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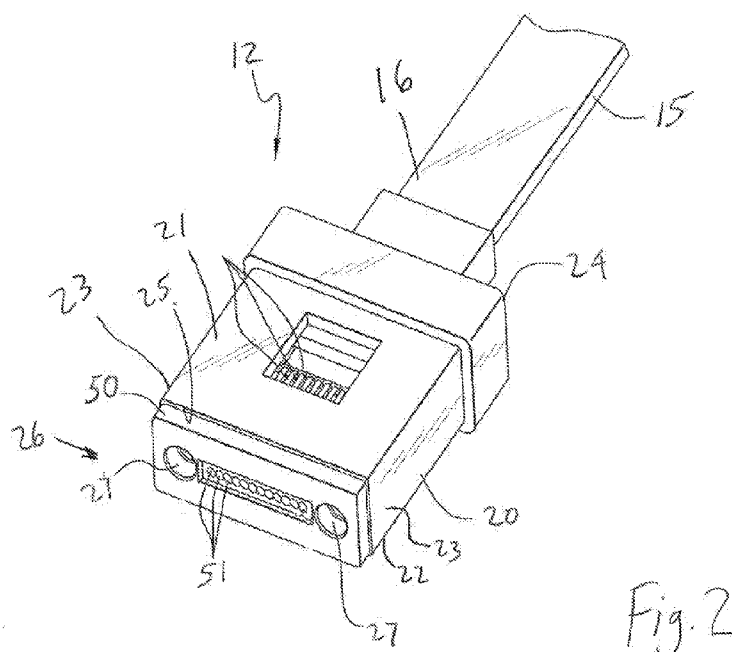


Fig. 2

(57) Abstract: A method of assembling an optical fiber cable and ferrule includes providing the optical fiber cable, the optical fiber cable having a plurality of optical fibers and a first end. The first end of the optical fiber cable is inserted into a mold cavity. A moldable material is inserted into the mold cavity and about the optical fibers to form a ferrule about the plurality of optical fibers adjacent the first end of the optical fiber cable.



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MULTI-FIBER OPTICAL ASSEMBLIES AND METHOD OF MAKING SAME**RELATED APPLICATIONS**

[0001] This application claims priority to United States Provisional Application No. 62/459,401, filed February 15, 2017.

TECHNICAL FIELD

[0002] The present disclosure relates generally to optical fiber and ferrule assemblies and, more particularly, to methods of manufacturing multi-fiber optical assemblies.

BACKGROUND

[0003] Systems for interconnecting optical fibers typically utilize mating ferrule assemblies to facilitate handling and accurate positioning of the fibers. The optical fibers are secured within a ferrule body with an end surface of each fiber being positioned generally flush with or slightly protruding from an end face of the ferrule body. The end surfaces or faces of the fibers are sometimes polished to desired finish. When complementary ferrules assemblies are mated, each optical fiber of one ferrule assembly is aligned with a mating optical fiber of the other ferrule assembly.

[0004] In some applications, the end faces of the mating optical fibers physically contact one another in order to effect signal transmission between the mating optical fiber pair. In other applications, lenses are positioned within the optical path to expand the width of the optical beam and transmit the beam over an air gap between the connectors.

[0005] The foregoing background discussion is intended solely to aid the reader. It is not intended to limit the innovations described herein, nor to limit or expand the prior art discussed. Thus, the foregoing discussion should not be taken to indicate that any particular element of a prior system is unsuitable for use with the innovations described herein, nor is it intended to indicate that any element is essential in implementing the innovations described herein. The implementations and application of the innovations described herein are defined by the appended claims.

SUMMARY

[0006] In one aspect, a method of assembling an optical fiber cable and ferrule includes providing an optical fiber cable having a first end and a plurality of optical fibers, inserting the first end of the optical fiber cable into a mold cavity, and inserting a moldable material into the mold cavity and about the optical fibers to form a ferrule about the plurality of optical fibers adjacent the first end of the optical fiber cable.

[0007] In another aspect, a method of assembling a plurality of optical fiber cable and ferrule assemblies includes robotically feeding a plurality of optical fiber cables, with each optical fiber cable having a plurality of optical fibers, and robotically feeding a plurality of ferrules, with each ferrule having a fiber receiving section configured to received a plurality of optical fibers from one of the optical fiber cables. The method further includes robotically aligning the plurality of optical fibers with the fiber receiving section of the ferrule, robotically moving the plurality of optical fibers relative to the fiber receiving section of the ferrule to position the optical fibers within the fiber receiving section, and securing the optical fibers within the fiber receiving section.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Fig. 1 is a perspective view of an end portion of an optical fiber cable assembly including an optical fiber and ferrule assembly;

[0009] Fig. 2 is a perspective view of an alternate embodiment an optical fiber and ferrule assembly including a lens plate;

[0010] Fig. 3 is a fragmented view of another alternate embodiment of a ferrule assembly;

[0011] Fig. 4 is a fragmented view of still another alternate embodiment of a ferrule assembly;

[0012] Fig. 5 is a schematic illustration of a pair of ferrule assemblies of Fig. 4 aligned for mating;

[0013] Fig. 6 is a flowchart of an automated process for assembling optical fiber and ferrule assemblies;

[0014] Fig. 7 is a schematic illustration of a system operating in accordance with the automated process of Fig. 6;

[0015] Fig. 8 is flowchart of another process for assembling optical fiber and ferrule assemblies;

[0016] Figs. 9-14 are a sequence of views illustrating the process of Fig. 8;

[0017] Fig. 15 is flowchart of still another process for assembling optical fiber and ferrule assemblies;

[0018] Figs. 16-23 are a sequence of views illustrating the process of Fig. 15;

[0019] Fig. 24 is a perspective view of another alternate embodiment an optical fiber and ferrule assembly with a lens plate mounted to the ferrule and the lens plate including latch arms integrally formed therewith;

[0020] Fig. 25 is an exploded perspective view of the optical fiber and ferrule assembly of Fig. 24;

[0021] Fig. 26 is a perspective view of an optical fiber and ferrule assembly inserted into an adapter and a second optical fiber and ferrule assembly aligned for insertion therein;

[0022] Fig. 27 is a cross-sectional view taken generally along line 27-27 of Fig. 2 but with only the adapter in section;

[0023] Fig. 28 is a perspective view of still another alternate embodiment an optical fiber and ferrule assembly with a lens plate mounted to the ferrule and the ferrule including latch arms integrally formed therewith

[0024] Fig. 29 is an exploded perspective view of the optical fiber and ferrule assembly of Fig. 28;

[0025] Fig. 30 is a schematic representation of a further embodiment of a pair of optical fiber and ferrule assemblies aligned for insertion into a further embodiment of an adapter;

[0026] Figs. 31-34 are a sequence of views illustrating a process of inserting the optical fiber and ferrule assemblies of Fig. 30 into the adapter.

DETAILED DESCRIPTION

[0027] Fig. 1 depicts a first end portion 11 of an optical fiber cable assembly 10. The end portion 11 includes an optical fiber and ferrule assembly or multi-fiber optical assembly 12 comprising an optical fiber cable 15 and a ferrule 20 secured to at least one end 16 of the cable. The optical fiber cable 15 is depicted as being generally planar or flat and includes any number and any type of optical fibers 18. The optical fiber cable 15 may include a sheathing 17 surrounding the cable as well as other materials (not shown) that surround the optical fibers 18 within the cable such as a buffer. In an alternate embodiment that is not depicted, the cable 15 may be round or may include a plurality of loose optical fibers 18. The optical fibers 18 may have any configuration or be any type such as a single-mode or multi-mode configuration.

[0028] The ferrule 20 may have any configuration but is depicted as a generally rectangular cuboid configured to support and align an end 19 of each of the optical fibers 18. The ferrule 20 has an upper surface 21, an opposite lower surface 22, and a pair of spaced apart side surfaces 23 that interconnect the upper surface and lower surface. The optical fibers 18 extend through a fiber receiving section 28 of the ferrule 20 past the rear face 24 of the ferrule and terminate generally adjacent the front face 25 of the ferrule. The fiber receiving section 28 may be configured as a plurality of adjacent bores 29 configured to receive the optical fibers 18. Although the ferrule 20 is depicted as being configured to receive twelve optical fibers 18, the ferrule may be configured to receive any number of optical fibers in one or more rows.

[0029] The end 19 of each optical fiber 18 may extend slightly past the front face 25 of the ferrule 20. In some embodiments, the end 19 of each optical fiber 18 may be formed and/or polished to be generally perpendicular to the axis of the optical fiber. In other embodiments, the end 19 of each optical fiber may be formed and/or polished to be at a slight angle relative to perpendicular to the axis of the optical fiber. In one embodiment, the angle may be approximately 8°. By configuring the ends 19 of the optical fibers 18 to be at a slight angle to perpendicular to the optical axis, optical transmission is not significantly degraded while reducing the likelihood of reflection at the interface between mating optical fibers 18.

[0030] In some embodiments, as depicted in Fig. 2, a lens plate 50 may be disposed on the front face 25 of the ferrule 20. The lens plate 50 may include a plurality of lens elements 51 with each lens element aligned with one of the optical fibers 18. The lens element 51 may

be operative to expand and contract light signals passing through the optical fibers 18. In some embodiments, the lens elements 51 may be integrally formed as part of the ferrule 20 rather than being formed as part of a separate element mounted on the front face 25 of the ferrule.

[0031] The front face 25 of the ferrule 20 (and/or the lens plate 50) may include one or more alignment components 26 to facilitate alignment between mating optical fiber cable assemblies 10. In one embodiment depicted in Figs. 1-2, the alignment components 26 include a pair of bores 27 in the front face 25 of the ferrule 20 (and/or lens plate 50) vertically aligned with the ends 19 of the optical fibers 18 within the ferrule 20. One bore 27 is positioned between each end most optical fiber 18 and its adjacent side surface 23. In one embodiment, one of the ferrules 20 of each mating pair will have a mounting pin (not shown) disposed in each bore to align the mating optical connectors.

[0032] Other embodiments of the alignment components 26 are contemplated. For example, referring to Fig. 3, an alternate embodiment of a ferrule 20 (or lens plate 50) includes a bore 31 and a correspondingly shaped post 32 vertically aligned with the ends 19 of the optical fibers 18 within the ferrule 20. The bore 31 is positioned between one endmost optical fiber 18 and its adjacent side surface 23 and the post 32 is positioned between the opposite end most optical fiber and the other side surface. Through such a configuration, the bore 31 and post 32 of a first ferrule 20 engage the post 32 and bore 31 of an aligned second ferrule to accurately align the optical fibers from each ferrule.

[0033] Referring to Figs. 4-5, another alternate embodiment of a front face 35 of a ferrule 20 is depicted. The front face 35 includes a bore 38 at opposite corners 36 of the front face and a correspondingly shaped and positioned post 39 in each of the other corners 37 of the front face. Front face 35 is depicted as being formed at an angle to the upper surface 21 and lower surface 22 of the ferrule 20. The configuration of front face 35 may be particularly useful when the ends 19 of the optical fibers 18 within the ferrule 20 are formed at an angle (e.g., approximately 8°) to a line perpendicular to the axis of each optical fiber. Although exaggerated in Figs. 4-5, the angle between the front face 35 of the ferrule 20 and the upper and lower surfaces 21, 22 may generally match the angle of the end 19 of the optical fiber 18 relative to perpendicular. Cable assemblies 10 formed with ferrules 20 having an angled front face 35 with pairs of bores 38 and posts 39 configured as described ensure that the angled ends 19 of the optical fibers 18 will be properly aligned when the pairs of cable assemblies 10 are mated.

[0034] Referring to Figs. 24-25, still another alternate embodiment of an optical fiber and ferrule assembly 55 is depicted. Optical fiber and ferrule assembly 55 is similar to the optical fiber and ferrule assembly 12 depicted in Fig. 2 and like elements are identified by like reference numbers. However, the ferrule 56 of optical fiber and ferrule assembly 55 is configured to receive a pair of optical fiber cables 15 and the lens plate 60 includes two rows of lens elements 51 with each lens element aligned with one of the optical fibers 18 of the optical fiber cables.

[0035] In addition, lens plate 60 further includes a pair of deflectable latch arms 65 configured to secure the optical fiber and ferrule assembly 55 to an adapter 80 (Figs. 26-27). Each latch arm 65 is integrally formed with or as part of the lens plate 60 and projects rearwardly from a side wall or edge 61 of the lens plate. Each latch arm 65 includes a first section 66 and a second section 68. The first section 66 is generally linear and extends rearwardly from the lens plate 60 towards the rear face 24 of the ferrule 56 along the side wall 23 of the ferrule. As depicted, the first section 66 is approximately equal to the length of the ferrule 56. The side wall 23 of the ferrule 56 may include a latch alignment channel or recess 57 in which a portion of the first section 66 may be disposed.

[0036] The second section 68 of each latch arm 65 includes sequentially an angled section or leg 70, a latch section 71, and a release section 74. The angled section 70 extends rearwardly from a rear edge 67 of the first section 66 and away from the side wall 23 of ferrule 56. The latch section 71 includes a ramp surface 72 configured to engage surface 81 of adapter 80 while inserting the optical fiber and ferrule assembly 55 into the adapter. Engagement of the ramp surface 72 latch arms 65 with the surface 81 of adapter 80 will cause the deflection of the latch arms 65.

[0037] Latch section 71 of latch arms 65 further includes a rearwardly facing latching surface 73 configured to be disposed in and engage the window or opening 82 in adapter 80 to lock the optical fiber and ferrule assembly 55 within the adapter. The release section 74 includes a manually manipulatable projection or tab 75 projecting therefrom away from the optical fiber cables 15. Depressing the projection 75 towards the optical fiber cables 15 will cause the deflection of latch arms 65 and permit removal of the optical fiber and ferrule assembly 55 from the central cavity or bore 83 of adapter 80.

[0038] Figs. 28-29 depict a further alternate embodiment of an optical fiber and ferrule assembly 90. Optical fiber and ferrule assembly 90 is similar to the optical fiber and ferrule

assembly 55 depicted in Figs. 24-25 and like elements are identified by like reference numbers. However, the latch arms 93 of optical fiber and ferrule assembly 90 are integrally formed with the ferrule 91 and extend laterally from the side walls 23 of the ferrule generally adjacent the rear face 24. More specifically, the latch arms 93 are not formed as part of the lens plate 92 and do not include the first section 66 of latch arms 65 but rather only include structure similar to the second section 68 of the latch arms 65. The latch arms 93 may be integrally formed about or as part of the ferrule 91 during a single molding process or may be integrally formed about or as part of the ferrule through by using a secondary or overmolding process to form the latch arms. Inasmuch as the lens plate 92 is separate from the ferrule 91, the lens plate may be omitted from the optical fiber and ferrule assembly 90.

[0039] In still another embodiment, the optical fiber and ferrule assembly may include boot or strain relief (not shown) that surrounds the latch arms and/or cable to limit the extent to which the latch arms and/or the cable may bend or deflect. Such boot or strain relief may be secured to the optical fiber and ferrule assembly at any stage of the assembly or manufacturing process. In one example, the boot or strain relief may be separately formed and secured to the assembly at or near the end of the manufacturing process. In another example, the boot or strain relief may be molded about a portion of the optical fiber and ferrule assembly.

[0040] In some instances, it may be desirable to simplify the mold and/or molding process for forming the ferrules and lens plates. In such case, the deflectable locking structure, such as latch arms 65, 93, may be moved from the optical fiber and ferrule assembly to the adapter. Referring to Fig. 30, a pair of optical fiber and ferrule assemblies 200 are depicted with an adapter 220. Each optical fiber and ferrule assembly 200 includes an optical fiber cable 15 and a ferrule 201 configured to support and align each of the optical fibers (not shown) of the cable. Ferrule 201 includes a rear face 202 and a front face 203 opposite the rear face. The ends (not shown) of the optical fibers may extend slightly past the front face 203 of the ferrule 201. The ferrule 201 includes a reduced cross-section portion 205, between the rear face 202 and the front face 203, which defines a pair of rearwardly facing locking edges or surfaces 206.

[0041] The adapter 220 may include a generally rectangular body 221 having a central cavity or bore 222 configured to receive the optical fiber and ferrule assemblies 200 therein. In addition, the body 221 includes a pair of deflectable latch arms 225 associated with each end or opening 223 of the cavity 222. Each deflectable latch arm 225 includes a resilient

cantilevered arm 226 and a locking projection 227 at the free end of the cantilevered arm. The locking projection 227 may include a first tapered or angled lead-in surface 228 and a second tapered or angled locking surface 229. The angled lead-in surface 228 is configured to engage the front face 203 of the ferrule 201 (or the front face of a lens plate) to cause the deflection of the latch arms 225 to permit the insertion of an optical fiber and ferrule assembly 200. The angled locking surface 229 is configured to engage one of the locking surfaces 206 of the reduced cross-section portion 205 of ferrule 201 of optical fiber and ferrule assembly 200 to retain the optical fiber and ferrule assembly within the adapter 220.

[0042] In operation and as depicted in Fig. 30, one or both of the optical fiber and ferrule assemblies 200 are aligned with the axis 224 of central cavity 222 of adapter 220. Referring to Fig. 31, movement of one of the optical fiber and ferrule assemblies 200 along the axis 224 in a mating direction causes the front face 203 of the ferrule 201 to engage the angled lead-in surfaces 228 of the latch arms 225.

[0043] As depicted in Fig. 32, continued insertion movement of the optical fiber and ferrule assembly 200 causes the deflection of the latch arms 225. The tip 230 of the locking projection 227 may engage the outer surfaces 204 of the ferrule 201 as the optical fiber and ferrule assembly 200 continues to be moved into the central cavity 222. Once the optical fiber and ferrule assembly 200 is inserted sufficiently into the central cavity 222, the locking projection 227 will be aligned with the reduced cross-section portion 205 of the ferrule 201. The resilient nature of the cantilevered arms 226 of deflectable latch arms 225 will cause the locking projection 227 to enter the reduced cross-section portion 205 with the angled locking surface 229 engaging the locking surface 206 to retain the optical fiber and ferrule assembly 200 within the adapter 220.

[0044] Figs. 33-34 depict a similar operation in which a second optical fiber and ferrule assembly 200 is inserted into the adapter 220. By doing so, each optical fiber of the first optical fiber and ferrule assembly 200 is accurately aligned with an engaging one of the optical fibers of the second optical fiber and ferrule assembly along a mating plane 210.

[0045] As depicted in Figs. 30-34, the locking surface 229 is angled and interacts with the locking surface 206 of the reduced cross-section portion 205 of the ferrule 201 to bias the optical fiber and ferrule assembly 200 inwardly or towards the mating plane 210. In other embodiments, the locking surface 206 of the ferrule 201 and the locking surface 229 of the latch arms 225 may not bias the mating pair of optical fiber and ferrule assemblies together or

may not provide a sufficient biasing force. In such case, it may be desirable to utilize springs or other biasing members to generate a sufficient force between the mating pair of optical fiber and ferrule assemblies.

[0046] Each optical fiber and ferrule assembly 12, 55, 90, 200 of the optical fiber cable assembly 10 may be formed in any desired manner. Referring to Fig. 6 and the flowchart of Fig. 7, a first process for forming an optical fiber and ferrule assembly 12 of the optical fiber cable assembly 10 is depicted. At stage 100, a plurality of ferrules 20 are formed, such as by molding. The ferrules 20 may be formed of any desired material. In some embodiments, the ferrules 20 may be formed of a moldable material such as a polymer or resin such as polyphenylene sulphide or polyetherimide and may include an additive such as silica (SiO_2) to increase the strength and stability of the moldable material. At stage 101 and as depicted at 115 in Fig. 6, a plurality of ferrules 20 maybe fed in an automated manner towards a termination system 130.

[0047] A plurality of optical cables 15 are provided at stage 102 and depicted at 116 in Fig. 6. The ends 16 of a plurality of optical fibers cables 15 may be prepared at stage 103 and as depicted in Fig. 6 at 117. To do so, a length "L" of sheathing 17 may be removed from the end 16 of each optical fiber cable 15 and additional components surrounding the optical fibers 18 such as a buffer may also be removed. In addition, the optical fibers 18 are cut or cleaved to their desired length to form ends. In some embodiments, the ends 19 of the optical fibers 18 may be formed by mechanical cleaving and, in other embodiments, the ends may be formed by laser cleaving. In some embodiments, the ends 19 of optical fibers 18 may be cleaved at an angle relative to perpendicular to the axis of the fiber, such as approximately 8° .

[0048] At stage 104 and as depicted at 118 in Fig. 6, a plurality of optical fiber cables 15 with prepared ends maybe fed in an automated manner towards the termination system 120. At stage 105, each ferrule 20 is aligned with the ends 19 of the optical fibers 18 of a cable 15 at alignment station 119. At stage 106, the ends 19 of the optical fibers 18 are moved relative to the ferrule 20 to insert the ends of the optical fibers into the ferrule at insertion station 120. The ends 19 of the optical fibers 18 are inserted until the ends reach a stop surface 131 at the insertion station 120. As depicted in Fig. 6, the ends 19 of the optical fibers 18 may move relative to the ferrule 20 as the optical fibers and the ferrule move laterally at the insertion station 120.

[0049] At stage 107, an adhesive such as epoxy may be inserted or applied to the optical fibers 18 and the ferrule 20 by an adhesive injection system 132 at injection station 121. At stage 108, the adhesive applied to the optical fibers 18 and the ferrule 20 may be cured by an energy source 133 at a curing station 122. In one embodiment, the adhesive may be a UV curable epoxy and the energy source 132 configured as a UV energy source. At stage 109, the ends 19 of the optical fibers 18 may be polished at polishing station 123 to complete the optical fiber and ferrule assembly 12. If desired, the optical fiber and ferrule assembly 12 may be tested at stage 110 at test station 124 in Fig. 6. It should be noted that each of the processes at the different stations may take a different length of time so that the distance between, the length of, or the processing time at each station may not be uniform.

[0050] Figs. 8-13 and the flowchart of Fig. 14 depict another process for forming an optical fiber and ferrule assembly 12 of the optical fiber cable assembly 10. At stage 150 and as depicted in Fig. 8, one or more optical fiber cables 15 may be provided. The end 16 of each optical fiber cable 15 may be prepared. To do so, the sheathing 17 may be removed from a length "L" at the end 16 of each optical fiber cable 15 and additional components surrounding the optical fibers 18 such as a buffer may be removed at stage 151 and depicted in Fig. 9. At stage 152, the optical fibers 18 are cut or cleaved to their desired length as depicted in Fig. 10 to form ends 19. In some embodiments, the ends 19 of the optical fibers 18 may be formed by mechanical cleaving and, in other embodiments, the ends may be formed by laser cleaving. Regardless of the manner in which the optical fibers 18 are cleaved, in some instances, the end 19 of each fiber may be cleaved at an angle relative to perpendicular to the axis of the fiber, such as approximately 8°.

[0051] At stage 153 and as depicted in Fig. 11, an optical fiber cable 15 with the cleaved ends is inserted into a mold cavity 160 that is configured to form a ferrule 20. The cleaved ends 19 may be inserted into a portion of the mold 181 to assist in positioning and securing the optical fibers 18 during the molding process. At stage 154 and as depicted in Fig. 12, a moldable material is injected into the mold cavity 160 to form the ferrule 20 about or around the optical fibers 18. As stated above, the ferrule 20 may be formed of any desired material. In some embodiments, the ferrule 20 may be formed of a moldable material such as a polymer or resin together with an additive to increase the strength and stability of the moldable material.

[0052] If the ends 19 of the optical fibers 18 are laser cleaved, they may not require any polishing after forming the optical fiber and ferrule assembly at stage 154. If the ends 19 of

the optical fibers 18 are mechanically cleaved, they may be polished prior to stage 153 or after molding the ferrule 20 at stage 154. In some instances, if the ends 19 of the optical fibers 18 are laser cleaved, they may not require polishing. In other instances, polishing may be required. At stage 155 and as depicted in Fig. 13, the optical fiber and ferrule assembly 12 may be tested, if desired.

[0053] Figs. 15-22 and the flowchart of Fig. 23 depict still another process for forming an optical fiber and ferrule assembly 12 of the optical fiber cable assembly 10. At stage 170 and as depicted in Fig. 15, one or more optical fiber cables 15 may be provided. At stage 171 and as depicted in Fig. 16, the end 16 of each optical fiber cable 15 may be prepared. To do so, the sheathing 17 may be removed from a length “L” at the end 16 of the optical fiber cable 15 and additional components surrounding the optical fibers 18 such as a buffer may be removed. At stage 172, the ends 19 of the optical fibers 18 are cut or cleaved to their desired length as depicted in Fig. 17 to form initial ends 45. In some embodiments, the initial ends 45 of the optical fibers 18 may be formed by mechanical cleaving and, in other embodiments, the initial ends may be formed by laser cleaving.

[0054] At stage 173 and as depicted in Fig. 18, an optical fiber cable 15 with a prepared end 16 is inserted into an insert 180. At stage 174 and as depicted in Fig. 19, the cable end 16 and insert 180 are inserted into a mold cavity 181 configured to form a ferrule 20. In an alternate embodiment, the insert 180 may be inserted into the mold cavity 181 prior to inserting the optical fibers 18 into the insert. The initial ends 45 may be inserted into a portion of the mold cavity 181 to assist in positioning the optical fibers 18 during the molding process.

[0055] At stage 175 and as depicted in Fig. 20, a moldable material is injected into the mold cavity 181 to form the ferrule 20 about or around the optical fibers 18 and the insert 180. As stated above, the ferrule 20 may be formed of any desired material. In some embodiments, the ferrule 20 may be formed of a resin or polymer together with an additive to increase the strength and stability of the moldable material.

[0056] After molding the ferrule 20 about or around the optical fibers 18 and the insert 180, at stage 176 and as depicted in Fig. 21, the optical fibers may be cleaved adjacent the end 182 of the insert 180 to form the desired ends 19 of the optical fibers. In some instances, the optical fibers 18 may be mechanically cleaved and in other instances may be laser cleaved. As stated above, if the ends 19 of the optical fibers 18 are laser cleaved, they may

not require any polishing after forming the optical fiber and ferrule assembly 12 at stage 175. At stage 177 and as depicted in Fig. 22, the optical fiber and ferrule assembly 12 may be tested, if desired.

[0057] Various alternate embodiments and processes are contemplated. For example, if the optical fiber and ferrule assembly 12 includes lens elements 51, a lens plate 50 including the lens elements may be mounted to the front face 25 of ferrule 20 after otherwise forming the optical fiber and ferrule assembly. More specifically, lens plate 50 may be mounted to the front face 25 of the ferrule 20 after stages 110, 155, 177 in each of the flowcharts depicted in Figs. 7, 14, and 23, respectively.

[0058] In another embodiment as depicted in Fig. 24, the lens plate 60 may include latch arms 65 integrally formed and molded with the lens plate. The lens plate 60 and latch arms 65 may be molded together and subsequently mounted to the ferrule 60 with each optical fiber 18 aligned with one of the lens elements 51.

[0059] In still a further embodiment, the ferrule 91 may include latch arms 93 integrally formed and molded with the ferrule as depicted in Fig. 28. The latch arms 93 may be molded while molding the ferrule 91 or may be molded after molding the ferrule 91 as part of a secondary molding process that molds the latch arms 93 to or about the ferrule 91. If the latch arms 93 are molded as part of a secondary molding process, it may be desirable to mold the ferrule 91 by injecting a first moldable material into a mold cavity, such as mold cavity 160 (Fig. 11), and subsequently inserting the molded ferrule into a second mold cavity (not shown) and inserting a second moldable material into the second mold cavity to form the latch arms 93 to or about the ferrule 91. In such case, the first moldable material used to form the ferrule 91 may be a resin or polymer together with an additive to increase the strength and stability of the material and the second moldable material from which the latch arms 93 are formed may be a resin or polymer that is more resilient than the first moldable material.

[0060] In still another embodiment, the lens elements 51 may be integrally formed with or as part of the ferrule 20. In such case, the lens elements may be formed during the process of forming each ferrule 20, such as at stage 100 in Fig. 7, stage 154 in Fig. 14, and stage 175 in Fig. 23.

[0061] In another embodiment, the optical fiber and ferrule assembly may be formed by inserting the optical fibers 18 into the ferrule 20, such as according to the flowchart of Fig. 7,

or with the ferrule molded about the optical fibers, such as according to the flowcharts of Figs. 14, 23, and latch arms secured or overmolded to the ferrule or lens plate as part of an additional manufacturing step.

[0062] In another embodiment, alternate manners of precisely positioning the optical fibers 18 prior to insert molding the ferrule 20 are contemplated. For example, a precision positioning or alignment plate or member may be placed over, about, around or onto the optical fibers 18 prior to over molding thus providing for precision alignment of the fiber tips and pins with respect to the endface. The insert 180 described above is one example of such a precision positioning or alignment plate. Other configurations are contemplated.

[0063] If desired, a boot or strain relief (not shown) may also be secured to the optical fiber and ferrule assembly to limit the extent to which the latch arms (if applicable) and/or the cable may bend or deflect. In one example, the boot or strain relief may be separately formed and secured to the assembly at or near the end of the manufacturing process. In another example, the boot or strain relief may be molded about a portion of the optical fiber and ferrule assembly.

[0064] It will be appreciated that the foregoing description provides examples of the disclosed system and technique. However, it is contemplated that other implementations of the disclosure may differ in detail from the foregoing examples. All references to the disclosure or examples thereof are intended to reference the particular example being discussed at that point and are not intended to imply any limitation as to the scope of the disclosure more generally. All language of distinction and disparagement with respect to certain features is intended to indicate a lack of preference for those features, but not to exclude such from the scope of the disclosure entirely unless otherwise indicated.

[0065] Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context.

[0066] Accordingly, this disclosure includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the disclosure unless otherwise indicated herein or otherwise clearly

contradicted by context. Still further, the advantages described herein may not be applicable to all embodiments encompassed by the claims.

CLAIMS:

1. A method of assembling an optical fiber cable and ferrule, the optical fiber cable having a plurality of optical fibers, the method comprising:
providing the optical fiber cable, the optical fiber cable having a first end;
inserting the first end of the optical fiber cable into a mold cavity; and
inserting a moldable material into the mold cavity and about the optical fibers to form a ferrule about the plurality of optical fibers adjacent the first end of the optical fiber cable.
2. The method of claim 1, further including inserting the plurality of optical fibers into an alignment insert and inserting the moldable material about the alignment insert when forming the ferrule.
3. The method of claim 2, wherein the alignment insert is disposed outside of the mold cavity while inserting the optical fibers into the alignment insert and further including inserting the alignment insert with the optical fibers disposed therein into the mold cavity.
4. The method of claim 2, further including inserting the alignment insert into the mold cavity prior to inserting the optical fibers into the alignment insert.
5. The method of claim 2, further including cleaving the optical fibers adjacent the alignment insert;
6. The method of claim 5, wherein the cleaving step occurs after molding the ferrule.
7. The method of claim 1, further including molding latch arms integrally with the ferrule.
8. The method of claim 1, further including molding latch arms about the ferrule.
9. The method of claim 8, wherein the step of molding the ferrule includes inserting a first moldable material and the step of molding the latch arms includes inserting a second moldable material, the second moldable material being more resilient than the first material.

10. The method of claim 8, further including molding a bend limiting member about a portion of the latch arms.

11. The method of claim 8, further including molding a bend limiting member about a portion of the optical fiber cable adjacent the ferrule.

12. The method of claim 1, further including molding lens elements integrally with the ferrule.

13. The method of claim 1, further including fixing a lens plate having a plurality of lens elements to the ferrule, each of the lens elements being aligned with one of the optical fibers.

14. The method of claim 13, wherein the lens plate includes latch arms integrally formed therewith.

15. The method of claim 1, further including cleaving the optical fibers before inserting the first end of the optical fiber cable into the mold cavity.

16. The method of claim 1, further including cleaving the optical fibers after molding the ferrule.

17. A method of assembling a plurality of optical fiber cable and ferrule assemblies, the method comprising:

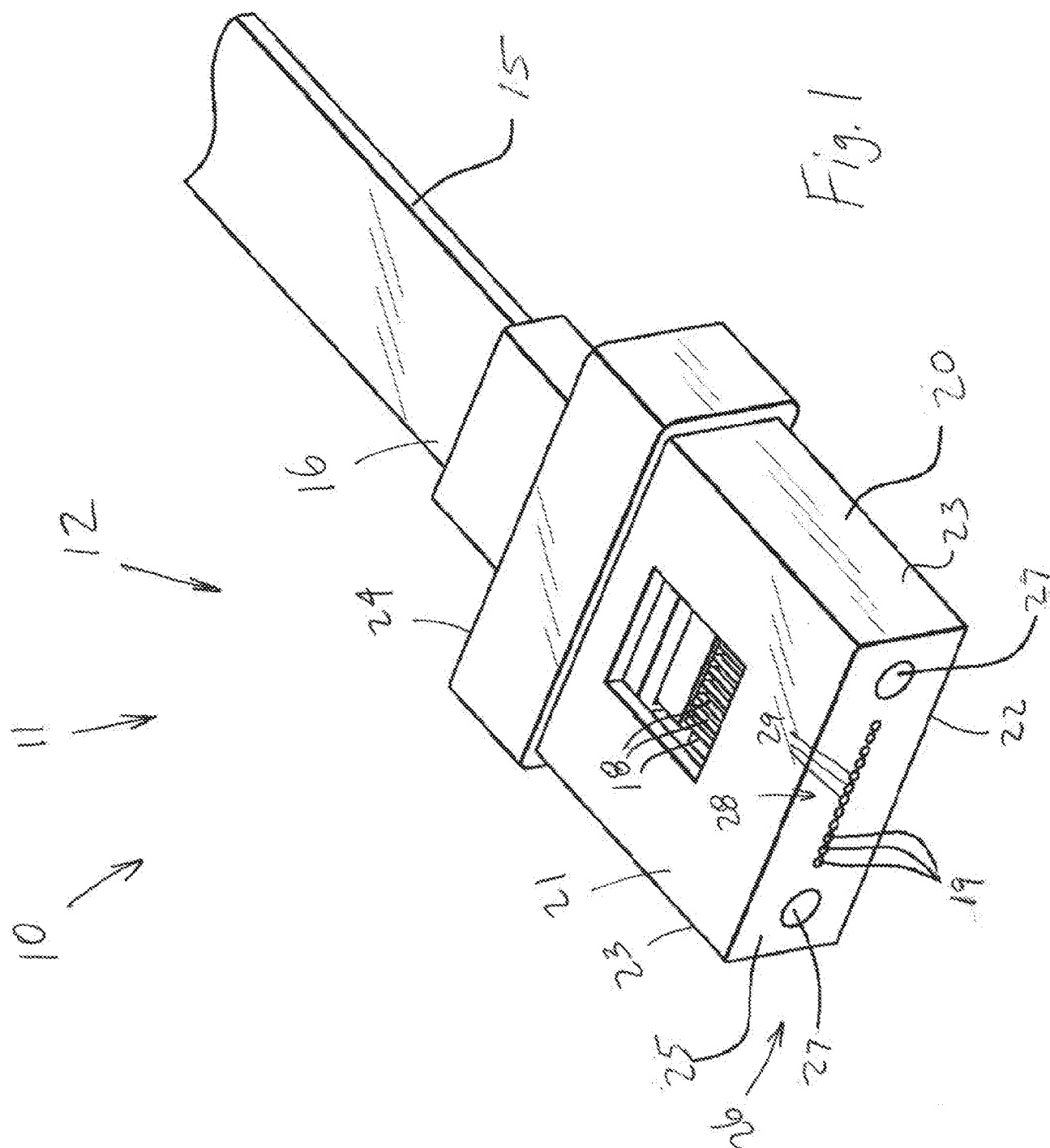
robotically feeding a plurality of optical fiber cables, each optical fiber cable having a plurality of optical fibers;

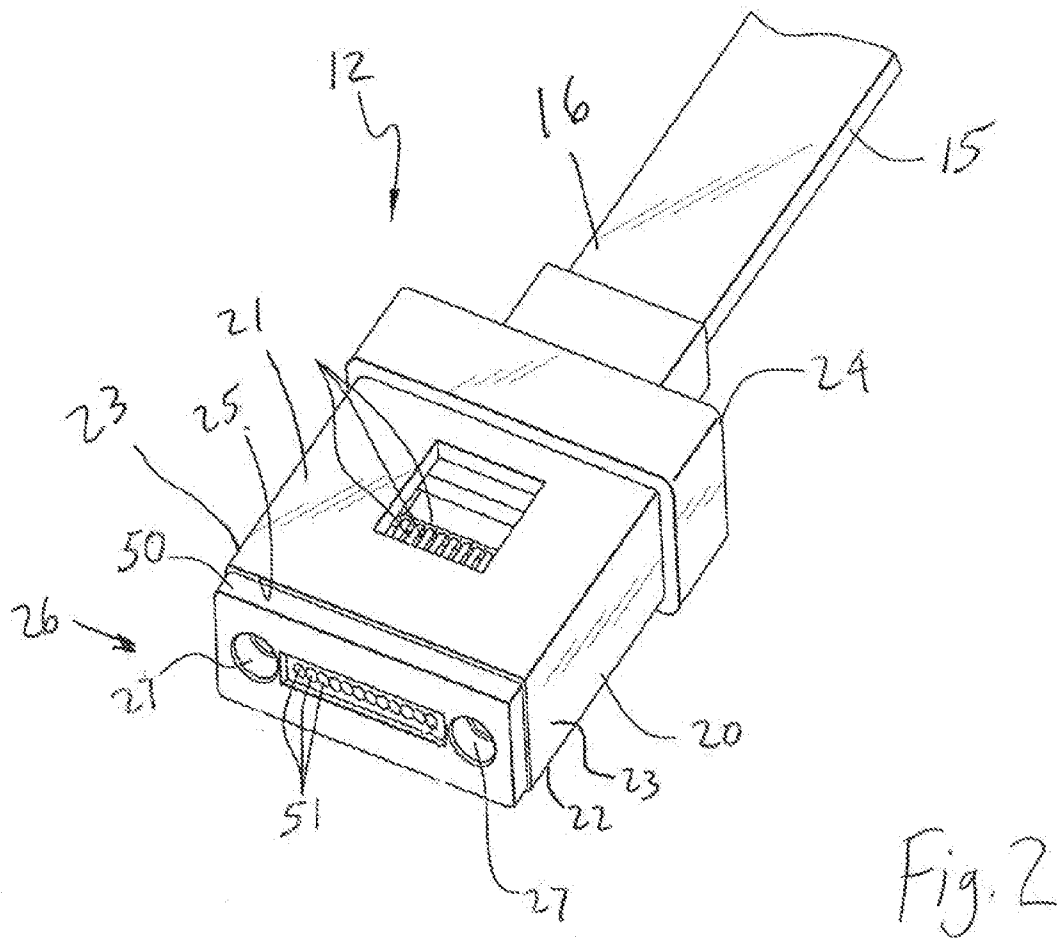
robotically feeding a plurality of ferrules, each ferrule having a fiber receiving section configured to received a plurality of optical fibers from one of the optical fiber cables;

robotically aligning the plurality of optical fibers with the fiber receiving section of the ferrule;

robotically moving the plurality of optical fibers relative to the fiber receiving section of the ferrule to position the optical fibers within the fiber receiving section; and

securing the optical fibers within the fiber receiving section.





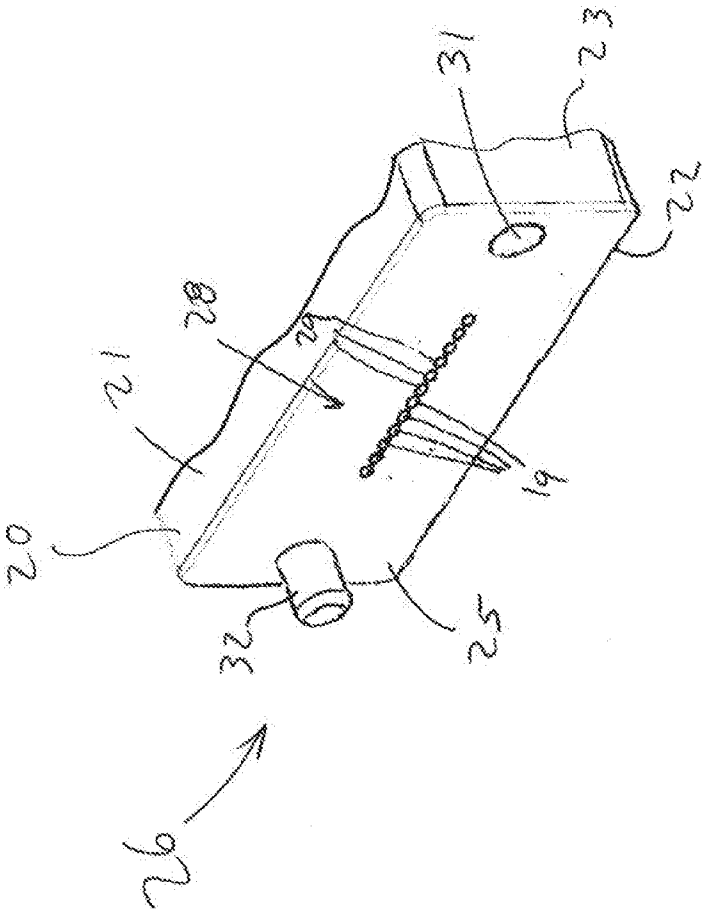


Fig. 3

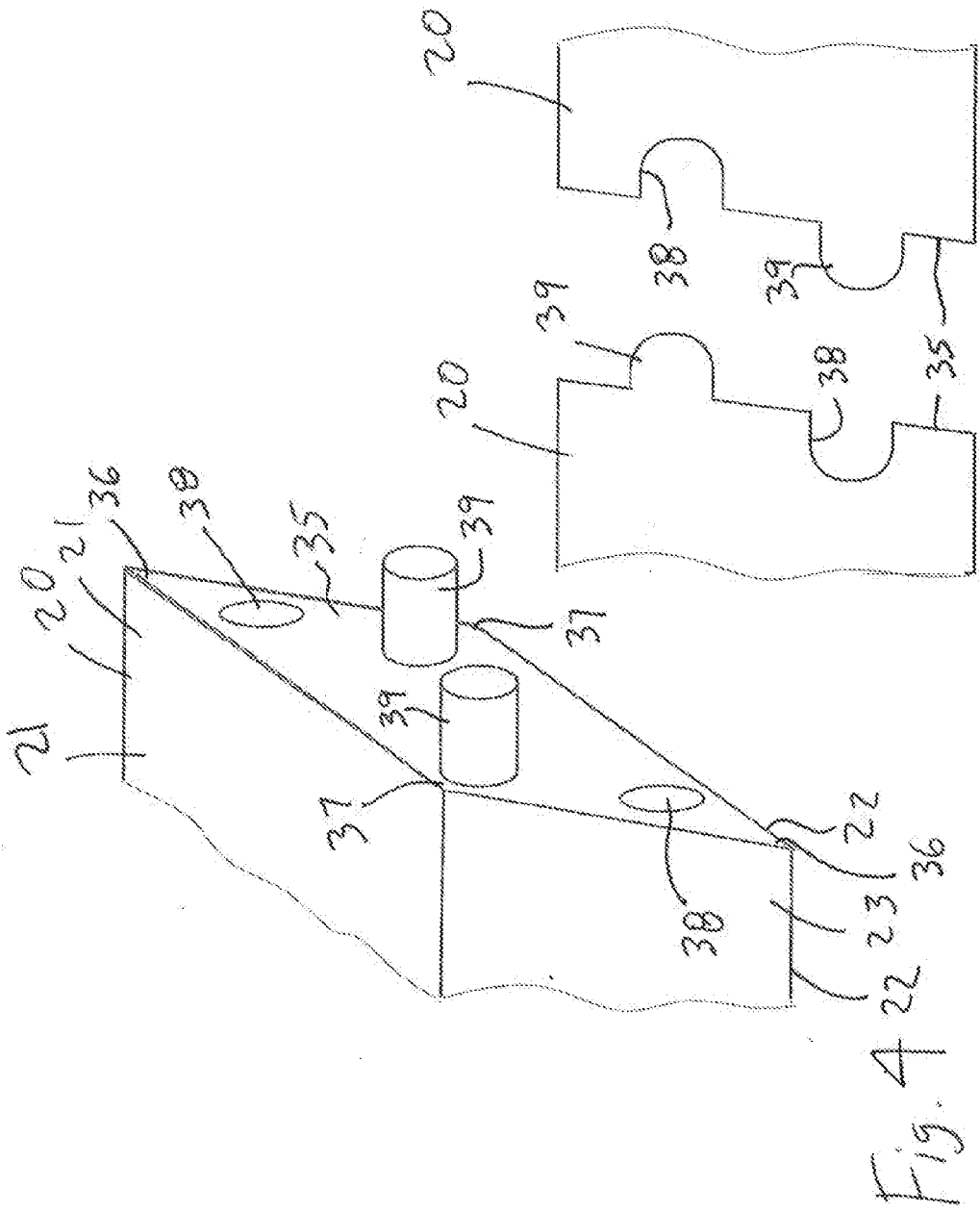
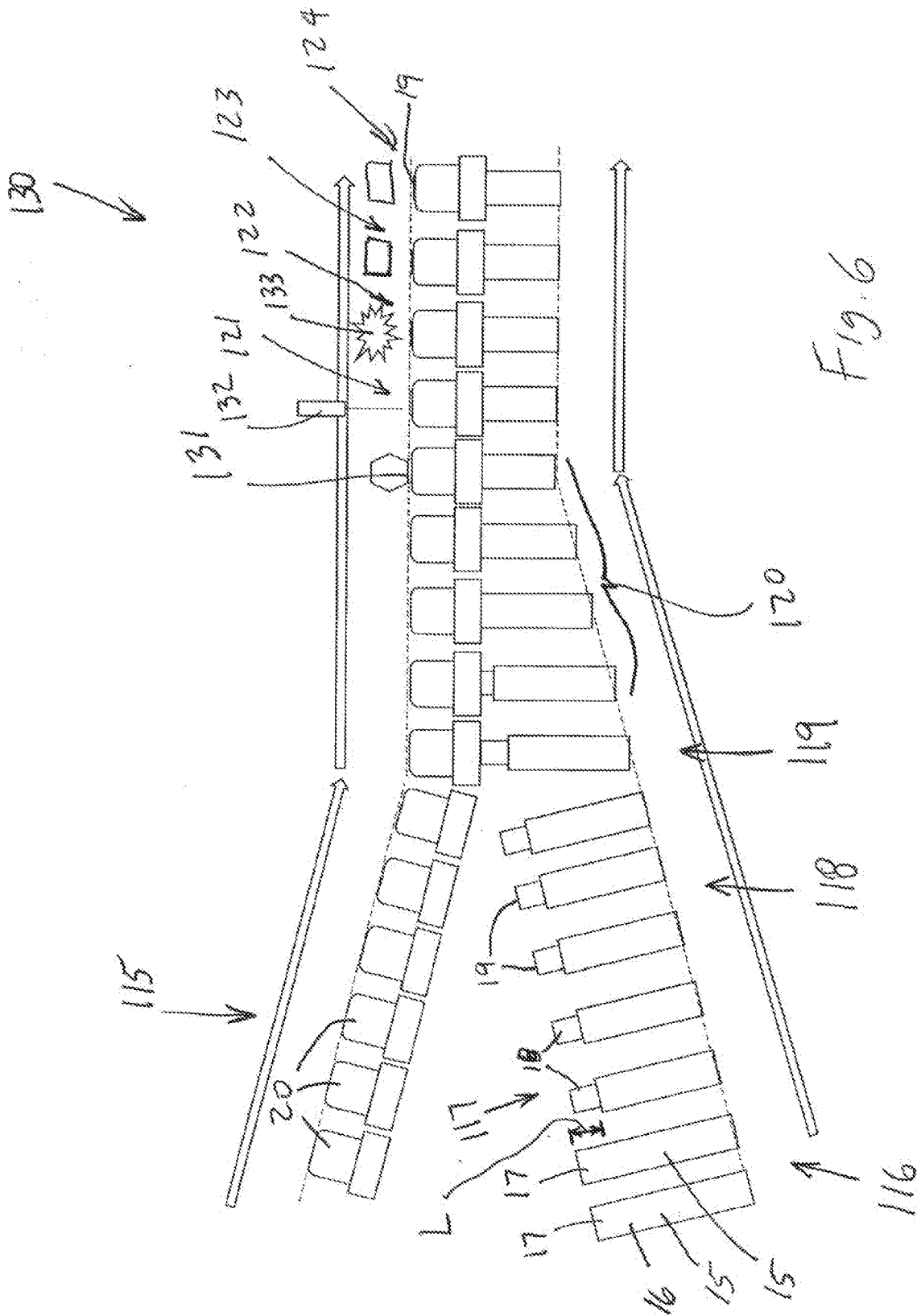


Fig. 5



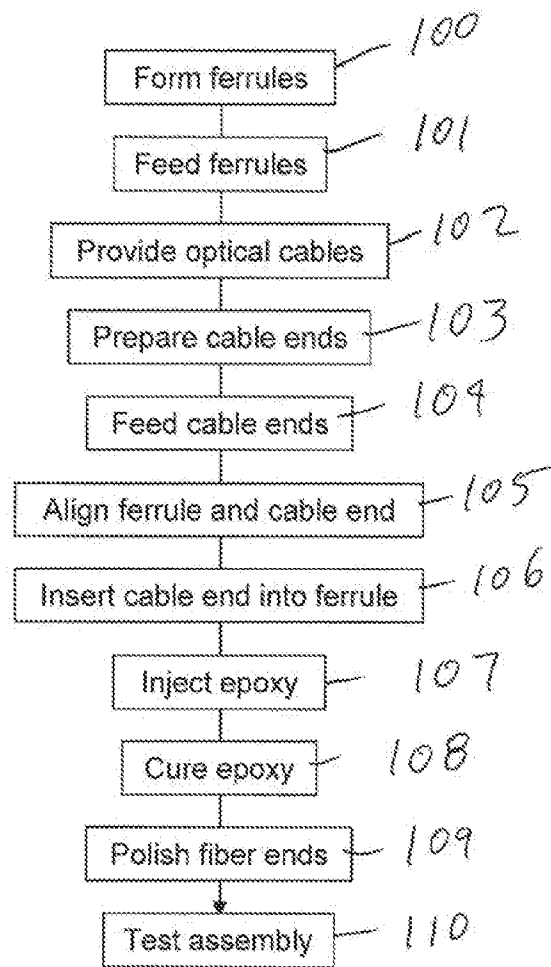


Fig. 7

Fig. 8

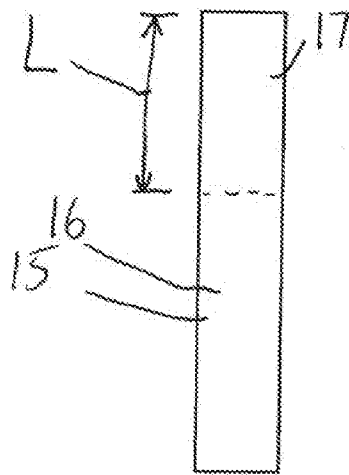


Fig. 9

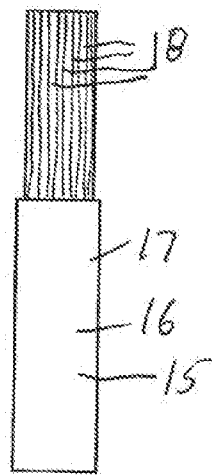


Fig. 10

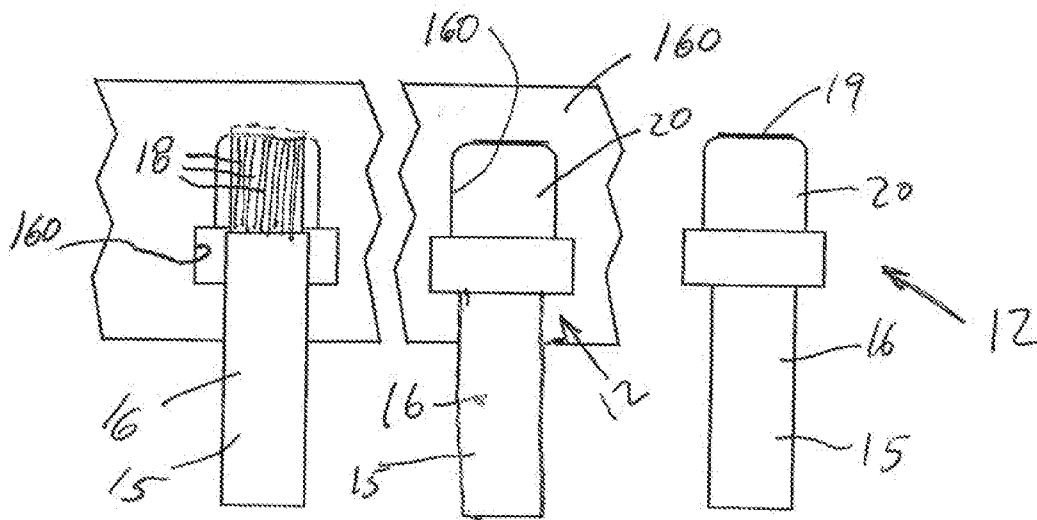
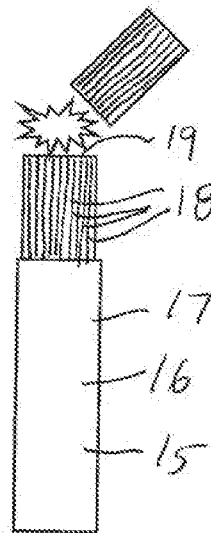


Fig. 11

Fig. 12

Fig. 13

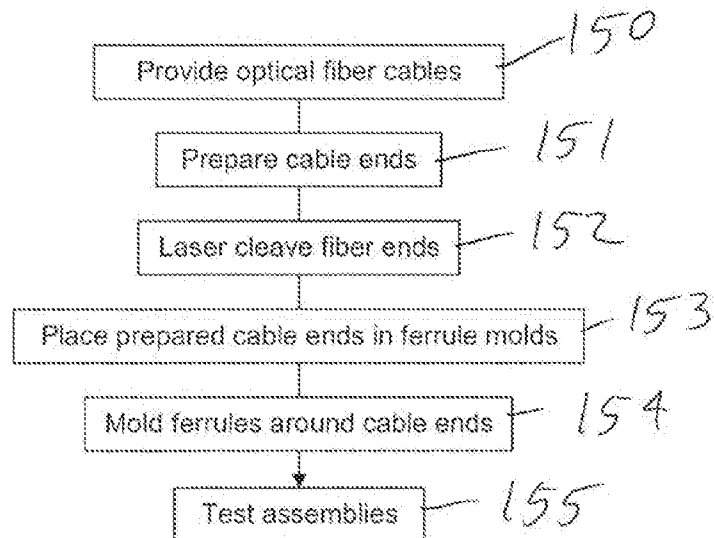


Fig. 14

Fig. 15

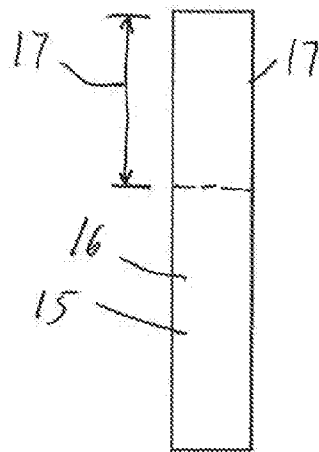


Fig. 16

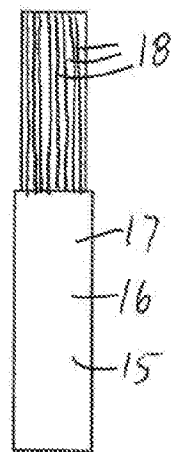


Fig. 17

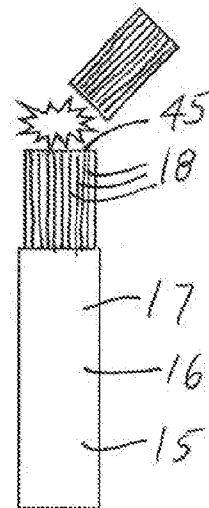


Fig. 18

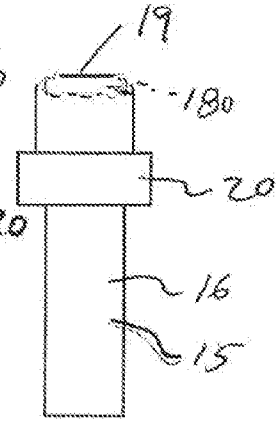
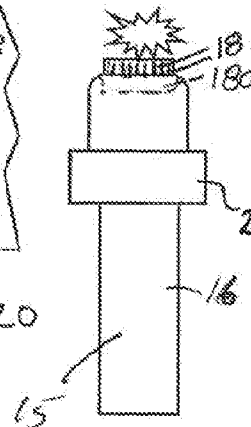
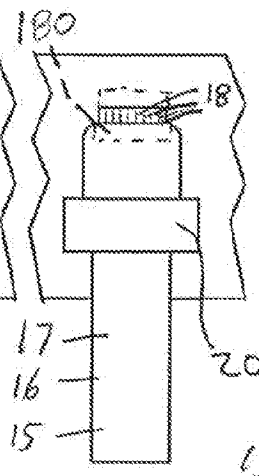
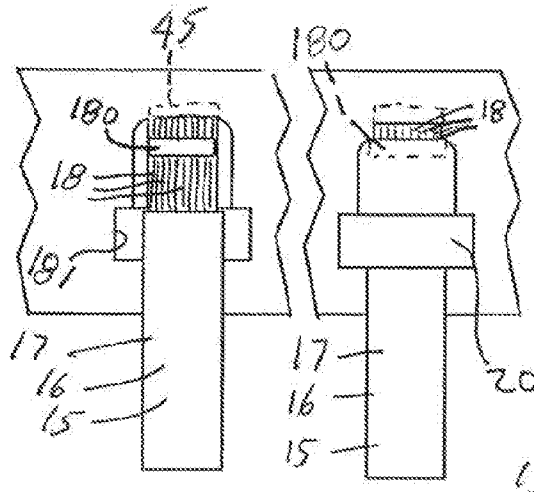
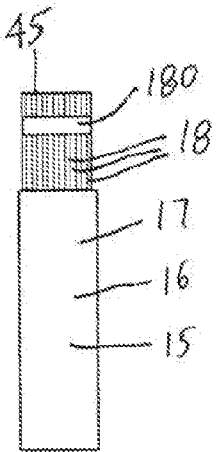


Fig. 19

Fig. 20

Fig. 21

Fig. 22

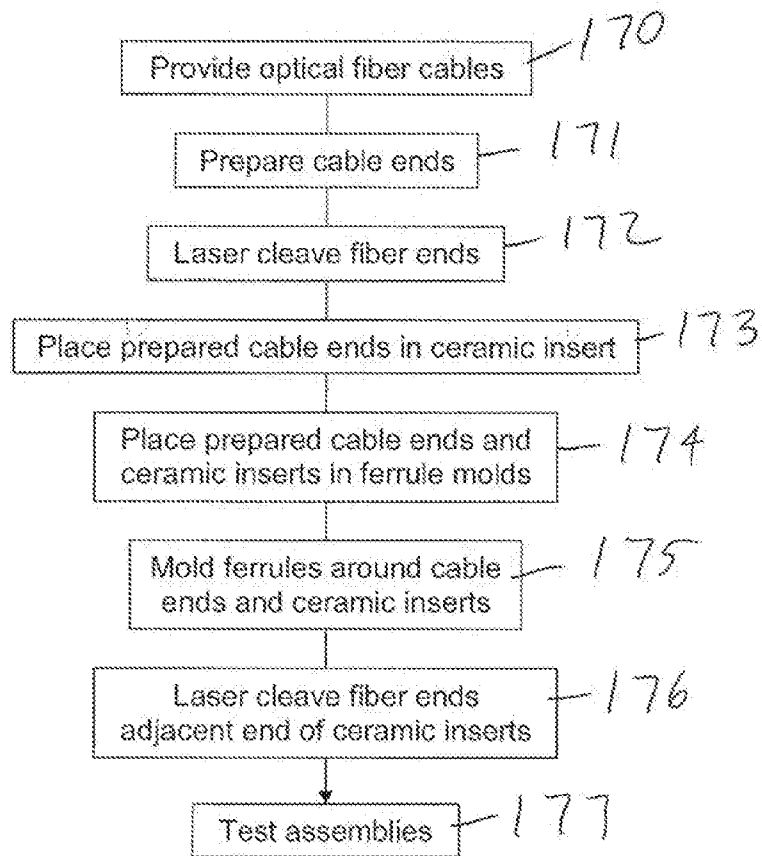
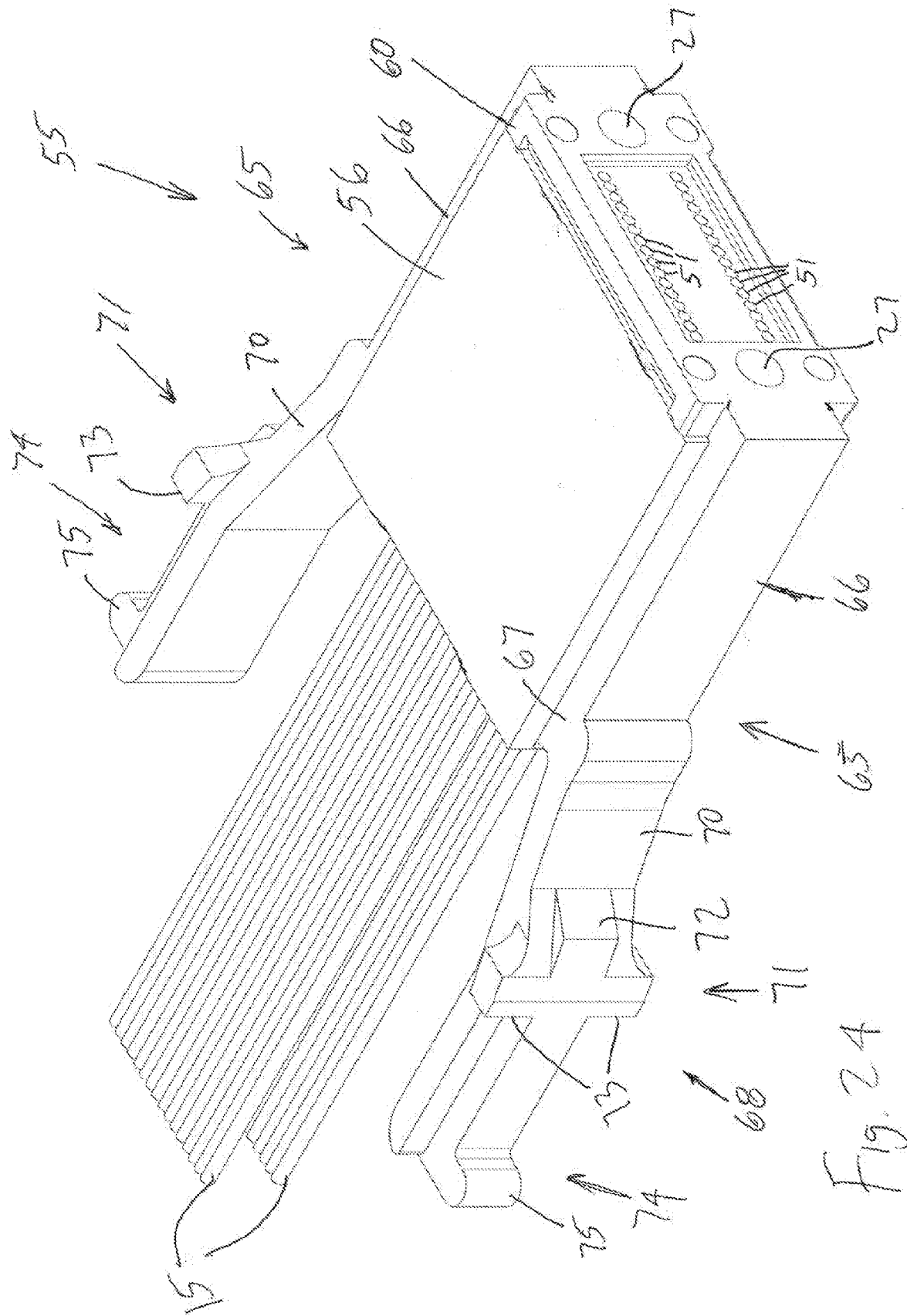
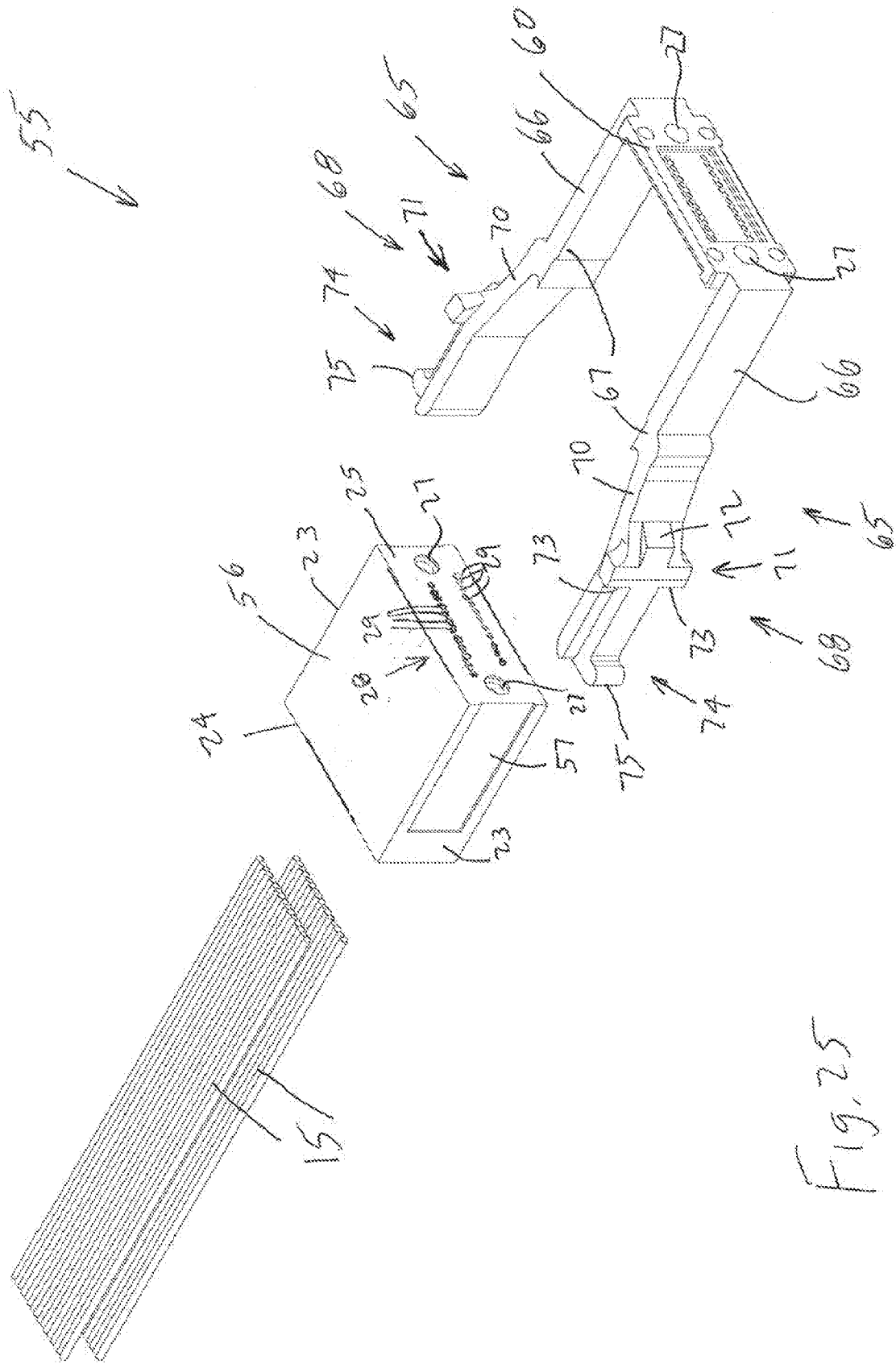


Fig. 23





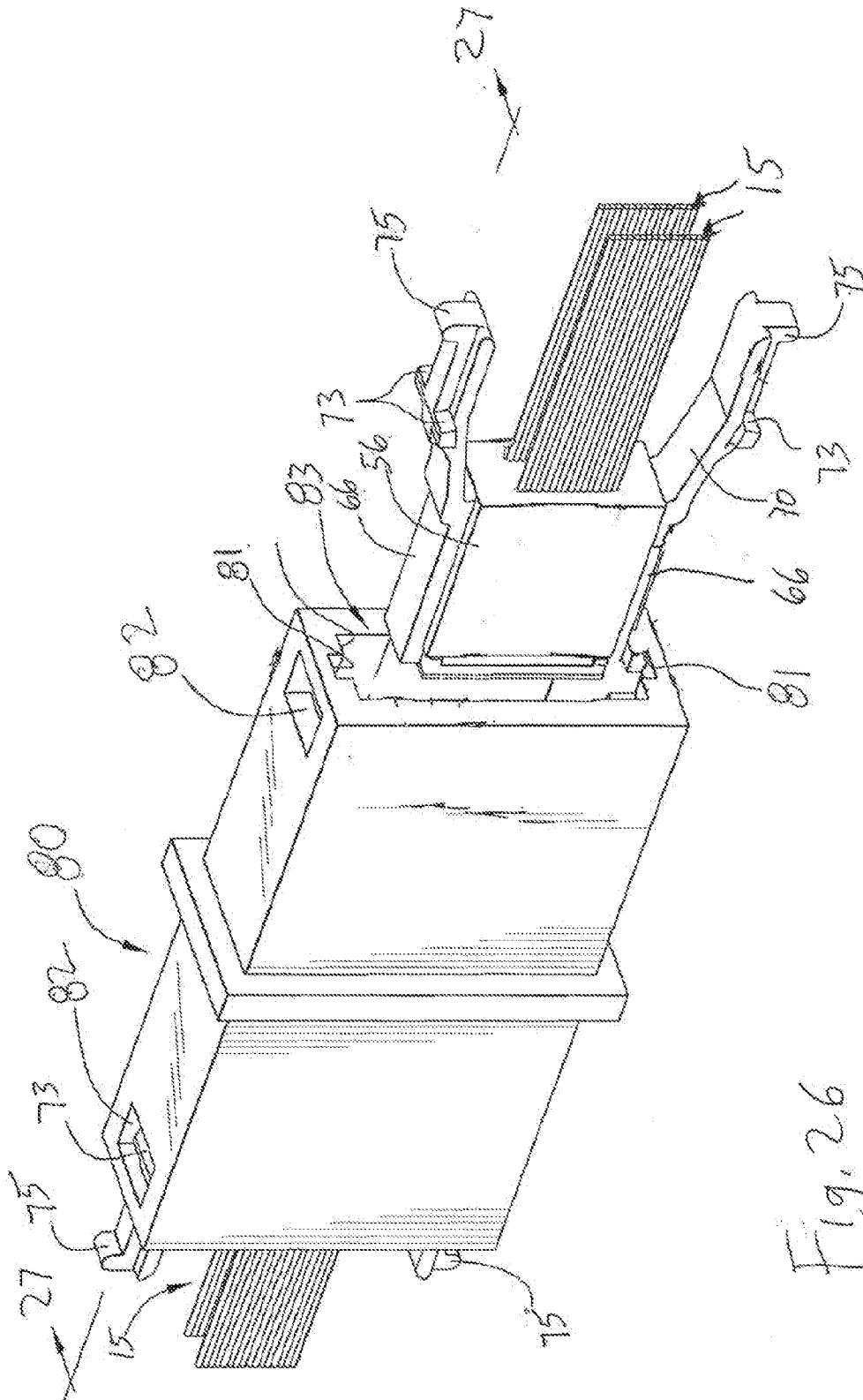


Fig. 26

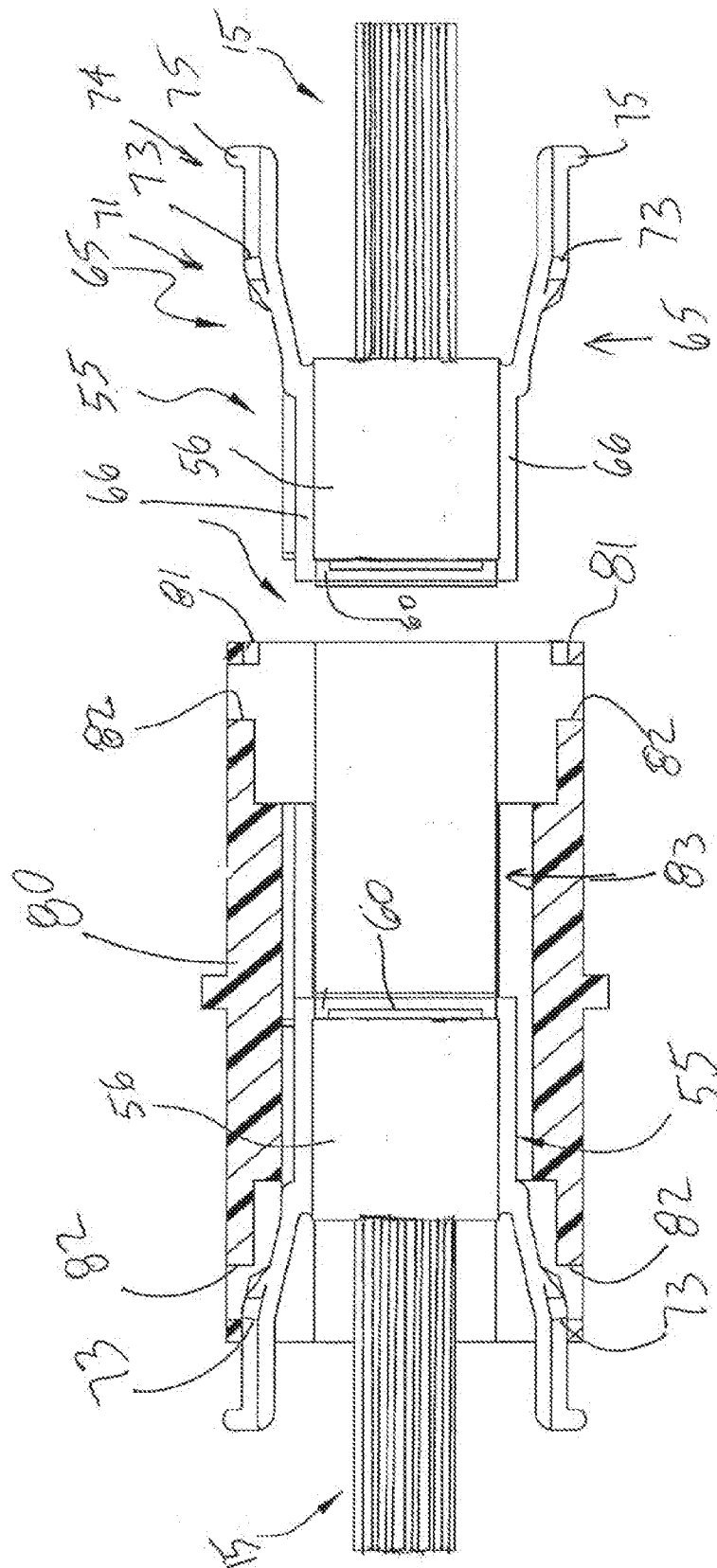


Fig. 27

Fig. 28

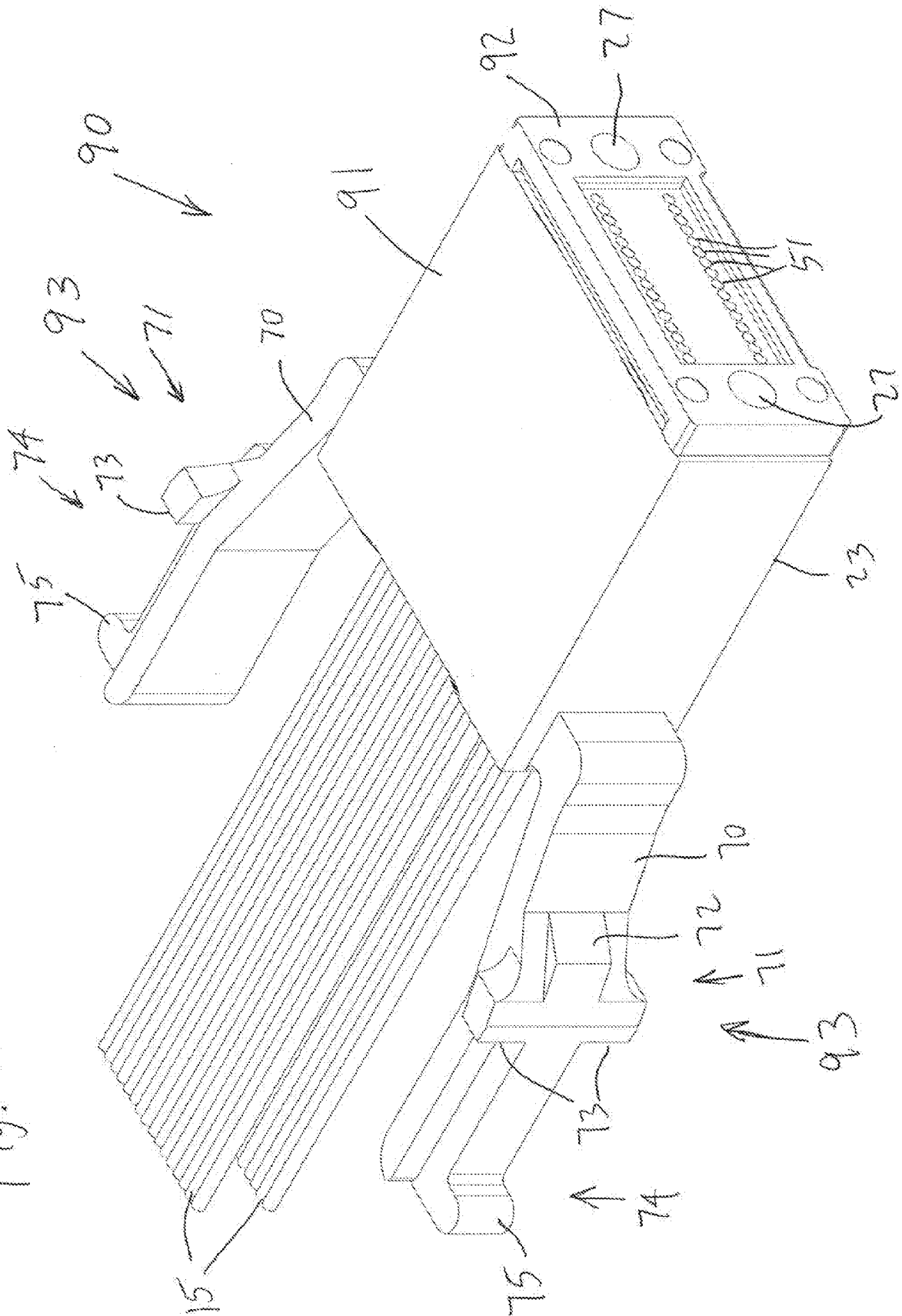
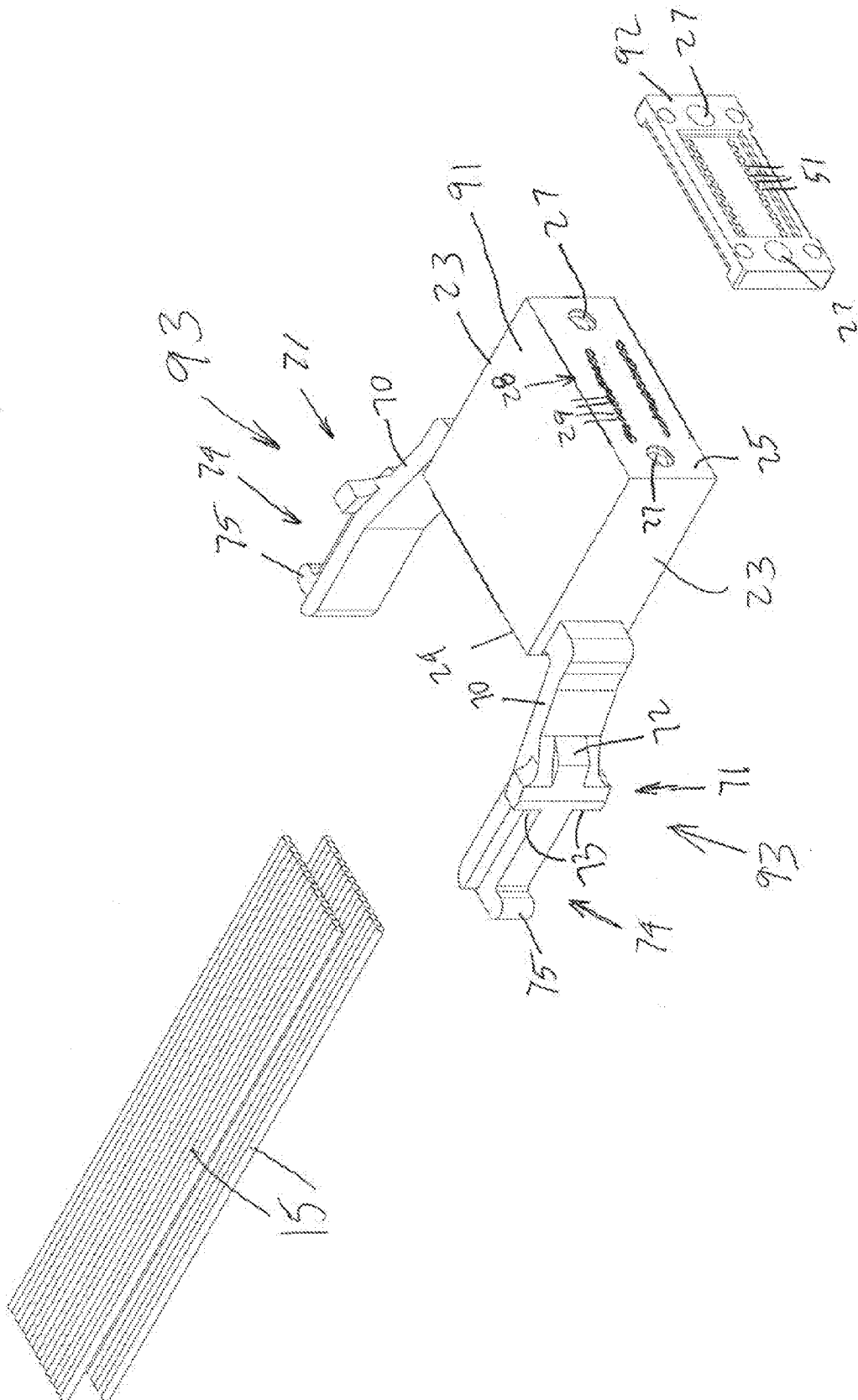


Fig. 29



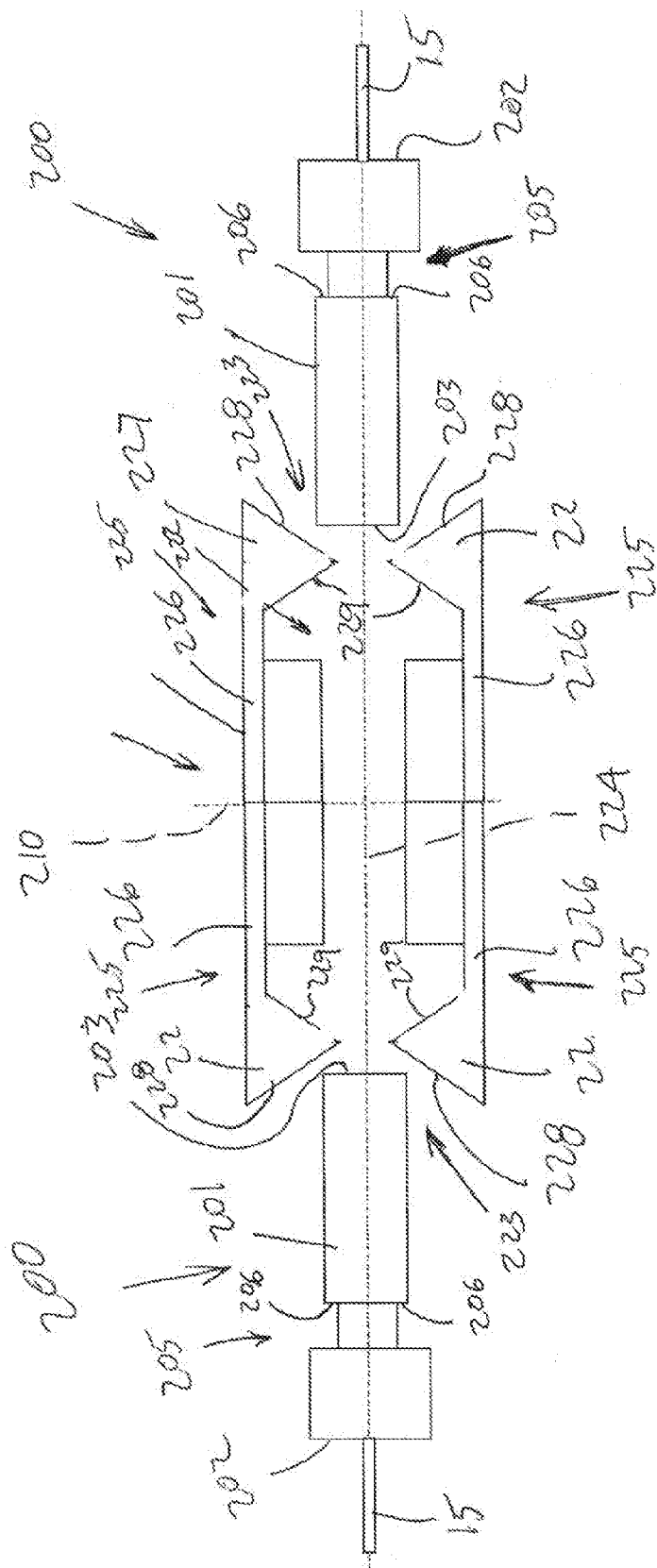


Fig. 30

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/018141**A. CLASSIFICATION OF SUBJECT MATTER****G02B 6/38(2006.01)i**

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 6/38; A01J 21/00; G02B 6/26; G02B 6/36

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: multi-fiber, assembly, molding, robotic, ferrule

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6726370 B2 (AKIHIRO SHIMOTSU) 27 April 2004	1-16
A	See column 3, lines 9-16, claims 1,5-6 and figures 5-6.	17
Y	US 7261469 B1 (DAVID L. DEAN, JR. et al.) 28 August 2007	1-16
	See column 3, lines 23-47 and claim 1.	
Y	US 2015-0226922 A1 (US CONEC, LTD.) 13 August 2015	12-14
	See claim 12 and figures 3-4.	
X	US 6307983 B1 (KEITH W. GOOSSEN) 23 October 2001	17
	See columns 1-2 and claims 7-8.	
A	US 5975770 A (SHUICHI YANAGI et al.) 02 November 1999	1-17
	See claims 1-5.	



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

28 May 2018 (28.05.2018)

Date of mailing of the international search report

29 May 2018 (29.05.2018)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

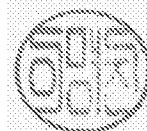


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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/018141

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US 6307983 B1	23/10/2001	None	
US 05975770 A	02/11/1999	EP 0860723 A2 EP 0860723 A3 EP 1130435 A1 EP 1146370 A2 EP 1146370 A3 EP 1146370 B1 JP 10-293232 A JP 11-211934 A JP 3642380 B2	26/08/1998 04/08/1999 05/09/2001 17/10/2001 24/10/2001 10/11/2004 04/11/1998 06/08/1999 27/04/2005