aligned and in optical communication via GRIN lens elements **210**, and so that the receptacle and electrical contacts **63** and **73** are in electrical contact with each other. Receptacle fiber optic interface device **60** includes an enclosure **61e** in the form of a shroud **62**. In an example, enclosure **61e** is configured to compel alignment of receptacle ferrule **10** and plug ferrule **20** and to avoid stubbing. Other mating geometries may be used, such as tongue-and-groove, so that receptacle and plug ferrules **10** and **20** are registering front ends **12F** and **22F**.

[0083] In the example shown in **FIG. 15** and **FIG. 16**, receptacle ferrule front end **12F** and plug ferrule front end **22F** are essentially planar, i.e., they have no pins, holes or slots, except for the ends **14E** of optical pathways **14**. This allows for these ferrule front ends to be readily cleaned of contaminants while in the unretracted position.

[0084] **FIG. 17** is a cut-away, elevated isometric view of receptacle and plug fiber optic interface devices **60** and **70** in the process of being mated, with just receptacle ferrule **10** of receptacle **60** shown for ease of illustration. **FIG. 18** is a close-up view of the receptacle and plug ferrules **10** and **20** of **FIG. 17**, but with the receptacle and plug fiber optic interface devices **60** and **70** in the mated state. A single one of the optical pathways **14** in the plug ferrule **20** is shown in phantom in **FIG. 18** by way of illustration. **FIGS. 19** and **20** are close-up, cut-away elevated isometric views of plug ferrule guide **74** and plug ferrule **20** of plug **70** in the unretracted and retracted states, respectively. Plug ferrule **20** has a front end **22F**, a rear end **22R** and a lip **22L** between the front and rear ferrule ends.

[0085] With reference to **FIGS. 17** and **18**, plug **70** is shown with the shroud **72** and the top portion of housing **71** removed, leaving just a bottom housing portion **71B** that has a front end **71F** and a rear end **71R**. Bottom housing portion **71B** includes at least one retention feature **27**. A plug ferrule guide **74** is disposed at front end **71F** of bottom housing portion **71B** in a cut-away portion (niche) **71N** formed therein. Plug ferrule guide **74** has a central opening (slot) **76** sized to slidingly engage a central portion **22C** of plug ferrule **20**. Plug ferrule guide **74** has side slots **77** on either side of central slot **76** that support respective plug electrodes **73**.

[0086] At least one resilient member **75** operably resides between the at least one retention member **27** and plug ferrule rear end **22R**, and rests upon housing bottom portion **71B**. Four optical fibers **40** are shown as passing through a rear fiber guide **80** at housing rear end **71R** and to optical pathways **14**. Optical fibers **40** have a coiled or otherwise slack section **40C** comprising excess optical fiber portions that resides in a storage region (space) **71S** on bottom housing portion **71B** and adjacent housing rear end **71R**. In an example, storage region (space) **71S** is formed by receptacle housing bottom portion **71B** being extended relative to a conventionally sized USB receptacle fiber optic interface device.

[0087] In an example, plug ferrule **20** has a flared rear end **22R**. This feature allows for resilient members **75** to be arranged outboard of a plug ferrule central axis **A20** so that optical pathways **14** can be located on or about the plug ferrule central axis. This feature also provides clearance for optical fibers **40**.

[0088] **FIG. 17** shows receptacle and plug fiber optic interface devices **60** and **70** just prior to their being mating engaged, so that resilient members **75** are substantially relaxed (e.g., at most slightly compressed), with plug ferrule front end **22F** residing in substantially the same plane as the front ends **74F** of guide arms **74A** and contacting receptacle ferrule front end **22F**. Plug ferrule lip **22L** is configured to butt up against plug ferrule guide rear end **74R** to prevent plug ferrule front end **22F** from extending beyond front ends **74F** of plug ferrule guide arms **74A**. Thus, **FIG. 17** shows plug ferrule **20** in its forward-biased position.

[0089] **FIG. 18** shows the receptacle and plug fiber optic interface devices **60** and **70** as matingly engaged so that resilient members **75** are substantially compressed due to the force of receptacle ferrule **10** being urged against plug ferrule **20**, which slides within plug ferrule guide central slot **76** toward plug housing rear end **71R**. Optical fibers **40**, because they are coiled or otherwise are configured to have some slack, simply move as needed to accommodate the back and forth motion of plug ferrule **20**. Thus, **FIG. 18**

shows plug ferrule **20** in its rear-biased position with resilient members **75** being compressed.

[0090] **FIGS. 19** and **20** are close-up, cut-away elevated isometric views of the plug ferrule guide **74** and plug ferrule **20** of the plug fiber optic interface device **70** in the unretracted and retracted states, respectively. When matingly engaged, arms **74A** of plug ferrule guide **74** fit within the corresponding slots **13** of receptacle ferrule **10**, with the plug ferrule guide arm ends **74F** abutting respective stops **28'** on receptacle ferrule **10**. Plug ferrule **20** axially translates by a distance **D** relative to the front ends **74F** of arms **74A** of plug ferrule guide **74** (i.e., from plug shroud front end **72F**). When plug ferrule **20** is in the rear-biased position, distance **D** is 0.5 mm ≤ **D** ≤ 20 mm, or preferably 4 mm ≤ **D** ≤ 8 mm, and more preferably 5 mm ≤ **D** ≤ 7 mm.

[0091] Note that generally, distance **D** is measured from the front end **72F** of enclosure **71e**. In some cases, enclosure front end **72F** corresponds to the plug shroud front end. In other cases, **D** is the distance measured from housing front end **61F**, as shown in **FIG. 22** and discussed below. Thus, distance **D** is the distance from the front end of the particular ferrule (e.g., either ferrule **10** or **20**) to the front-most end of the particular structure in which the ferrule in question is contained, and the term enclosure is used in connection with distance **D** in this most general sense.

[0092] The translating configuration of plug ferrule **20** allows for the optical connection between respective optical waveguides **40** supported by the plug and receptacle optical interface devices to be established within plug shroud **72**. This configuration serves to reduce the adverse effects of contamination by covering the optical interface between the plug and receptacle and also improves angle suppression. In addition, when there is no connection, plug ferrule front end **22F** resides at or very near to plug shroud front end **72F** so that it is thus readily available for cleaning (e.g., can be wiped clean using, for example a micro denier cleaning cloth). This further serves to reduce the adverse effects of contaminants on the optical connection (or the optical and electrical connections, as the case may be).

[0093] **FIG. 21** is a close-up cut-away view of portions of the mated receptacle and plug fiber optic interface devices **60** and **70**. The receptacle and plug ferrules **10** and **20**

respectively support GRIN lens elements **210** within their respective optical pathways **14** and adjacent their respective ferrule front ends **12F** and **22F**. GRIN lens elements **210** have respective front surfaces **212** and rear surfaces **213.** Optical fibers **40** are arranged in optical pathways **14** such that the respective optical fiber ends **40E** interface with the rear surfaces **213** of GRIN lens elements **210**. In an example, rear surfaces **213** of GRIN lens elements **210** are planar, as are optical fiber ends **40E**.

[0094] It may be desirable that GRIN lens element front surfaces **212** do not contact another surface when one fiber optic interface device is mated to another fiber optic interface device. Thus, in an example, the GRIN lens elements **210** are arranged such that their front surfaces **212** are set back slightly (e.g., tens of microns) from their respective ferrule front ends **12F** and **22F**. This gives rise to a small gap **214** between the front surfaces **212** of the GRIN lens elements **210** when ferrule front surfaces **12F** and **22F** are in contact when the GRIN lenses confront each other, thereby avoiding lens surface contact. In an example, gap **214** has an axial dimension of between 25 microns and 100 microns. This spaced-apart configuration of the GRIN lens elements reduces the chances of damaging the GRIN lens element front surfaces **212** when mating the receptacle and plug fiber optic interface devices **60** and **70**.

[0095] In another example, front surfaces **212** of the GRIN lens elements **210** are arranged with their respective front surfaces **212** residing in their respective plug and receptacle ferrule front ends **12F** and **22F**. To avoid the GRIN lens element front surfaces **212** from coming into contact, in an example at least one of the mated receptacle and plug fiber optic interface devices **60** and **70** can include a projecting feature (not shown).

[0096] Alternatively, the portion of the plug ferrule front end **12F** that includes optical pathway ends **14E** can be slightly set back from the rest of the ferrule front end so that the front surfaces **212** of the GRIN lens elements **210** can reside at the optical pathway ends but still remain slightly spaced apart from the opposing GRIN lens front surfaces **212** of receptacle ferrule **20** when plug and receptacle ferrule front surfaces **12F** and **22F** are otherwise in contact. This set back can also be included in front end **22F** of receptacle ferrule **20**, or each of the plug and receptacle ferrules **10** and **20** can include this set-back configuration.

More examples of USB-based fiber optic interface devices

[0097] **FIG. 22** is similar to **FIG. 17** and illustrates another example embodiment of USB-based fiber optic interface devices where now receptacle **60** is configured with a translatable receptacle ferrule. Thus, the configuration of receptacle **60** in this example resembles that of plug **70** described above in connection with **FIGS. 13** through **20**.

[0098] Receptacle **60** is shown in **FIG. 22** with its receptacle ferrule **10** in the retracted (rear-biased) position. Note that receptacle ferrule front end **12F** has the aforementioned associated distance **D** from housing front end **61F** similar to that discussed above in connection with plug **70**. The side view **FIG. 23** shows the receptacle engaged with a plug **70**. Receptacle **60** includes multiple electrical contacts **63** supported by receptacle housing bottom portion **61B** adjacent housing front end **61F**. The plug and receptacle **60** and **70** are an example of a pin-aligned USB fiber optic interface device assembly configuration. Housing bottom portion **61B** also includes the aforementioned storage region (space) **61S** where extra lengths of optical fiber **40** can be stored in coiled or otherwise slack form.

[0099] When receptacle **60** and plug **70** are mated, receptacle ferrule front end **12F** contacts plug ferrule front end **22F**. Because receptacle ferrule **10** is configured to be translatable, it is pushed back into the retracted position by the axial force of the plug ferrule on the receptacle ferrule as the receptacle and plug are brought together. Note that the receptacle and plug shrouds **62** and **72** are omitted from **FIG. 22** and **FIG. 23** for ease of illustration. In operation, receptacle shroud **62** serves as a receptacle ferrule guide that assists in guiding and containing plug ferrule **20**.

[00100] **FIGS. 24A** through **24C** are top-down isometric views of receptacle **60** and plug **70**, illustrating different phases of the receptacle-plug mating operation. In **FIG. 24A**, receptacle **60** and plug **70** are arranged in opposition to each other along a common axis **A1** prior to the mating operation. In this relative position, receptacle ferrule **10** is in the unretracted (forward-biased) position and is adjacent front end **62F** of receptacle shroud **62**. This position allows for cleaning of receptacle ferrule body front end **12F** if desired. Such cleaning, for example, removes contaminants from the ends **40E** of optical fibers **40** or the end faces **212** of GRIN lens elements **210**, depending on the particular receptacle configuration.

[00101] In **FIG. 24B**, plug shroud **72** is inserted into receptacle shroud **62**. As receptacle **60** and plug **70** are urged together along axis **A1,** and plug shroud **72** slides within receptacle shroud **62**, plug ferrule **20** pushes against the receptacle ferrule **10**, causing the latter to slide axially in the direction of shroud rear end **62R** as resilient members **75** are compressed. **FIG. 24C** represents the final mated position where receptacle ferrule **10** is in its fully retracted (i.e., rear-biased) position, with plug shroud **72** substantially fully surrounded by receptacle shroud **62**.

[00102] In an example, resilient members **75** (see, e.g., **FIG. 22**) are configured (e.g., as a frustoconical spring) to be self-collapsing, thereby allowing for more travel distance for ferrule **20**. Also in an example, resilient members **75** are arranged about respective guide rods **75R** that serves to guide the resilient members **75** as they compress and uncompress. Guide rods **75R** can be configured to extend through retention features **27** and move therethrough during the translation of ferrule **20**.

[00103] **FIG. 25** is a front elevated isometric view of an example plug **70** that illustrates an example configuration for guide pins **25**. **FIG. 26** is a partial cross-sectional close-up view of plug ferrule **20** that shows an example of guide pin **25**. The example guide pin configuration includes a recess **26** in the form of a trench surrounding the base of guide pin **25**. Recess **26** is configured to collect contaminants **230** such as debris, dust, dirt, particulates, fluid, etc. rather than have such contaminants reside on plug ferrule front end **22F** and interfere with the plug and receptacle connection. Thus, recess **26** serves to mitigate the adverse effects of contaminants on the optical connection (or optical and electrical connection) formed by mating receptacle **60** and plug **70**.

Retractable Alignment Structure

[00104] **FIGS. 27A** and **27B** are front-end elevated isometric views of an example plug **70** having retractable alignment structure. The retractable alignment structure can be in the form of projections, pins, arms or other suitable alignment structure for alignment of the components. As an illustration, guide pins **25** are used. **FIGS. 28A** and **28B** are a top-down views of an example plug **70** having retractable guide pins, illustrating two different guide pin configurations.

[00105] Retractable guide pins **25** are mechanically or otherwise cooperatively connected to connected to a guide pin switch **250** that allows for the guide pins to be in a retracted position (**FIG. 27A**) or an unretracted (extended) position (**FIG. 27B**). **FIGS. 28A** and **28B** show retractable guide pins **25** mechanically connected to guide pin switch **250** via respective beams **260**. In an example, retractable guide pins **25** are electrically connected to respective electrical wires **275** carried by fiber optic cable **79** and thus can served as electrical contacts that can provide power transmission.

[00106] In an example, pin switch **250** is arranged atop plug housing **71** and slides along the plug housing when translating guide pins **25**. In an example, switch **250** is configured so that it can be readily engaged by a user's finger. Retractable guide pins **25** can be supported in guide pin channels **266** in plug ferrule **20** (**FIG. 28A**) or can be supported adjacent the plug ferrule, e.g., by guide pin channels **266** in ferrule guide **74** (**FIG. 28B**).

[00107] When the user wants to clean plug **70**, they engage switch **250** to retract pins **25** to allow open (unimpeded) access to ferrule front end **22F** and the optical interface represented by optical waveguide ends **40E**. In the unretracted position of **FIG. 27B**, pins **25** allow access to ferrule front end **22F**, but not the open access associated with the recessed pin position of **FIG. 27A**. Note that in the example shown in **FIG. 28A** and **FIG. 28B**, the ferrule front end **22F** includes a recessed front end portion **22F'** where optical fiber ends **40E** reside. Other examples can have optical fiber ends residing directly at ferrule front end **22F**. In either case, access to the optical fiber ends **40E** is facilitated by having guide pins **25** be retractable.

[00108] Although the disclosure has been illustrated and described herein with reference to preferred embodiments and specific examples thereof, it will be readily apparent to those of ordinary skill in the art that other embodiments and examples can perform similar functions and/or achieve like results. All such equivalent embodiments and examples are within the spirit and scope of the disclosure and are intended to be covered by the appended claims. It will also be apparent to those skilled in the art that various modifications and variations can be made to the present disclosure without departing from the spirit and scope of the same. Thus, it is intended that the present disclosure cover the modifications and variations of this disclosure provided they come within the scope of the appended claims and their equivalents.

We claim:

1. A fiber optic interface device comprising:

a ferrule having front and rear ends connected by one or more optical pathways configured to respectively operably support one or more optical waveguides;

one or more optical waveguides respectively supported by the one or more optical pathways;

an enclosure having front and rear ends and an interior in which the ferrule is translatably supported therein, the interior having a storage region adjacent the ferrule that is configured to loosely store one or more excess portions of the one or more optical waveguides; and

at least one resilient member operably configured relative to the ferrule to provide a forward-bias position of the ferrule when the fiber optic interface device is unmated and a rear-bias position of the ferrule when the fiber optic interface device is mated.

2. The fiber optic interface device of claim 1, further comprising at least one retention feature on the ferrule rear end that engages at least one resilient member.

3. The fiber optic interface device of claim 1, further comprising:

a ferrule guide supported within the enclosure and configured to slidably engage the ferrule so that the ferrule can translate between the forward-bias and rear-bias positions.

4. The fiber optic interface device of claim 1, wherein the one or more optical waveguides include at least one of: one or more optical fibers and one or more gradient-index (GRIN) lens elements.

5. The fiber optic interface device of claim 1, wherein:

the ferrule front end resides within the enclosure interior at a distance D from the enclosure front end while in the rear-biased position, where $0.5 \text{ mm} \leq D \leq 20 \text{ mm}$.

6. The fiber optic interface device of claim 5, wherein 5 mm $\leq$ D $\leq$ 7 mm.

7. The fiber optic interface device of claim 1, the ferrule comprising an angled portion adjacent the ferrule front and the optical pathway ends, the angled portion being configured to allow for laser processing of the one or more optical waveguides.

8. The fiber optic interface device of claim 1, further comprising at least one alignment structure at or adjacent the ferrule front end.

9. The fiber optic interface device of claim 8, further comprising the at least one alignment structure configured to provide power transmission.

10. The fiber optic interface device of claim 8, wherein the at least one alignment structure is retractable.

11. A fiber optic interface device comprising:

an enclosure having an axis, front and rear ends and an interior;

a ferrule configured to operably support a plurality of optical fibers, the ferrule being supported within the housing interior and being axially translatable therein;

a plurality of optical waveguides operably supported by the ferrule; and

at least one resilient member operably arranged within the enclosure interior and configured to provide a forward-bias position of the ferrule when the fiber optic interface device is unmated and a rear-bias position of the ferrule when the fiber optic interface device is mated.

12. The fiber optic interface of claim 11, further comprising the enclosure having a storage region configured to loosely store excess portions of the plurality of optical fibers.

13. The fiber optic interface of claim 11, wherein the at least one resilient member comprises a spring.

14. The fiber optic interface device of claim 11, wherein the ferrule front end resides within the enclosure interior at a distance D from the enclosure front end when in the rear-biased position, and where D is $0.5 \text{ mm} \leq D \leq 20 \text{ mm}$.

15. The fiber optic interface device of claim 14, wherein D is $5 \text{ mm} \leq D \leq 7 \text{ mm}$.

16. The fiber optic interface device of claim 11, further comprising one or more GRIN lens elements having respective front and rear surfaces, the GRIN lens elements being operably supported by the ferrule such that the GRIN lens element rear surfaces are interfaced with respective optical fiber ends and the GRIN lens front surfaces reside at or recessed from the ferrule front surface.

17. The fiber optic interface device of claim 11, further comprising the enclosure being configured so that the fiber optic interface device constitutes a USB fiber optic interface device.

18. The fiber optic interface device of claim 11, wherein the ferrule supports at least one electrical contact.

19. The fiber optic interface device of claim 11, wherein the ferrule front end is essentially planar and has no guide pins.

20. The fiber optic interface device of claim 11 constituting a first fiber optic interface device and further comprising the first fiber optic interface device being mated with a second fiber optic interface device having a complimentary mating geometry to the first fiber optic interface device, to form an optical connection or an optical and electrical connection, where mating the first and second fiber optic interface devices

causes an axial translation of the ferrule from the forward-bias position to the rear-biased position.

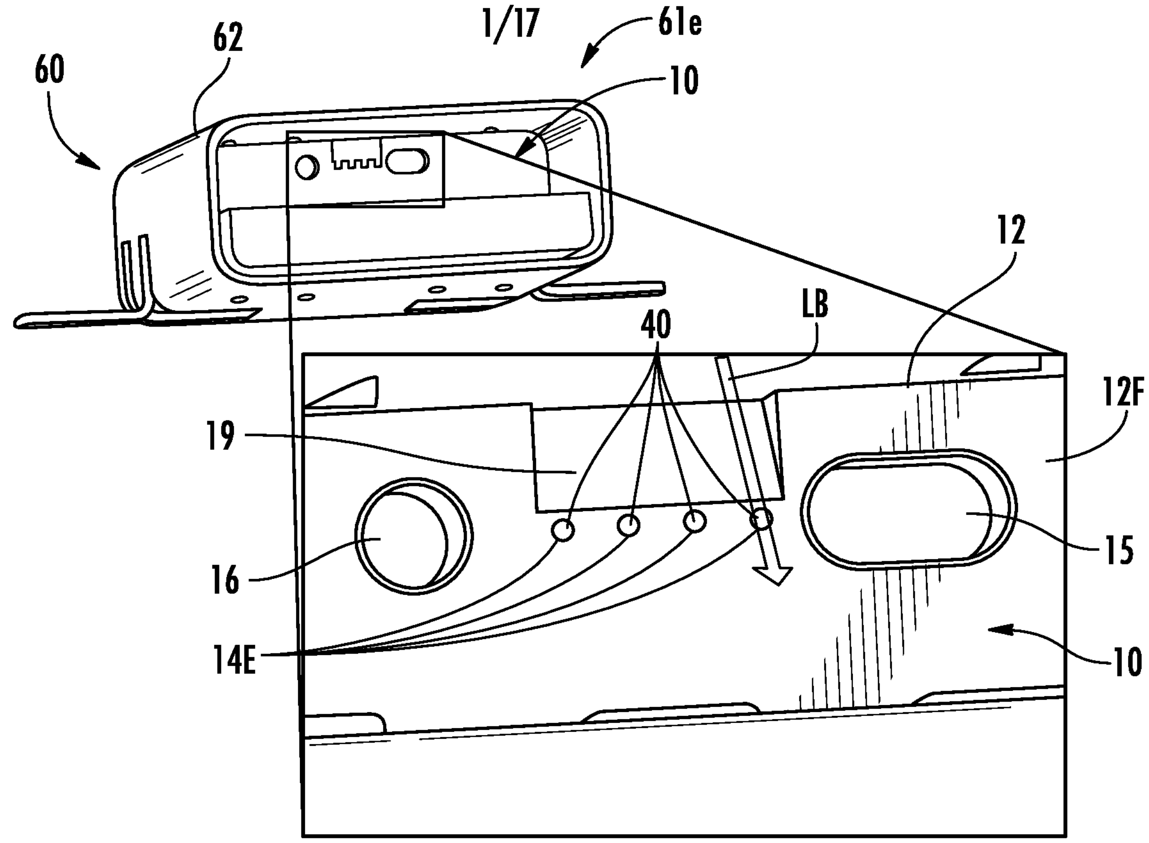


FIG. 1A

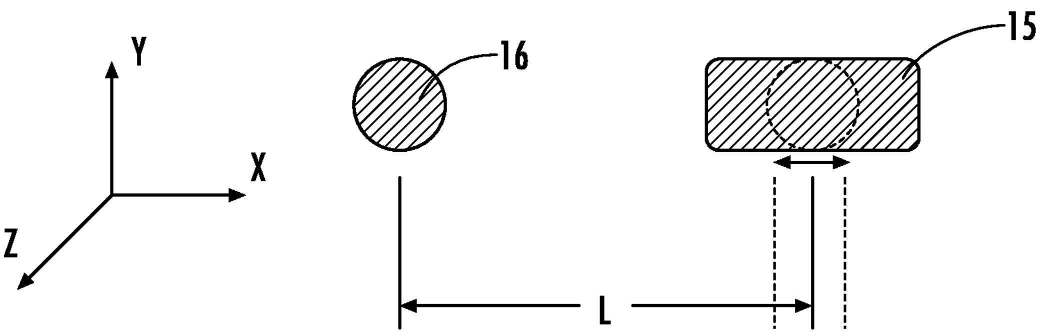


FIG. 1B

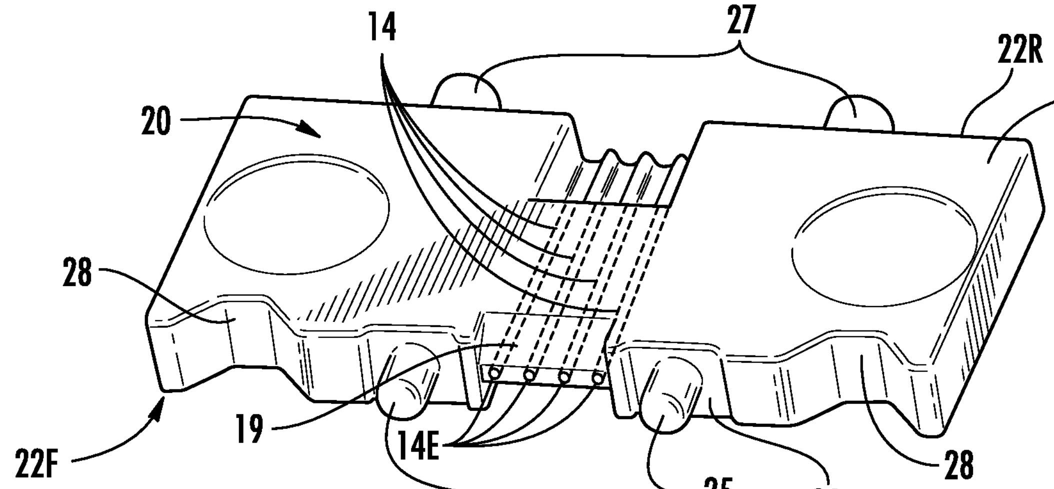


FIG. 2

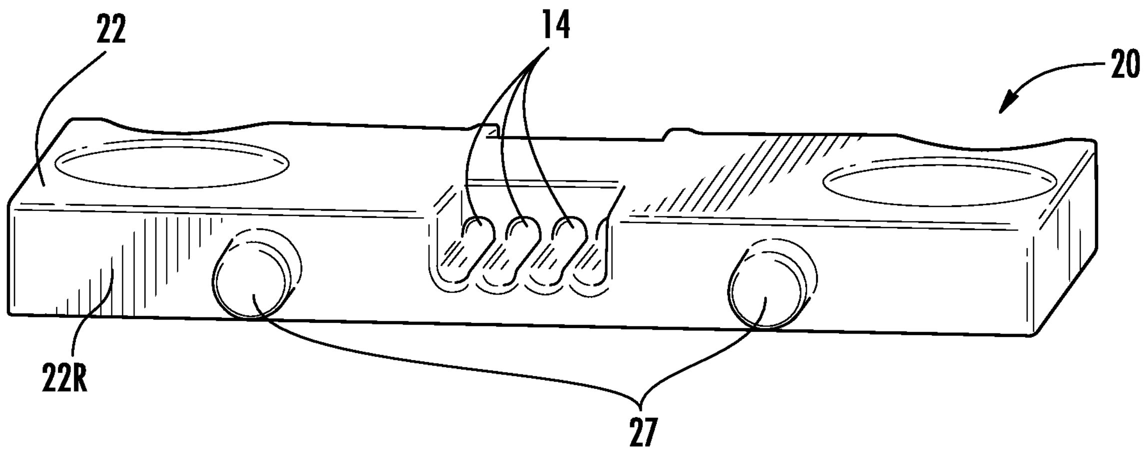


FIG. 3

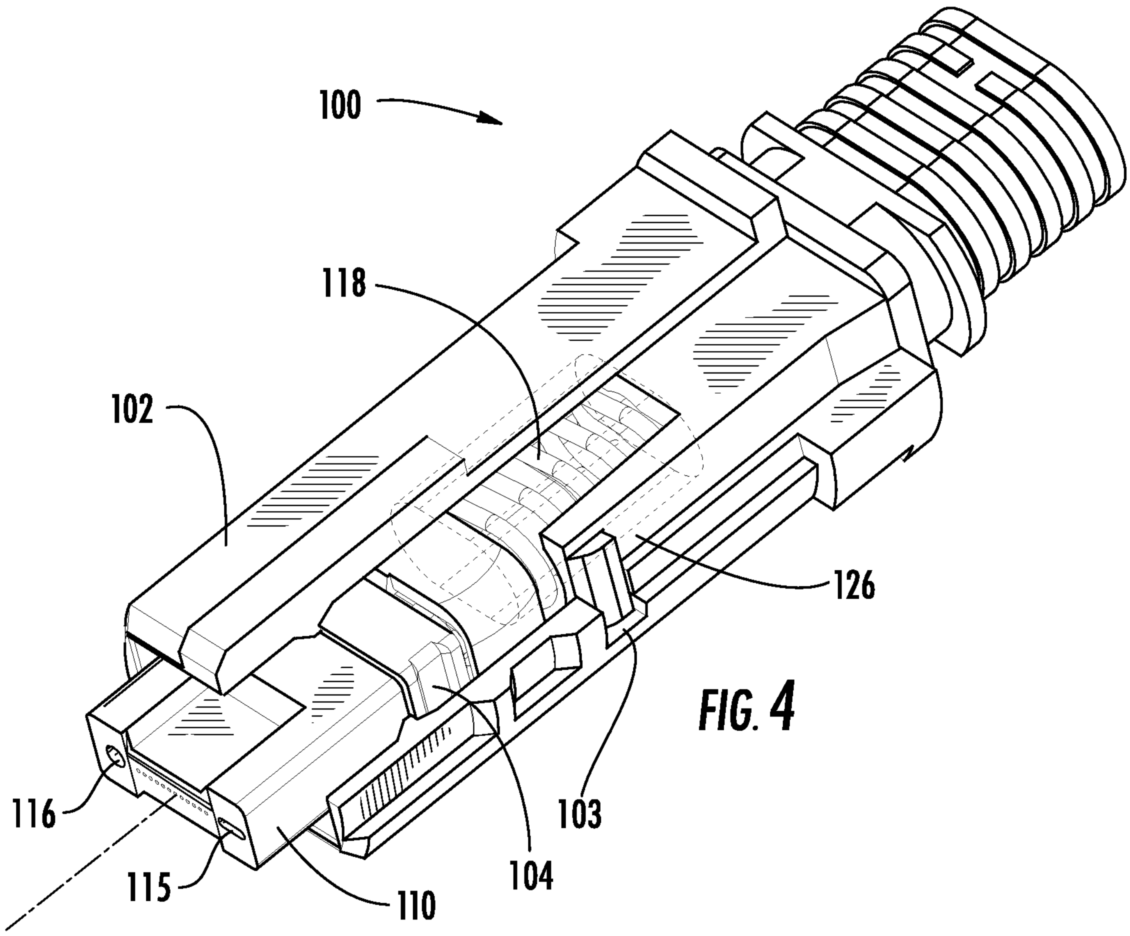
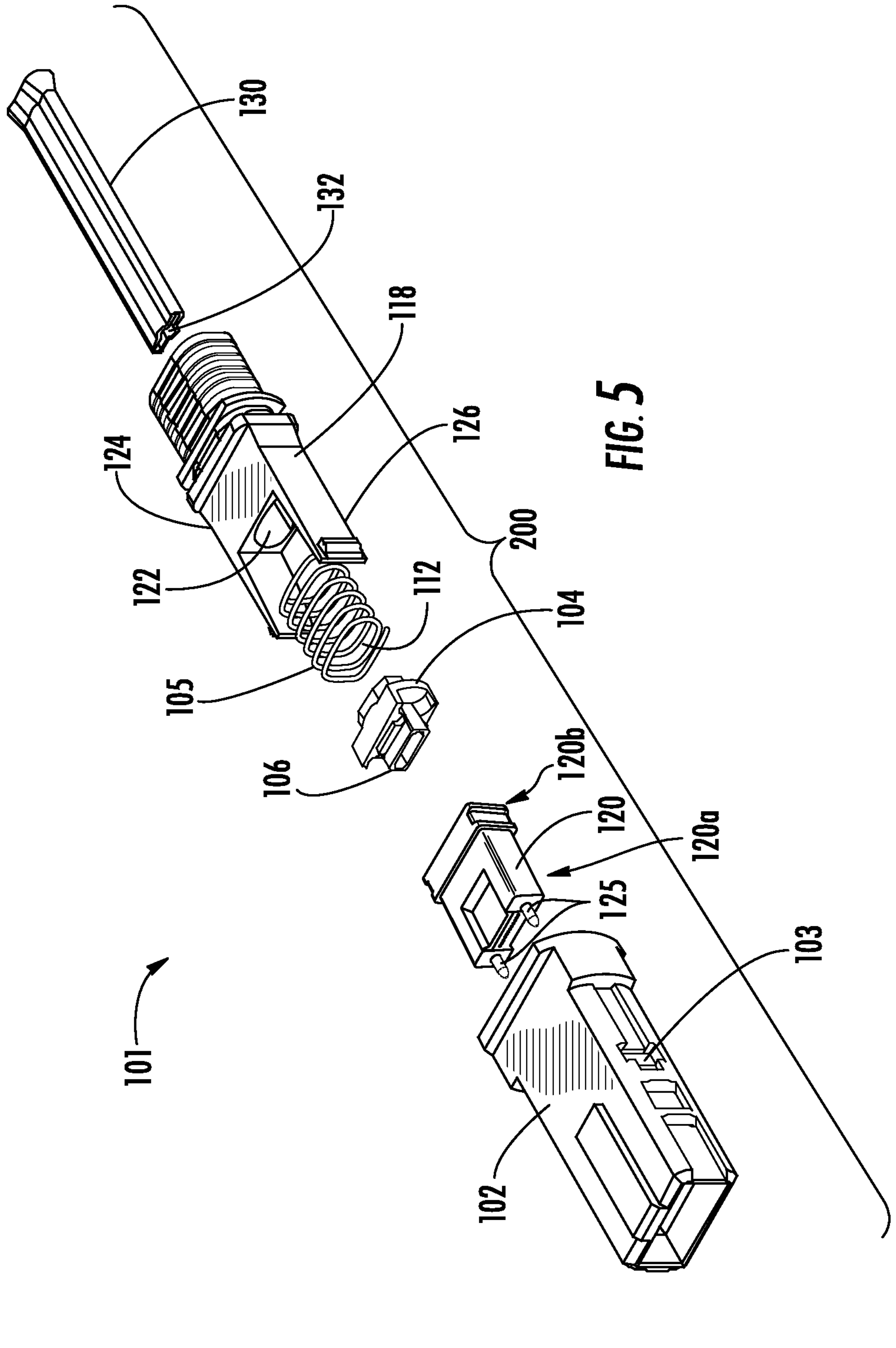


FIG. 4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104
106
120b
120
120a
125
103
101
102

FIG. 5

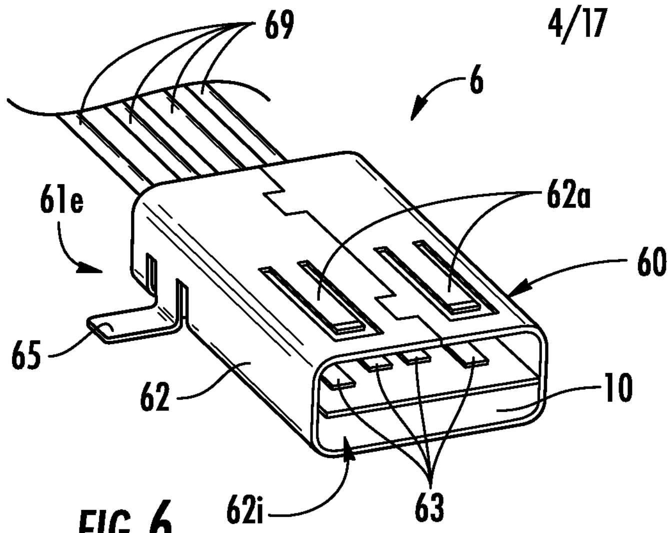


FIG. 6

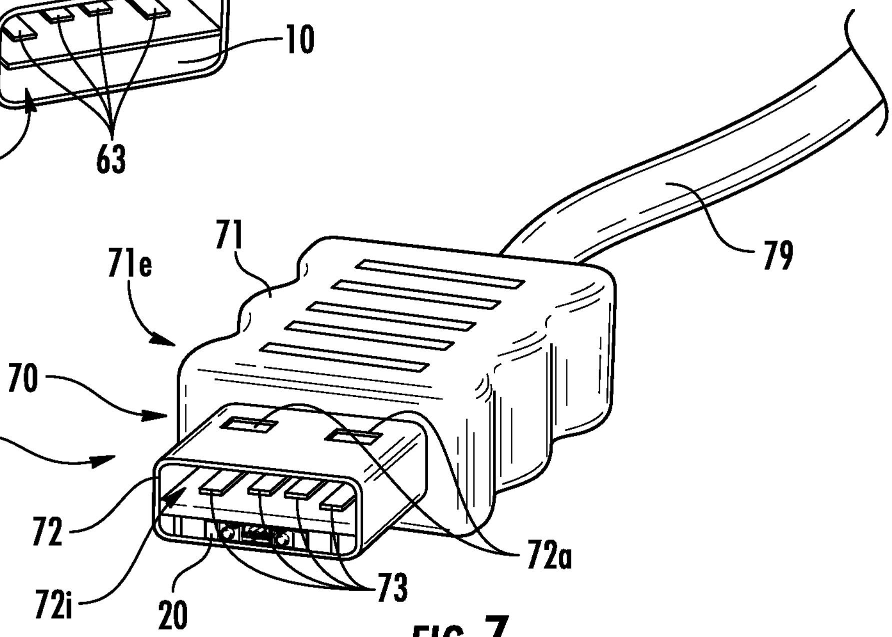


FIG. 7

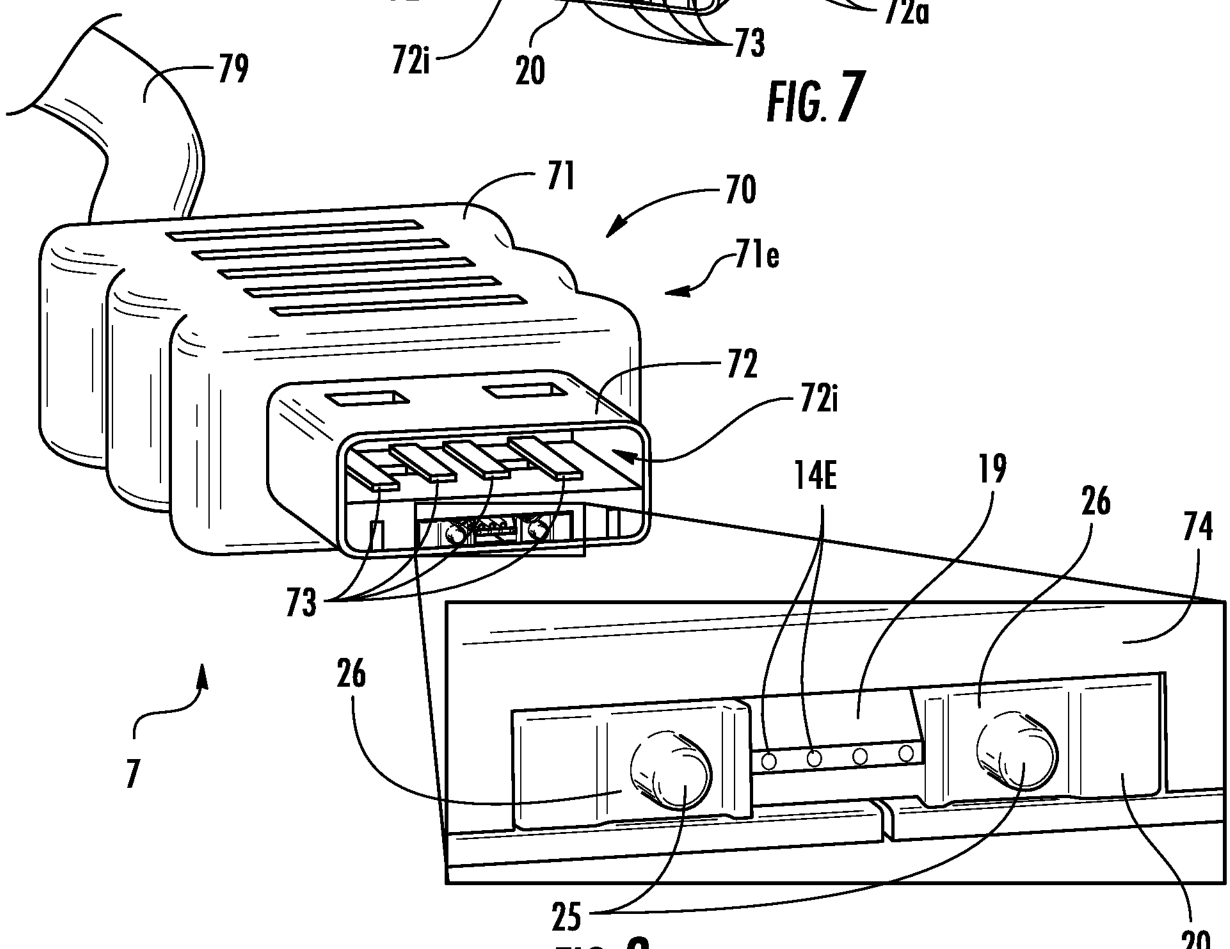
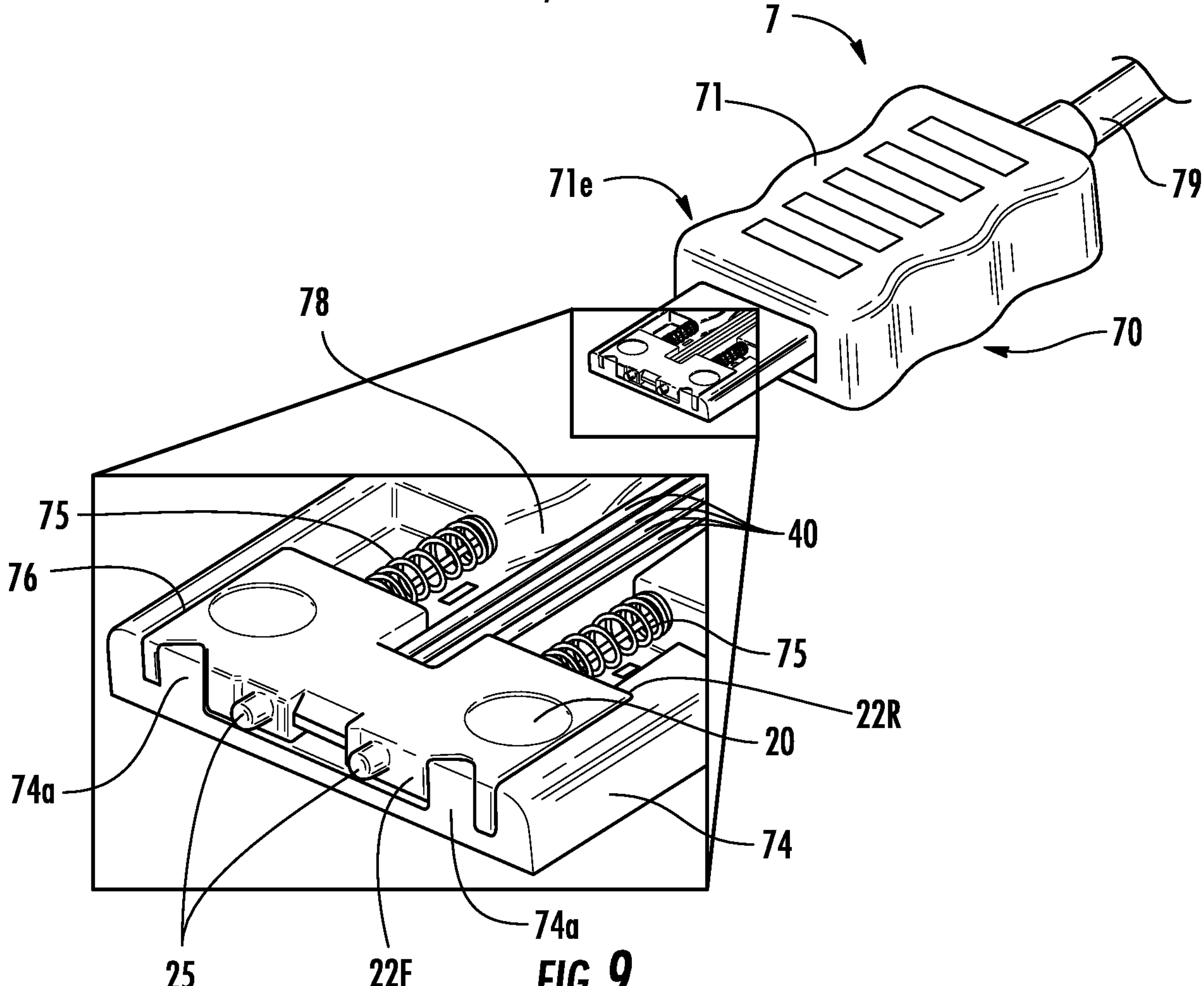


FIG. 8



7
71
71e
79
78
70
75
40
76
75
22R
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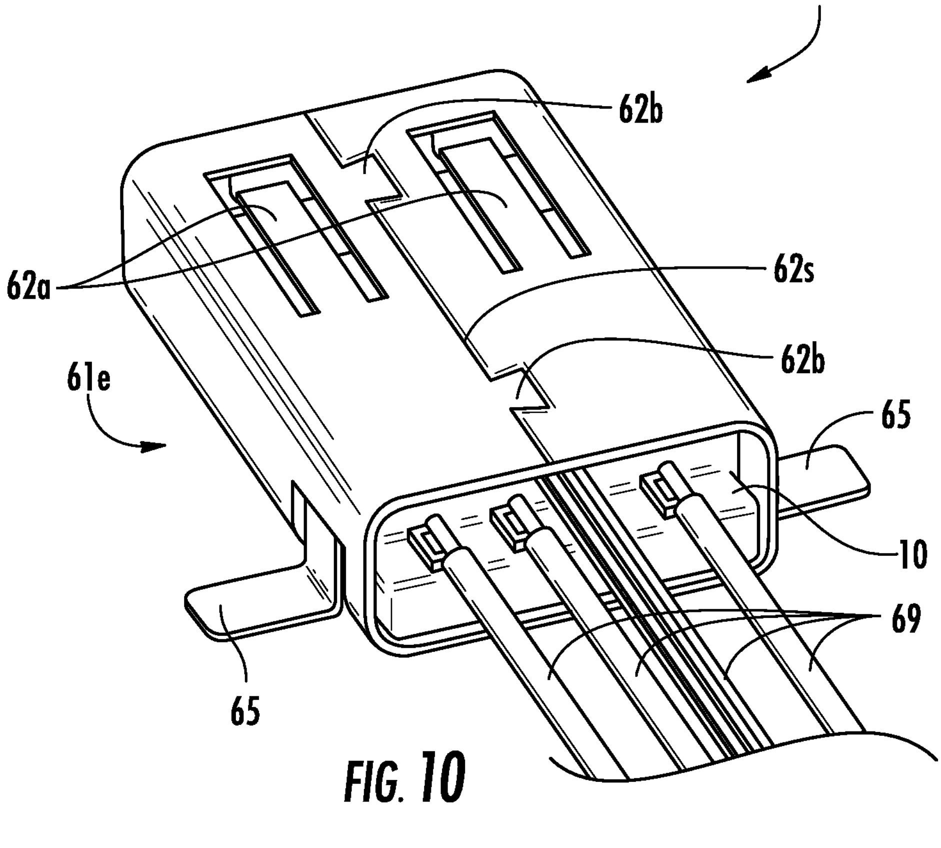
74a
74
74a
25
22F

FIG. 9



60
62b
62a
62s
62b
61e
65
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69
65

FIG. 10

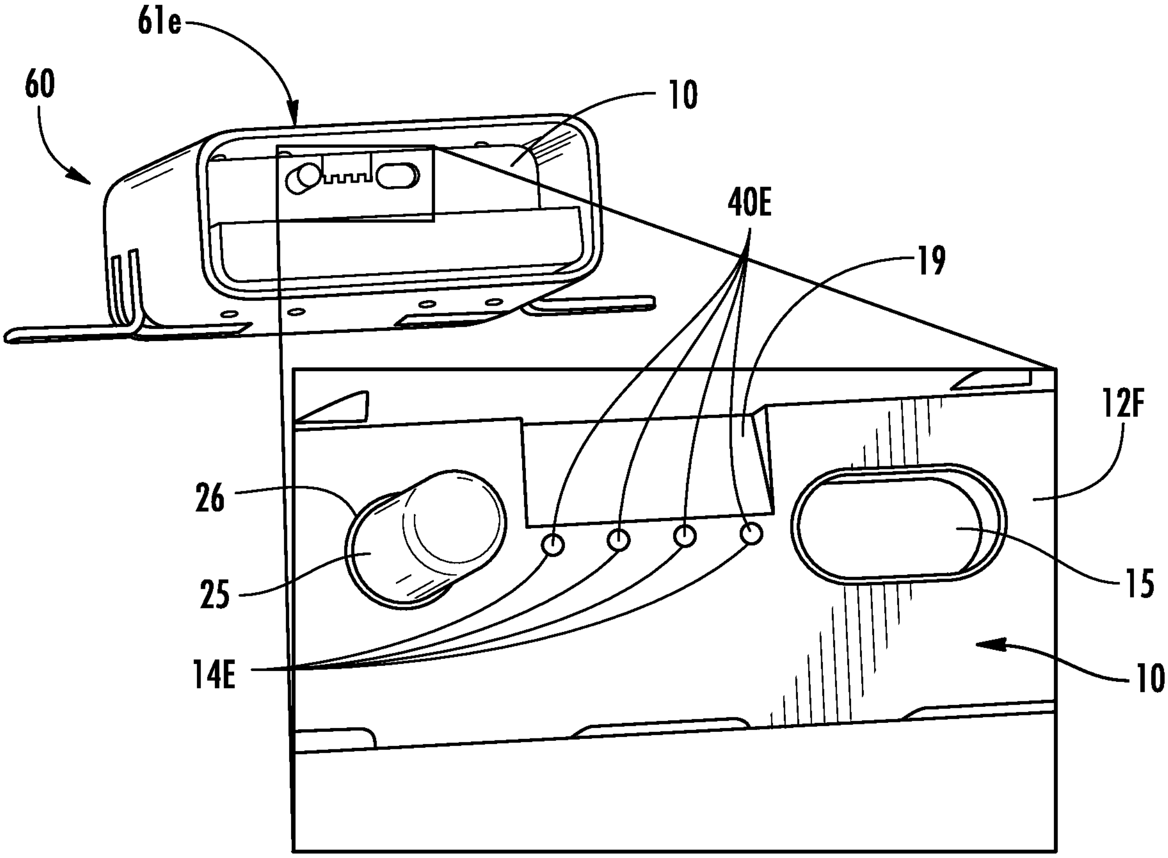


FIG. 11

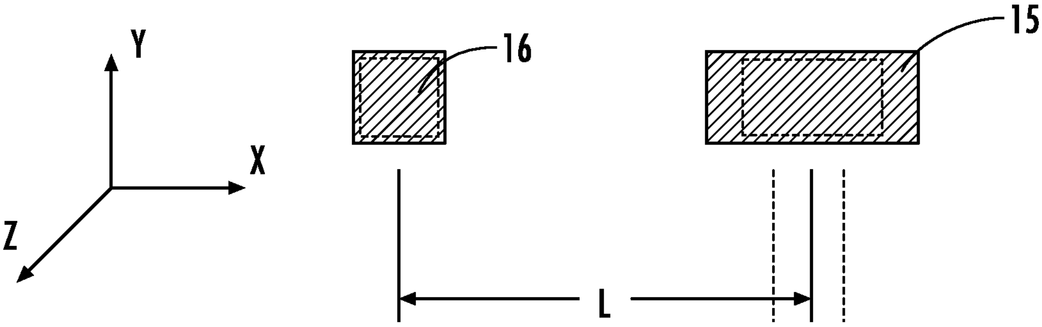


FIG. 12

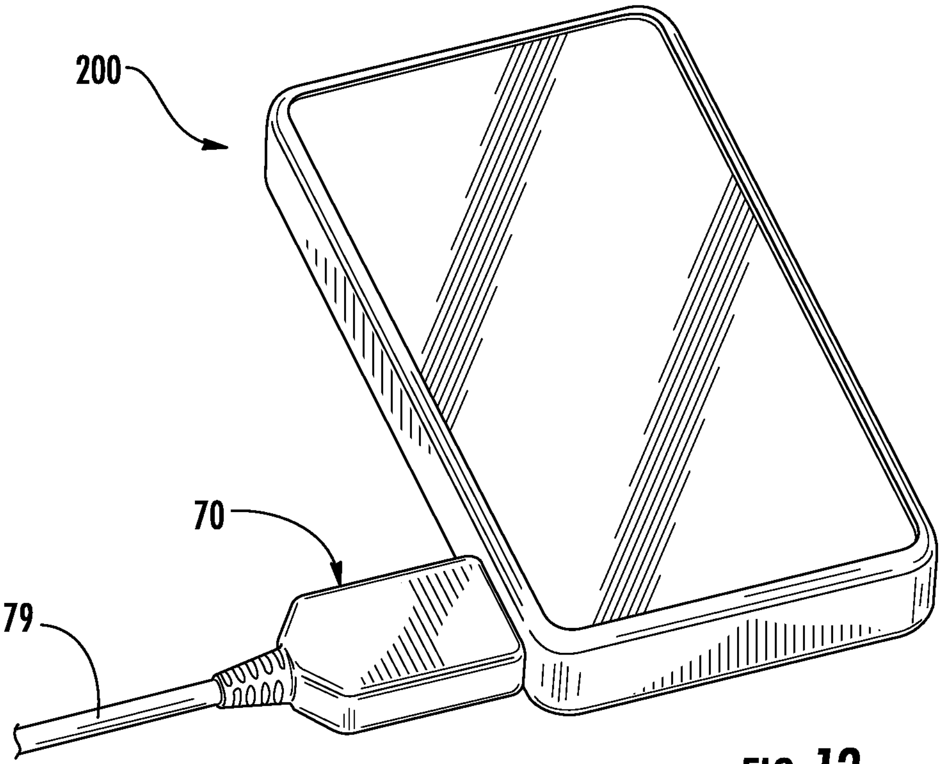


FIG. 13

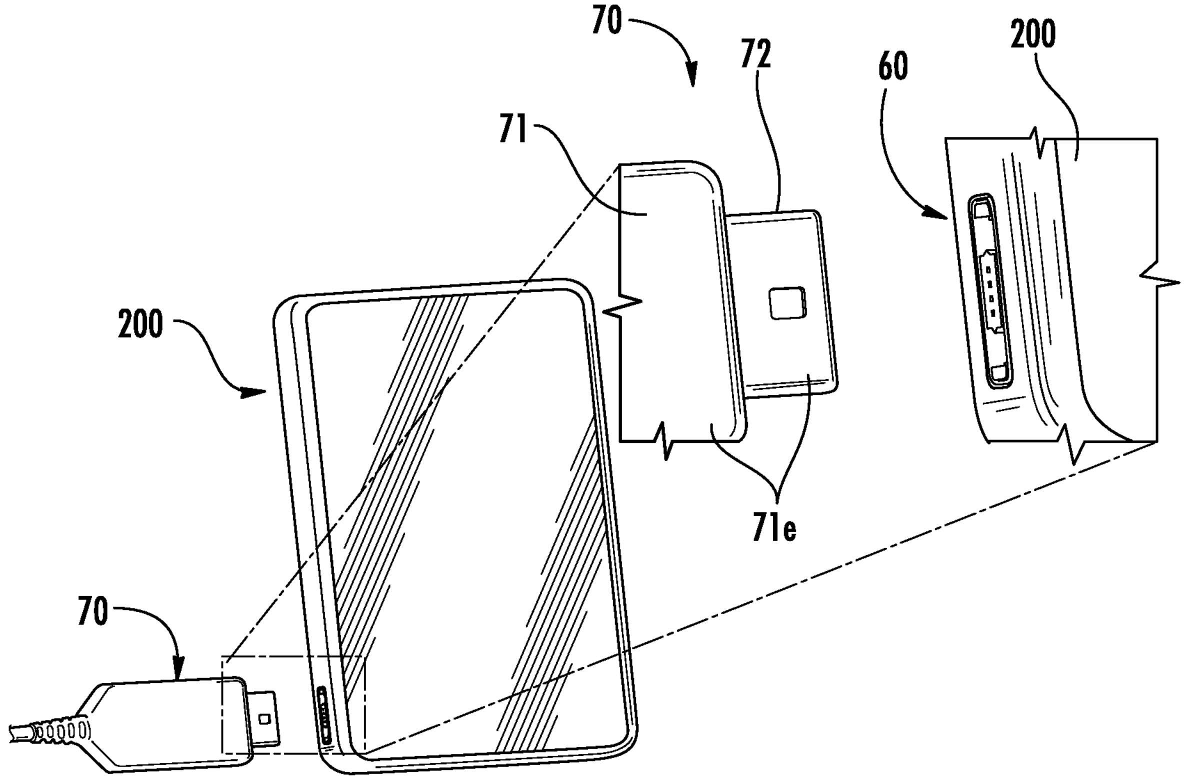
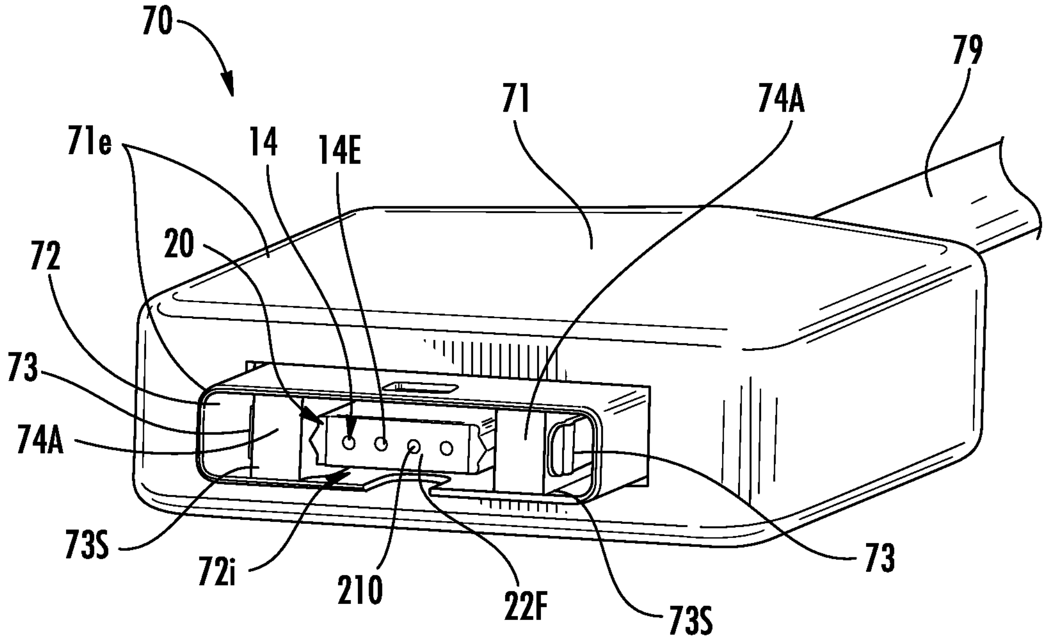
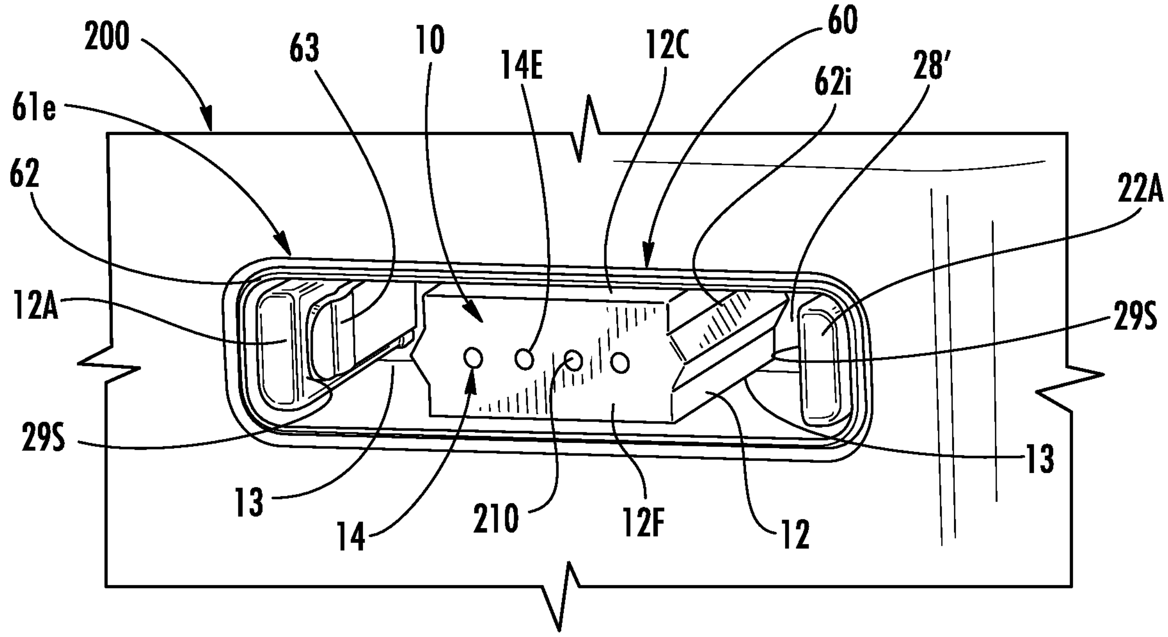


FIG. 14



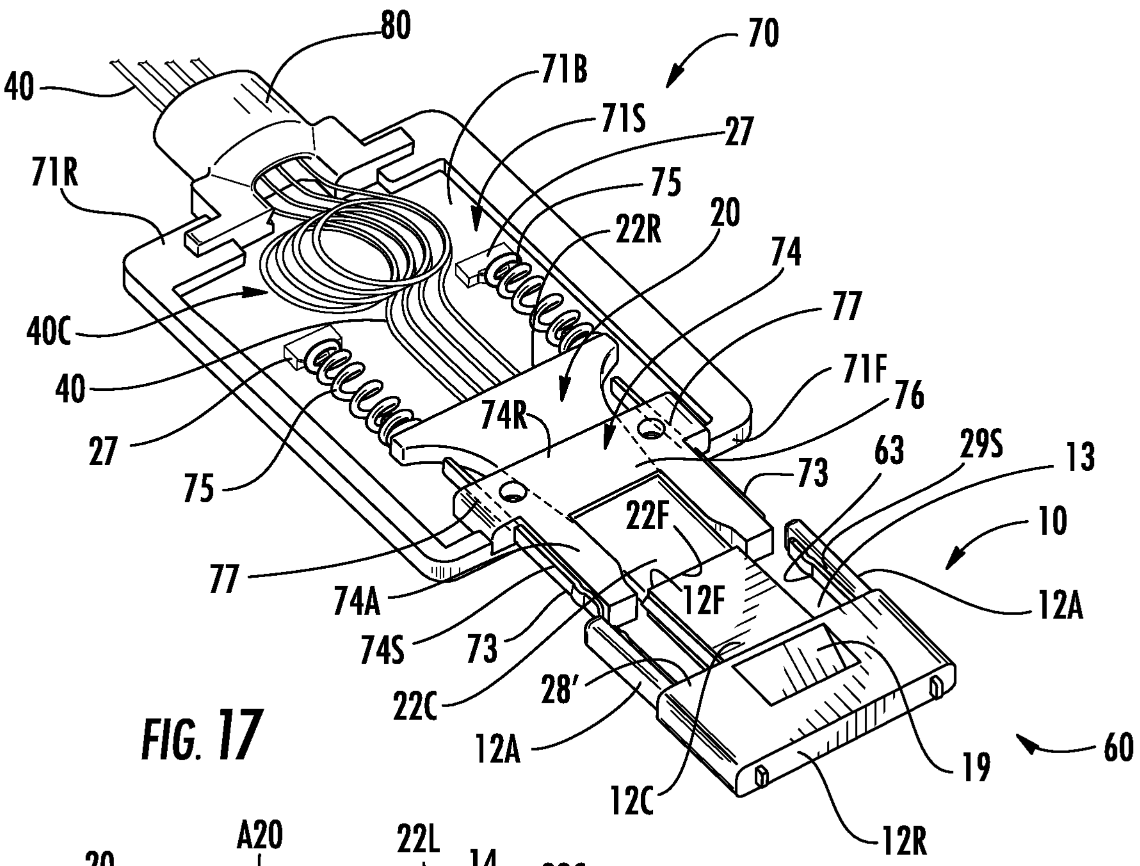
70
79
71
74A
71e
14
14E
20
72
73
74A
73S
72i
210
22F
73
73S

FIG. 15



200
63
10
14E
12C
60
62i
28′
61e
62
22A
12A
29S
29S
13
13
14
210
12F
12

FIG. 16


80
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71B
71S
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71R
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20
22R
74
77
40C
40
71F
76
74R
27
63
29S
13
73
75
22F
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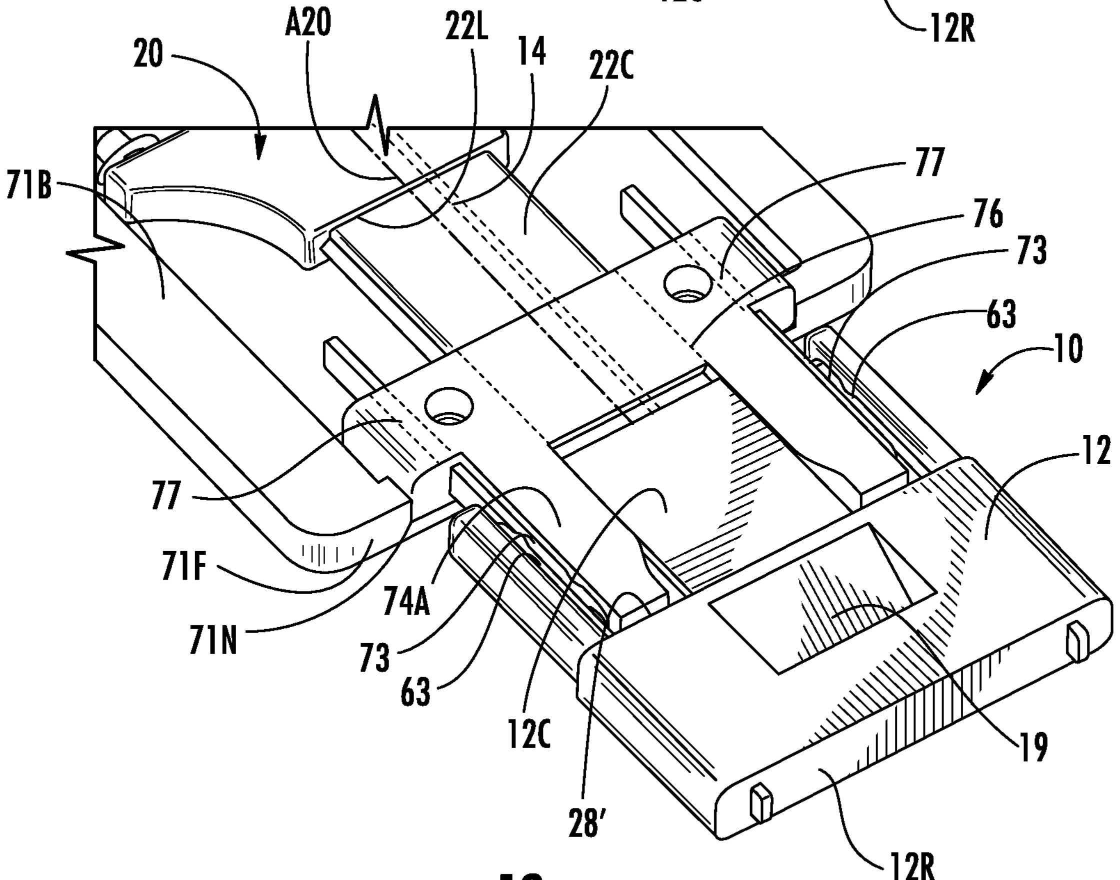
77
12F
12A
74A
74S
73
19
22C
28′
60
12A
12C
12R

FIG. 17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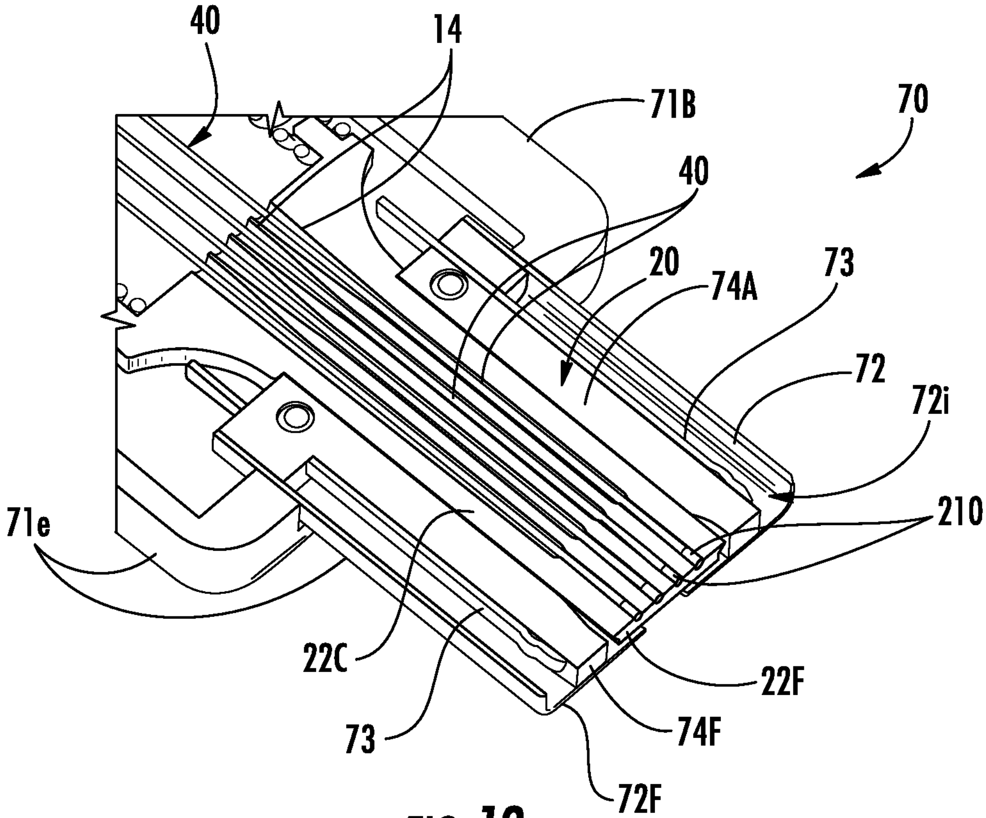
71F
71N
74A
73
63
12C
28′
19
12R

FIG. 18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72i
210
71e
22C
22F
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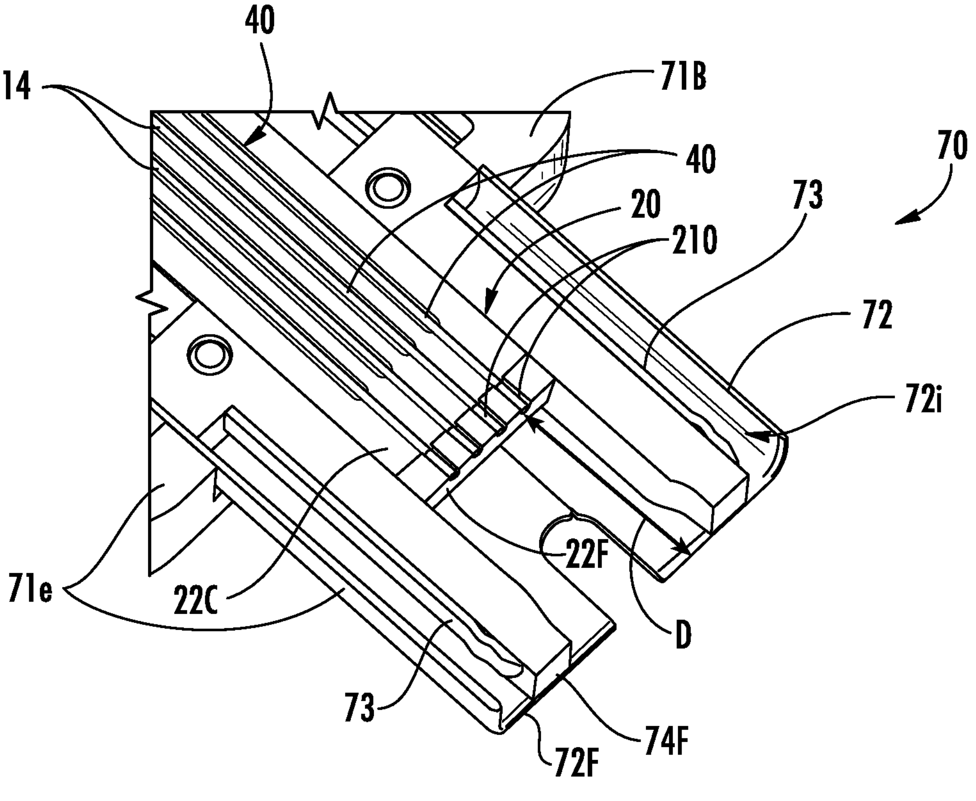
74F
72F

FIG. 19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210
73
72
72i
22F
71e
22C
D
73
74F
72F

FIG. 20

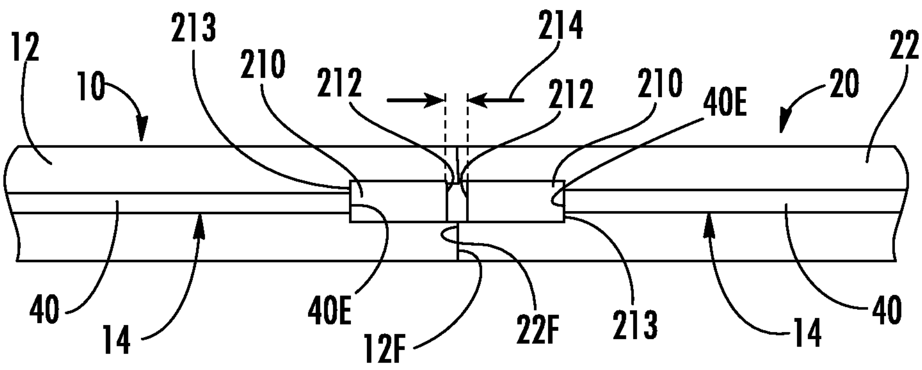
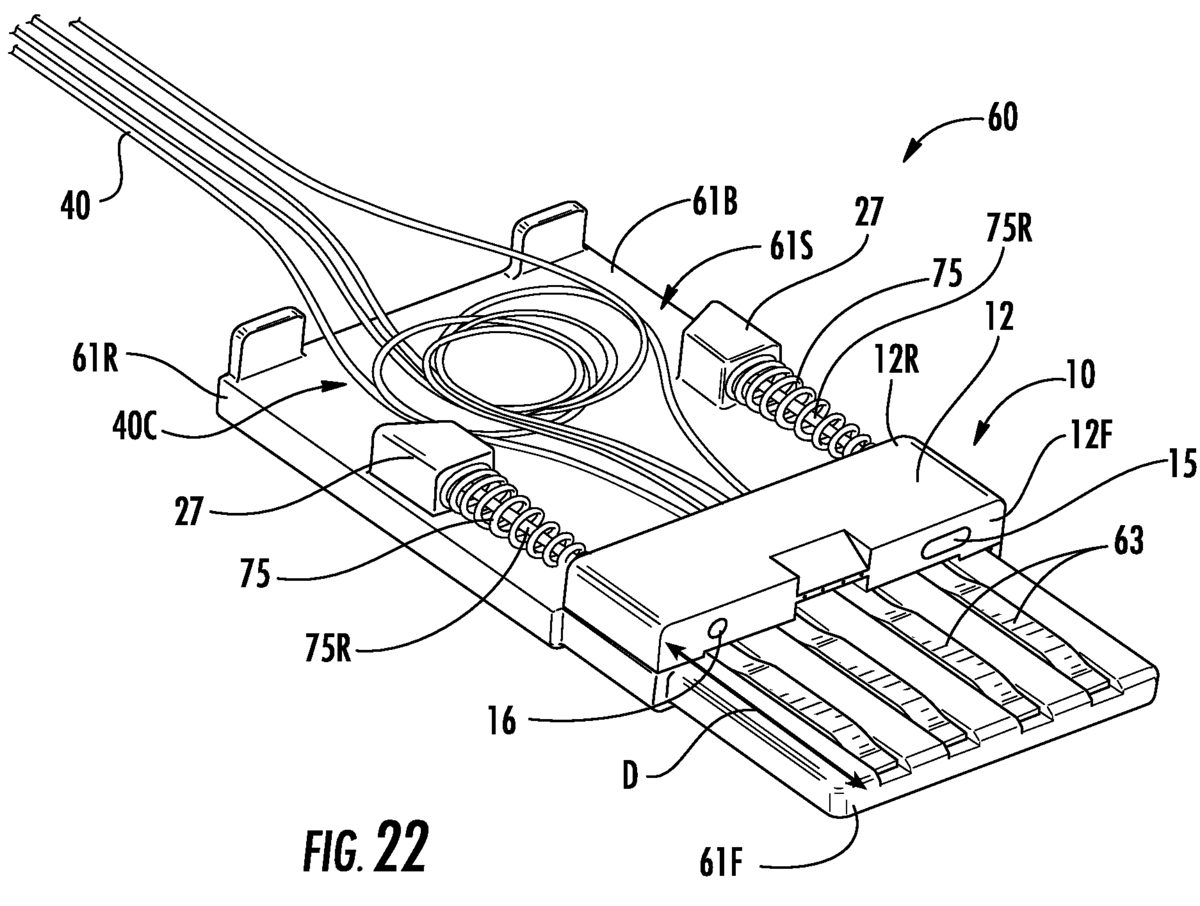


FIG. 21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40
61B
61S
27
75R
75
12
12R
10
61R
40C
12F
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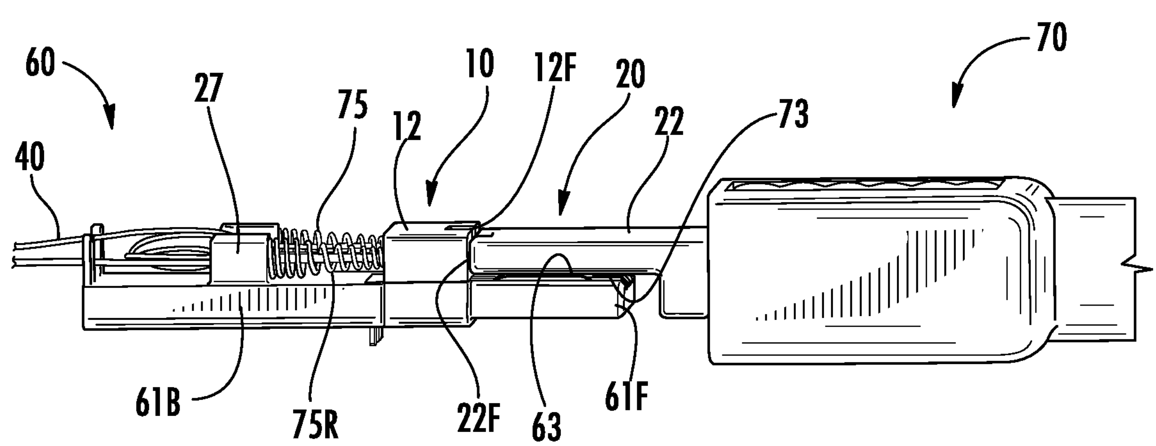
27
63
75
75R
16
D
61F

FIG. 22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61B
75R
22F
63
61F

FIG. 23

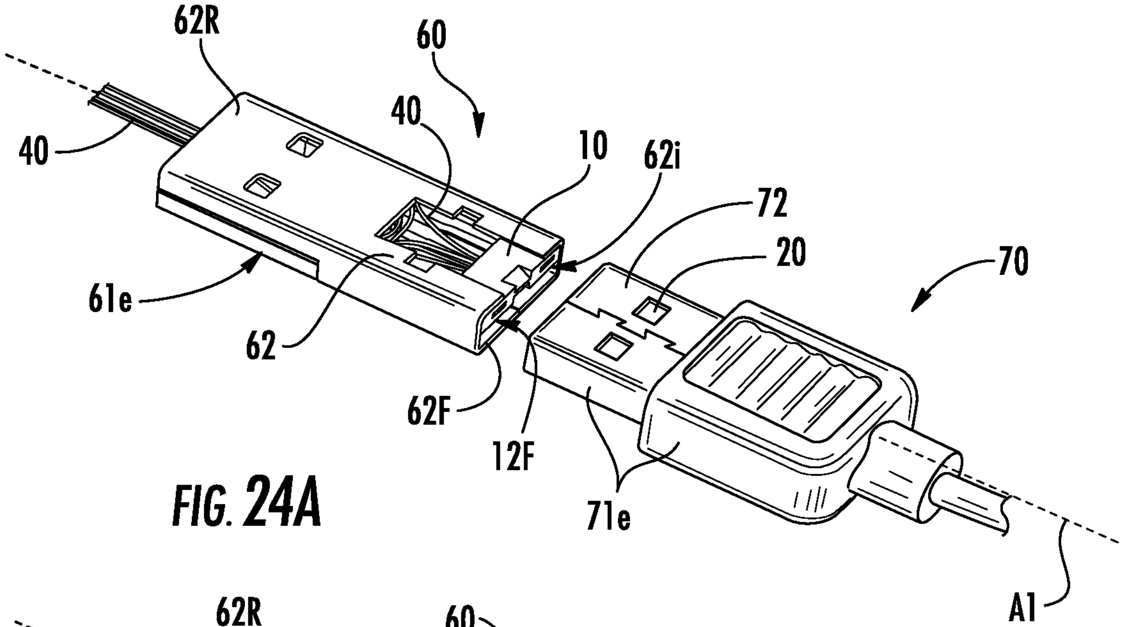


FIG. 24A

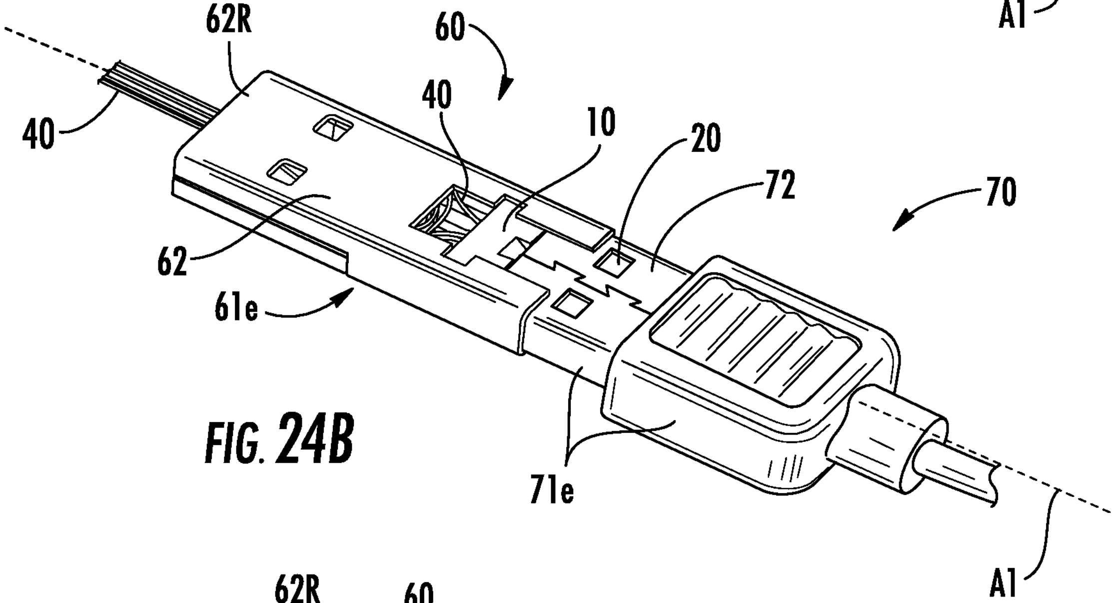


FIG. 24B

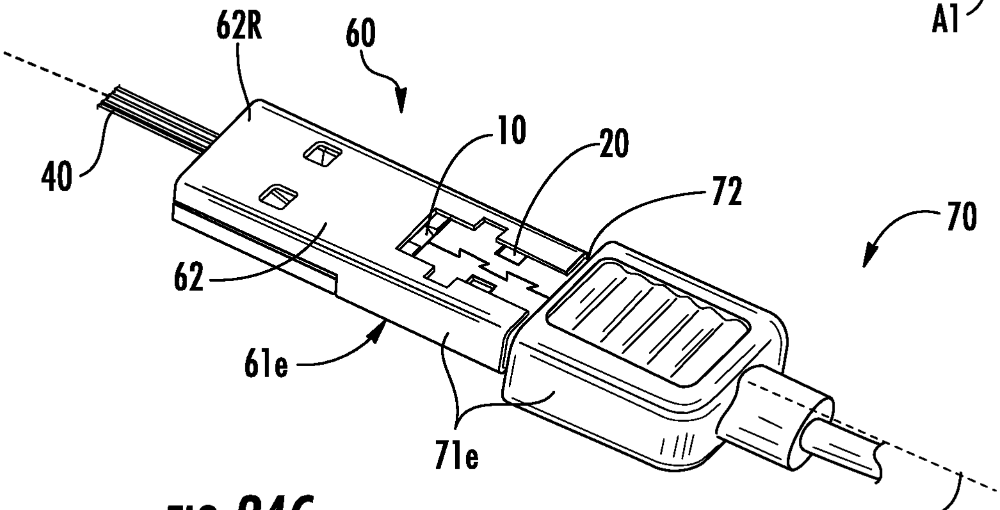


FIG. 24C

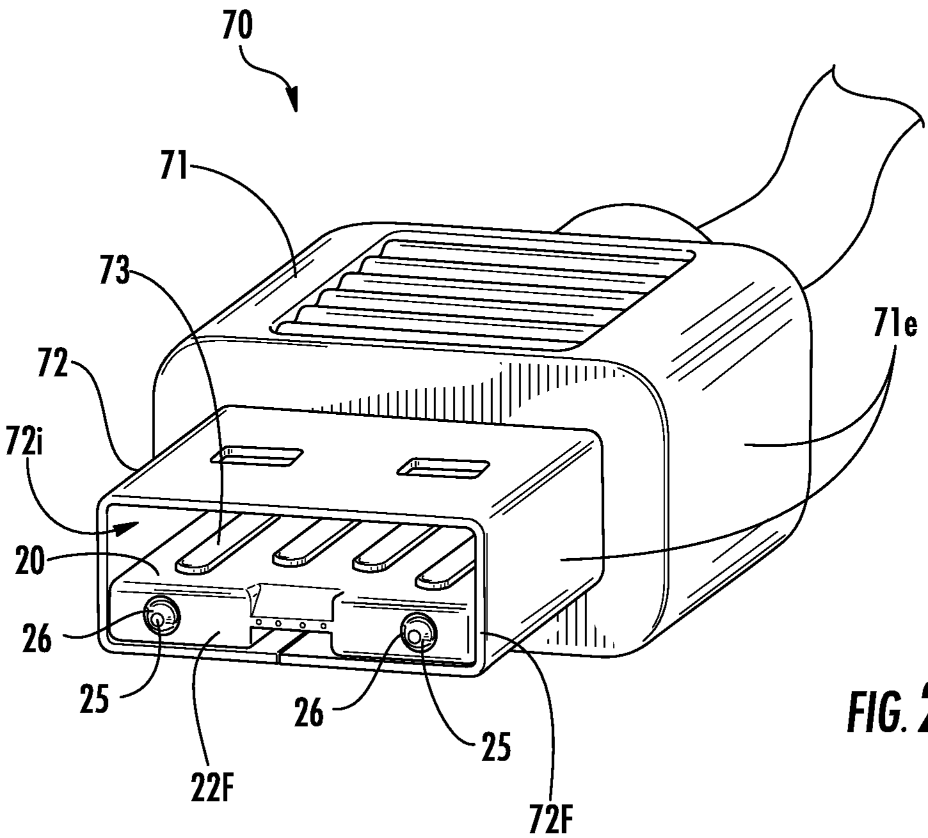


FIG. 25

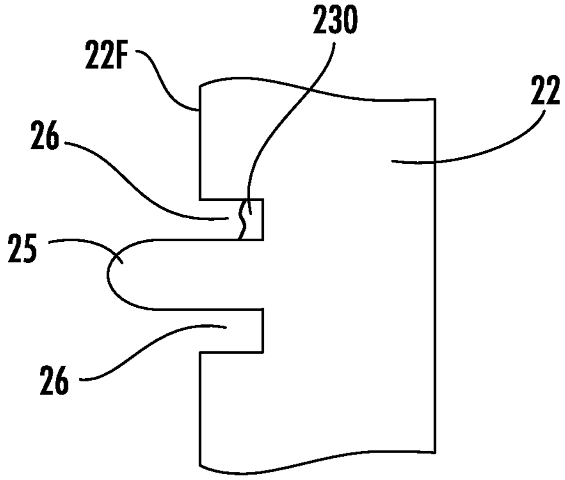


FIG. 26

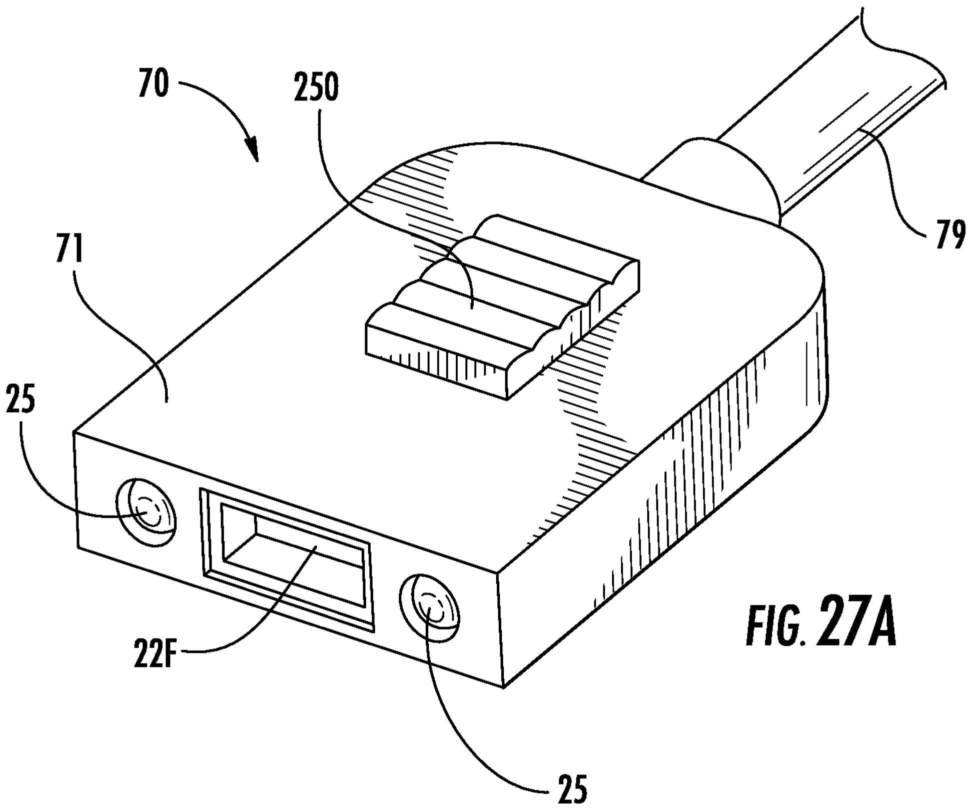


FIG. 27A

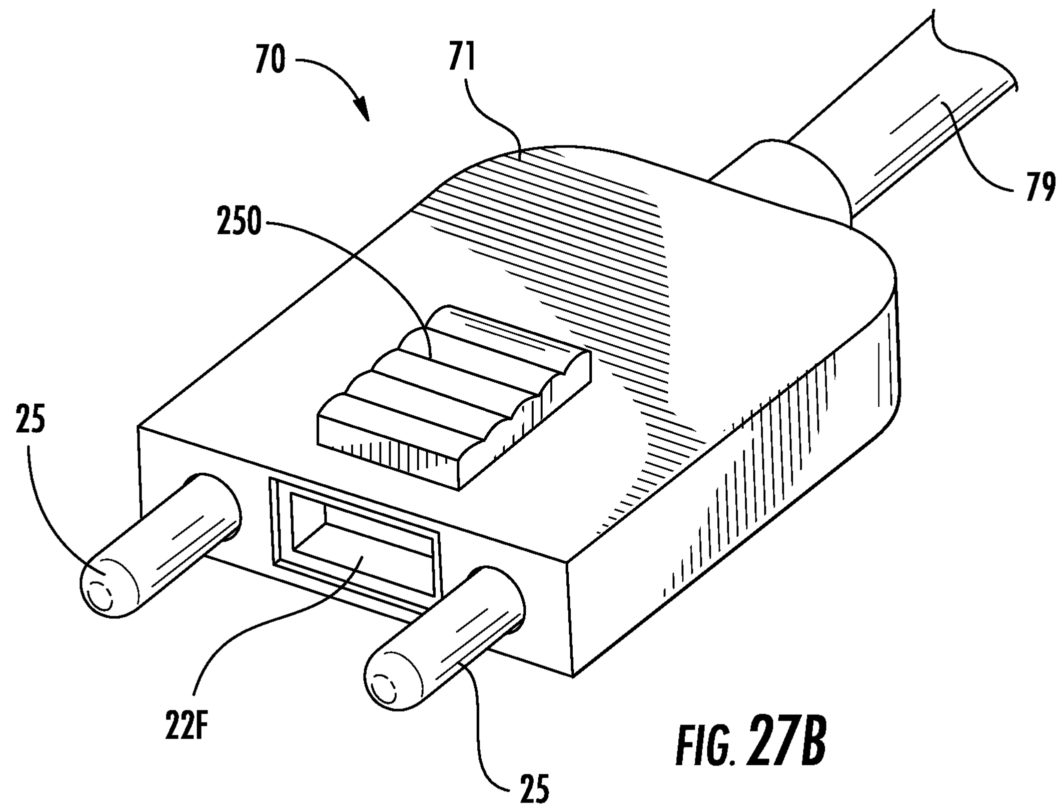
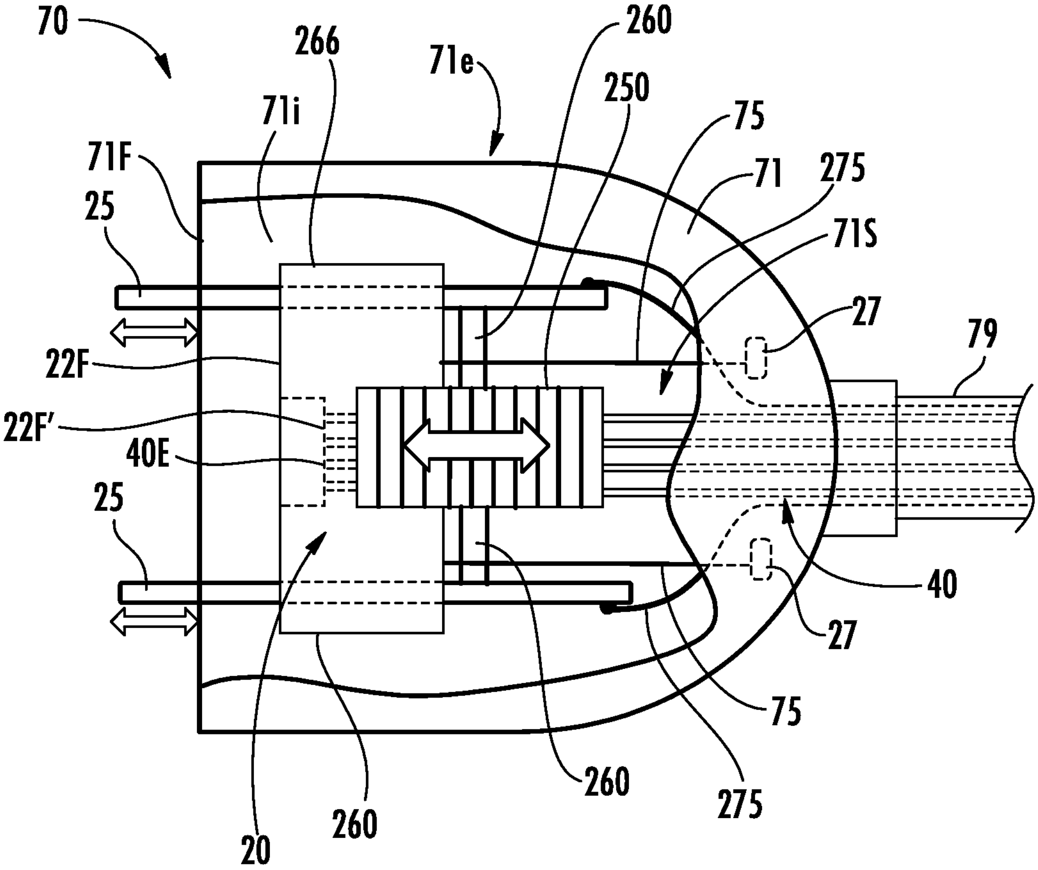


FIG. 27B


70
266
71e
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71F
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22F'
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75
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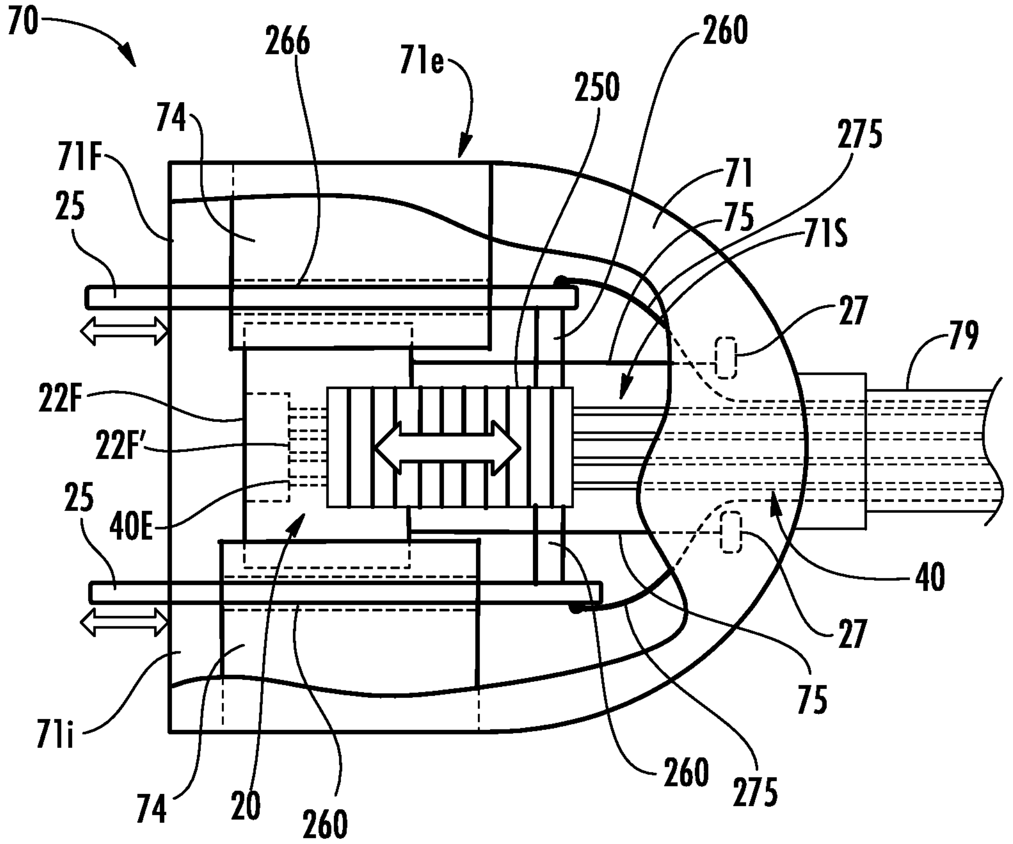
20

FIG. 28A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266
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71F
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25
75
71S
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22F
22F'
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27
75
71i
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275
74
20
260

FIG. 28B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 11/28781

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G02B 6/38 (2011.01)
USPC - 385/60
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)
USPC: 385/60

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 385/59,60 (see search terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWest (PGPB, USPT, USOC, EPAB, JPAB), Google Scholar, USPTO
Search Terms: ferrule, gradient, index, lens, move, translate, slide, forward, rear, biased, slack, coil, storage, spring, fiber, portion, excess, loop, laser, processing, electrical, power, copper, wire, USB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ----- Y	US 7,077,576 B2 (Luther et al.) 18 July 2006 (18.07.2006) entire document especially col 5, ln 61 to col 6, ln 18, col 7, ln 14-54, Fig. 1, col 9, ln 34 to col 10, ln 25, col 6, ln 19-51, Fig. 5, col 5, ln 31-43.	11, 13-15, 19, and 20 ----- 1-10, 12, and 16-18
Y	US 5,923,802 A (Giebel et al.) 13 July 1999 (13.07.1999) entire document especially col 5, ln 31 -43.	1-10, and 12
Y	US 6,837,625 B2 (Schott et al.) 04 January 2005 (04.01.2005) entire document especially Fig. 2, col 5, ln 4-11.	4, and 16
Y	US 2004/0009697 A1 (Clark et al.) 15 January 2004 (15.01.2004) entire document especially para [0027].	17
Y	US 6,033,125 A (Stillie et al.) 07 March 2000 (07.03.2000) entire document especially col 10, ln 49 to col 11, 28.	9, and 18
Y	US 2009/0041412 A1 (Danley et al.) 12 February 2009 (12.02.2009) entire document especially para [0014].	7

☐ Further documents are listed in the continuation of Box C. ☐

* 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	Date of mailing of the international search report
12 May 2011 (12.05.2011)	24 MAY 2011

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774