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(71) Applicant: COMMSCOPE TECHNOLOGIES LLC [US/US]; 1100 CommScope Place SE, Hickory, North Carolina 28602 (US).

(72) Inventor: LU, Yu; 12251 Princeton Avenue, Eden Prairie, Minnesota 55347 (US).

(74) Agent: KOWALCHYK, Katherine M.; Merchant & Gould P.C., P.O. Box 2903, Minneapolis, Minnesota 55402-0903 (US).

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(54) Title: METHOD AND APPARATUS FOR MEASURING ALIGNMENT PIN HOLE ANGLE OF FIBER OPTIC FERRULE

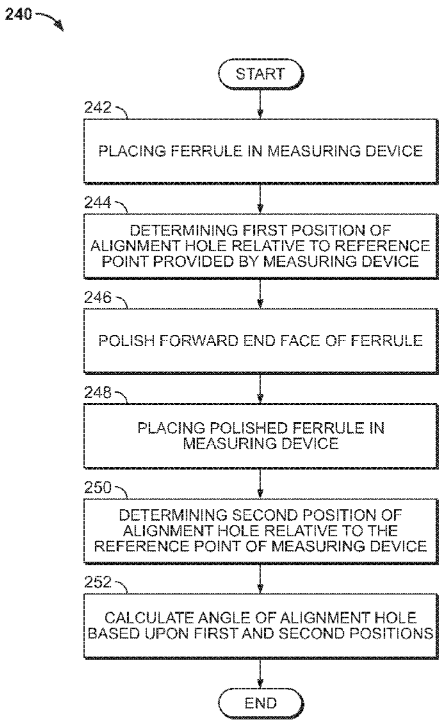

FIG. 9

(57) Abstract: A system for measuring an alignment pin hole angle of a fiber optic ferrule is provided. The system includes a measuring device configured to align a ferrule therewith and provide a reference point for determining a position of an alignment pin hole on an end face of the ferrule before and after polishing the end face of the ferrule. The measuring device The offset measuring device may provide at least one positioning surface configured to be abutted at least partially with at least one reference surface of the ferrule such that the ferrule is arranged at the same position in the measuring device every time that the ferrule is placed in the measuring device.

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METHOD AND APPARATUS FOR MEASURING ALIGNMENT PIN HOLE ANGLE OF FIBER OPTIC FERRULE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is being filed on April 7, 2016 as a PCT International Patent Application and claims the benefit of U.S. Patent Application Serial No. 62/145,671, filed on April 10, 2015, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Certain types of fiber optic ferrules, such as MT ferrules, have fiber holes for securing optical fibers therein. Signal transmission through the optical fibers can depend on precise coaxial alignment of the fibers corresponding to mating connectors. Precise positioning of the optical fibers is dependent upon precise positioning of the fiber holes through the ferrules. The angles of the fiber holes also affect positioning precision, particularly when polishing is taken into consideration. It is therefore necessary to accurately position the centers of fiber holes, at which optical fiber cores are located, to achieve low loss of signal transmission.

[0003] The precise positioning of fiber holes is dependent at least in part on the angles or inclinations of the fiber holes in the ferrule. The angle of each fiber hole can affect a position of the fiber hole before an end face of the ferrule is polished and a position of the fiber hole after the end face of the ferrule is polished. As the fiber hole angle increases, the positions of fiber holes can change more before and after polishing.

[0004] According to known measuring techniques, fiber hole angles are measured by referencing alignment pin holes, which are also referred to as guide pin holes, formed through a ferrule. For example, the true positions of fiber holes can be determined before and after polishing, using the alignment pin holes as reference locations. Based on the true position measurements, the angles of the fiber holes can be determined. However, the alignment pin holes of a ferrule are often angled or tilted in the ferrule, and, thus, the position of each alignment pin hole can change as the end face of the ferrule is polished. The offset of the alignment pin hole position on the end face of the ferrule can cause inaccurate measurement of the true position and angle of each fiber hole of the ferrule.

SUMMARY

[0005] In general terms, this disclosure is directed to a system for measuring an alignment pin hole angle of a fiber optic ferrule. In one possible configuration and by non-limiting example, the system includes a measuring device configured to align a ferrule therewith and provide a reference point for determining a position of an alignment pin hole on an end face of the ferrule before and after polishing the end face of the ferrule. The measuring device may provide at least one positioning surface configured to be abutted at least partially with at least one reference surface of the ferrule such that the ferrule is arranged at the same position in the measuring device every time that the ferrule is placed in the measuring device. Various aspects are described in this disclosure, which include, but are not limited to, the following aspects.

[0006] One aspect is a method of determining an angle of a guide pin hole of a fiber optic ferrule relative to at least one reference surface of the ferrule. The method may include placing the ferrule in an offset measuring device to arrange the at least one reference surface of the ferrule at a predetermined position of the offset measuring device; determining a first position of the guide pin hole at a forward end face of the ferrule relative to a reference point formed in the offset measuring device; removing a predetermined amount of material from the ferrule at the forward end face to form a butt end face of the ferrule; placing the ferrule in the offset measuring device to arrange the at least one reference surface of the ferrule at the predetermined position of the offset measuring device; determining a second position of the guide pin hole at the butt end face of the ferrule relative to the reference point formed in the offset measuring device; and calculating an angle of the guide pin hole of the ferrule based upon the first and second positions of the guide pin hole.

[0007] Another aspect is a system for measuring an angle of an alignment pin hole of a fiber optic ferrule. The system may include a body, a ferrule alignment portion, and a reference point. The body is configured to place the ferrule therein. The ferrule alignment portion is defined by the body and configured to arrange the ferrule in a same position every time that the ferrule is placed in the body. The reference point is formed in the body and used to measure a position of the alignment pin hole on an end face of the ferrule therefrom.

[0008] In certain examples, a system for measuring an alignment pin hole angle of a fiber optic ferrule may include a measuring device configured to align a ferrule therewith and provide a measuring pin for determining a position of an alignment pin hole on an end face of the ferrule. The measuring pin is displaceably inserted into the alignment pin hole of the ferrule and monitored to provide different position measurements. The different position measurements of the measuring pin are used to calculate the alignment pin hole angle of the ferrule.

[0009] One aspect is a method of determining an angle of a guide pin hole of a fiber optic ferrule relative to at least one reference surface of a ferrule. The method may include placing the ferrule in an offset measuring device to arrange the at least one reference surface of the ferrule at a predetermined position of the offset measuring device; inserting a measuring pin into the guide pin hole in a first position; determining a position of the measuring pin to generate a first position measurement of the measuring pin; displacing the measuring pin within the guide pin hole into a second position; determining a position of the measuring pin to generate a second position measurement of the measuring pin; and calculating an angle of the guide pin hole of the ferrule based upon the first and second position measurements and a difference between the first and second positions of the measuring pin. In certain examples, the measuring pin is arranged to protrude from an end face of the ferrule at a first length in the first positon, and protrude from the end face of the ferrule at a second length in the second position. The difference between the first and second positions may be defined as a difference between the first and second lengths.

[0010] Another aspect is a system for measuring an angle of a guide pin hole of a fiber optic ferrule. The system may include a body, a ferrule alignment portion, and a measuring pin. The body is configured to place the ferrule therein. The ferrule alignment portion is defined by the body and configured to arrange the ferrule in a predetermined position. The measuring pin is configured to be inserted into the guide pin hole of the ferrule and configured to be arranged in a first position and a second position different from the first position. The measuring pin is detectable in the first and second positions to provide first and second position measurements thereof.

[0011] In certain examples, the measuring pin is arranged to protrude from an end face of the ferrule at a first length in the first position, and protrude from an end face of the ferrule at a second length in the second position.

[0012] The above features and advantages and other features and advantages of the present teachings are readily apparent from the following detailed description of the best modes for carrying out the present teachings when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a top perspective view of an example fiber optic ferrule.

[0014] FIG. 2 is a bottom perspective view of the fiber optic ferrule of FIG. 1.

[0015] FIG. 3 is a front view of the ferrule, illustrating a forward end face or a butt end face of the ferrule of FIG. 1.

[0016] FIG. 4A is a side view of the ferrule before polishing.

[0017] FIG. 4B is a side view of the ferrule of FIG. 4A after polishing.

[0018] FIG. 5 is a side cross-sectional view of an example ferrule, illustrating an angle of a fiber hole relative to an alignment pin hole.

[0019] FIG. 6 is a bottom perspective view of the ferrule of FIG. 1.

[0020] FIG. 7 is a perspective view of an example offset measuring device for receiving a ferrule to measure a position of an alignment pin hole.

[0021] FIG. 8 is a front view of the offset measuring device of FIG. 7.

[0022] FIG. 9 is a flowchart illustrating an example method of using the offset measuring device to measure a position of an alignment pin hole before and after polishing.

[0023] FIG. 10 is a perspective view of the offset measuring device of FIG. 7, illustrating an example ferrule alignment portion.

[0024] FIG. 11 illustrates that the ferrule is aligned with the offset measuring device in a Y-axis direction.

[0025] FIG. 12 illustrates that the ferrule is aligned with the offset measuring device in a Z-axis direction.

[0026] FIG. 13 illustrates that the ferrule is aligned with the offset measuring device in an X-axis direction.

[0027] FIG. 14 schematically illustrates an example offset measuring device for determining an angle of the alignment pin hole of a ferrule relative to at least one of the references surfaces of the ferrule.

[0028] FIG. 15A illustrates a method of measuring an angle of the alignment pin hole relative to at least one of the reference surfaces of the ferrule.

[0029] FIG. 15B further illustrates the method of measuring an angle of the alignment pin hole relative to at least one of the reference surfaces of the ferrule.

[0030] FIG. 16 illustrates an example method of calculating a tilt angle of the alignment pin hole.

[0031] FIG. 17 schematically illustrates an example of the offset measuring devices.

DETAILED DESCRIPTION

[0032] Various embodiments will be described in detail with reference to the drawings, wherein like reference numerals represent like parts and assemblies throughout the several views.

[0033] In general, the present disclosure relates to a system for measuring an angle or inclination of an alignment pin hole formed in a ferrule, such as a multi-fiber ferrule (e.g., an MPO/MT ferrule). The system may use an offset measuring device configured to align a ferrule therewith and provide at least one reference point for determining a position of an alignment pin hole on an end face of the ferrule before and after the end face of the ferrule is polished. The offset measuring device may provide at least one positioning surface configured to be abutted at least partially with at least one reference surface of the ferrule such that the ferrule is arranged at the same position in the offset measuring device every time that the ferrule is placed in the offset measuring device. The reference point provided in the offset measuring device may be used to determine a position of the alignment pin hole on the end face of the ferrule that is placed in the offset measuring device before and after the end face of the ferrule is polished. A difference between the positions of the alignment pin hole of the ferrule is used to calculate an angle of the alignment pin hole in the ferrule. When an angle of a fiber hole in the ferrule is measured with respect to the alignment pin hole, the measurement of the fiber hole angle can be adjusted in accordance to the angle of the alignment pin hole. If the alignment hole pin angle is outside a predetermined acceptable range, the ferrule may be rejected. The offset measuring device in accordance with the present disclosure is easy to fabricate and use. Thus, the offset measuring device in accordance with present disclosure can replace expensive equipment using a sophisticating technology, such as X-ray Computerized Tomography (CT), and provide a convenient and cost-efficient structure for measuring an angle or inclination of alignment pin holes of a ferrule.

[0034] Referring to FIGS. 1 and 2, a fiber optic ferrule 100 is provided to hold fibers. FIG. 1 is a top perspective view of an example fiber optic ferrule 100. FIG. 2 is a bottom perspective view of the fiber optic ferrule 100 of FIG. 1.

[0035] In some examples, the fiber optic ferrule 100 is a mechanical transfer (MT) ferrule for multi-fiber connections. The fiber optic ferrule 100 can hold optical fibers such as optical fibers that are part of a multicore fiber tape or ribbon. A fiber ribbon has a plurality of optical fibers. A polymeric matrix material that encases the optical fibers of the ribbon is removed so that the optical fibers are exposed, and the exposed optical fibers are individually inserted into fiber holes 122 through a fiber insertion opening 128 (FIG. 2) of the ferrule 100. In some examples, the ferrule 100 has a fiber support portion therewithin that includes a plurality of grooves formed in parallel at regular pitch, each of the grooves configured to receive and support each of the optical fibers. The present disclosure primarily describes a fiber optic ferrule 100 configured to hold a plurality of optical fibers. In other examples, however, the same principles described in the present disclosure are also applicable to a fiber optic ferrule for holding a single optical fiber.

[0036] The ferrule 100 has a ferrule body 102 and an enlarged base 104. The ferrule 100 extends between a forward end 106 and a rearward end 108 and is formed in a substantially rectangular shape. For example, the ferrule body 102 has a upper surface 110 (also referred to herein as a second main surface or a second major side surface), a lower surface 112 (also referred to herein as a first main surface or a first major side surface) opposite to the upper surface 110, and opposite side surfaces 114 and 116 (also referred to herein as first and second side surfaces or minor side surfaces). The upper surface 110, the lower surface 112, and the opposite side surfaces 114 and 116 extend between the forward end 106 and the rearward end 108 to define a substantially rectangular shape of the ferrule body 102.

[0037] The enlarged base 104 is provided at the rearward end 108 of the ferrule 100 and meets with the ferrule body 102 at a shoulder 118 that extends outwardly from the exterior surface of the ferrule body 102. In the illustrated example, the shoulder 118 extends from the upper, lower and opposite side surfaces 110, 112, 114 and 116 at the ferrule body 102. . The shoulder 118 is a surface perpendicularly or radially extending from the exterior surface of the ferrule body 102. The shoulder 118 can be substantially parallel with a forward end face 120 of the ferrule 100. In other examples, the end face 120 can be angled relative to the shoulder 118.

[0038] As illustrated in FIG. 1, the ferrule 100 has a forward end face 120, a plurality of fiber holes 122, one or more alignment pin holes 124 (i.e., alignment holes or openings), and an adhesive window 126.

[0039] The forward end face 120 is a surface of the ferrule 100 at the forward end 106. Once the ferrule 100 is assembled with optical fibers and related components, the forward end face 120 is polished along with forward end faces of the optical fibers, thereby ensuring proper fiber-to-fiber contact and reduced signal loss. The polished forward end surface is referred to herein as a butt end face or an end face 170, as illustrated in FIG. 5. The end face 170 can be angled or inclined. The butt end face 170 is a surface of the ferrule 100 that opposes a butt end face 170 of another ferrule 100 when an optical connection is made between the two mated ferrules. The butt end faces 170 of the abutting ferrules 100 are arranged opposite to each other, and alignment pins (e.g., guide pins) (not shown) are inserted into the alignment pin holes 124 so as to be interposed between opposing alignment pin holes 124.

[0040] The fiber holes 122 are defined in the ferrule body 102 to be in communication with a fiber insertion opening 128 (FIG. 2). The fiber holes 122 are configured to receive optical fibers, respectively, that are inserted into the ferrule body 102 through the fiber insertion opening 128. The fiber holes 122 are open at the forward end face 120 of the ferrule body 102. As described herein, the fiber holes 122 are also open at the inclined butt end face 170 after a predetermined amount of material is removed from the ferrule body 102 at the forward end face 120. When receiving the optical fibers, the fiber holes 122 expose tip ends of bare fibers at the forward end face 120 or the butt end face 170.

[0041] The plurality of fiber holes 122 is arranged along a line at the forward end face 120 of the ferrule 100 so as to form a row of optical fibers. The plurality of fiber holes 122 can be arranged multiple lines such as two lines. As described below, the positions of fiber holes 122 are arranged with at least one of the lower surface 112, one of the side surfaces 114 and 116, and a shoulder 118.

[0042] One or more alignment pin holes 124 are provided at the forward end face 120 of the ferrule 100 to receive guide pins (not shown) that are configured to align two mating ferrules 100. The alignment pin holes 124 can also referred to herein as guide pin holes. In the illustrated example, the alignment pin holes 124 can be formed in a substantially circular shape in cross-section in a perpendicular direction relative to an inserting direction of a guide pin. Other cross-sectional shapes of the alignment pin holes

124 are possible in other examples. In some examples, the alignment pin holes 124 can extend through the ferrule 100 to open at a rearward end face 130 (FIG. 2), as well as the forward end face 120 of the ferrule 100. In the illustrated example, the ferrule 100 has two alignment pin holes 124. In other examples, however, the ferrule 100 has a single alignment pin hole or more than two alignment pin holes.

[0043] The adhesive window 126 is provided on the upper surface 110 of the ferrule 100 and in communication with at least a portion of the fiber holes 122 within the ferrule body 102. The adhesive window 126 is configured to receive adhesive (e.g., epoxy adhesive) to fix the optical fibers to the fiber holes 122.

[0044] Referring to FIG. 2, the ferrule 100 has a fiber insertion opening 128 at a rearward end face 130. The fiber insertion opening 128 is configured to insert optical fibers into the ferrule body 102. As illustrated, the fiber insertion opening 128 can be formed in substantially the center in the rearward end face 130 of the ferrule 100 and in a substantially rectangular shape with a wide width that can receive an optical fiber tape.

[0045] The fiber optic ferrule 100 can be made of synthetic resin. For example, the ferrule 100 is formed by transfer molding using thermosetting resin such as an epoxy resin, injection molding using thermoplastic resin such as polyphenylene sulfide resin (PPS) or liquid crystal polymer (LCP). Other materials can be used to form the ferrule 100.

[0046] Referring to FIGS. 3-5, an example method of measuring a position of each fiber hole 122 on the ferrule 100 relative to the alignment pin holes 124. The positions of each fiber hole 122 are measured both before and after the forward end face 120 of the ferrule 100 is polished. The positions of the fiber holes 122 before and after polishing of the ferrule 100 can be used to calculate an angle of the fiber hole 122 formed in the ferrule body 102 relative to the alignment pin holes 124.

[0047] FIG. 3 is a front view of the ferrule 100, illustrating the forward end face 120 or the butt end face 170 of the ferrule 100. In this example, the pair of alignment pin holes 124 are used as a reference point to measure a position of each fiber hole 122. A middle point 150 between the two alignment pin holes 124 is selected as a reference point for measuring the positions of fiber holes 122. For example, the middle point 150 can be selected as an origin of a coordinate system, such as an X-axis 152 and a Y-axis 154. The position of each fiber hole 122 can be measured along the X-axis 152 and the Y-axis 154 to generate an offset distance for the fiber hole 122 from the reference point 150. The offset distance for each fiber hole 122 can be reduced to an X-axis offset component and a Y-axis offset component. In an ideal case, the fiber holes 122 are arranged to lie substantially along the X-axis 152 (i.e., the Y-axis offset is zero).

[0048] FIG. 4A is a side view of the ferrule 100 before polishing, and FIG. 4B is a side view of the ferrule 100 of FIG. 4A after polishing. When the ferrule 100 is assembled with a plurality of optical fibers and associated hardware, the forward end face 120 of the ferrule 100 is polished to form a butt end face 170. By polishing the forward end face 120 of the ferrule 100, end portions of optical fibers exposed at the forward end face 120 and a predetermined amount of material of the ferrule are removed. As the optical fibers and ferrule materials are removed from the forward end face 120, the offset distances of the fiber holes 122 can change either in degree or direction, or both, due to an angle or inclination A (FIG. 5) of each fiber hole 122 with respect to a line L perpendicular to the pre-polished forward end face 120 and the shoulder 118 of the ferrule 100. Such an angle of each fiber hole 122 can be caused by, for example, manufacturing tolerances.

[0049] FIG. 5 is a side cross-sectional view of an example ferrule 100, illustrating an angle A of a fiber hole 122 relative to the alignment pin hole 124. An axis of the fiber hole 122 is designated as A_F and an axis of the alignment pin hole 124 is designated as A_A.

[0050] In this example, the angle or inclination A of the fiber hole 122 can be measured relative to the alignment pin hole 124. For example, the angle A of the fiber hole 122 is defined as an angle formed between the fiber hole axis A_F and the alignment pin hole axis A_A.

[0051] As described with reference to FIGS. 4A and 4B, the position of the fiber hole 122 changes after the forward end face 120 of the ferrule 100 is polished to form the butt end face 170. As illustrated in FIG. 5, a first position P_A of the fiber hole 122 prior to polishing is different from a second position P_B of the fiber hole 122 after polishing. Each of the first and second positions P_A and P_B can be reduced to an X-axis component and a Y-axis component, and used to calculate the angle A of the fiber hole 122 relative to the alignment pin hole 124.

[0052] As such, the angle A of each fiber hole 122 can be determined relative to at least one of the alignment pin holes 124 by measuring a position of the fiber hole 122 before and after polishing the forward end face 120 of the ferrule 100. In some examples, however, the alignment pin holes 124 are formed to be at least partially angled or inclined in the ferrule body 102 due to, for example, manufacturing tolerances. For example, the alignment pin hole axis A_A can be at least partially tilted along the length of the ferrule 100. In this case, the position of the alignment pin holes 124 can change as the forward end face 120 of the ferrule 100 is polished, and, therefore, cause inaccurate measurement of the position of each fiber hole 122 of the ferrule 100.

[0053] Referring to FIG. 6, which is a bottom perspective view of the ferrule 100, a position of each alignment pin hole 124 can be measured relative to one or more reference surfaces on the ferrule 100. In some examples, the ferrule 100 provides a first reference surface 202, a second reference surface 204, and a third reference surface 206. At least one of the first, second and third reference surfaces 202, 204 and 206 of the ferrule 100 can be used as a reference to determine a position of each alignment pin hole 124 (e.g., the alignment pin hole axis A_A) before and after polishing. The difference between two positions of the alignment pin hole 124 before and after polishing can be used to calculate an angle of the alignment pin hole 124 (e.g., an angle or inclination of the alignment pin hole axis A_A) in a similar manner to the angle A of each fiber hole 122 as described above. As described below, these reference surfaces (including the first, second, and third reference surfaces 202, 204, and 206) can be used to position the ferrule at a predetermined location relative to a measuring device or fixture.

[0054] In some examples, the first reference surface 202 is defined as the lower surface 112 of the ferrule body 102. The second reference surface 204 is defined as a shoulder 118 of the enlarged base 104. The third reference surface 206 is defined as one of the side surface 114 and 116 of the ferrule body 102.

[0055] Referring to FIGS. 7-13, an example method of measuring an offset of the alignment pin holes 124 before and after polishing the forward end face 120 of the ferrule 100. In some examples, the method is performed using an offset measuring device 210. As described below, the offset measuring device 210 is configured to arrange the ferrule 100 at a predetermined position by aligning at least one of the first, second, and third reference surfaces 202, 204, and 206 of the ferrule 100 with the offset measuring device 210.

[0056] FIG. 7 is a perspective view of an example offset measuring device 210 that receives the ferrule 100 to measure a position of each alignment pin hole 124. FIG. 8 is a front view of the offset measuring device 210 of FIG. 7. The offset measuring device 210 includes a device body 212, a ferrule alignment portion 214 and one or more reference points 216.

[0057] The device body 212 is configured to support the ferrule 100 for measurement of the alignment pin holes 124. In some examples, the device body 212 has a front wall 218, a rear wall 220, and opposite side walls 222 and 224.

[0058] The ferrule alignment portion 214 is defined at a top portion of the device body 212 and configured to receive and arrange the ferrule 100 at a predetermined position. As described in more detail with reference to FIGS. 10-13, the ferrule alignment portion 214 operates to arrange the ferrule 100 in the same position every time that the ferrule 100 is placed therein.

[0059] One or more reference points 216 are provided at predetermined positions of the offset measuring device 210. In the illustrated example, the offset measuring device 210 includes four reference points 216 formed on the front wall 218 of the device body 212 adjacent the ferrule alignment portion 214.

[0060] In some examples, the reference points 216 are configured as holes formed on the device body 212 (e.g., on the front wall 218 thereof) adjacent the ferrule alignment portion 214. These holes can be made in similar shape and size to the fiber holes 122 of the ferrule 100.

[0061] Referring to FIG. 8, the alignment pin hole axis A_A (i.e., the center of the alignment pin hole) can be measured from at least one of the reference points 216 formed in the offset measuring device 210. In the illustrated example, the offset measuring device 210 has four reference points 216 (e.g., a first reference point 216A, a second reference point 216B, a third reference point 216C, and a fourth reference point 216D). First arrows 228A, 228B, 228C, and 228D represent vectorized positions of the axes A_A of a first alignment pin hole 124A relative to the first, second, third and fourth reference points 226A-226D. Second arrows 230A, 230B, 230C, and 230D represent vectorized positions of the axes A_A of a second alignment pin hole 124B relative to the first, second, third and fourth reference points 226A-226D.

[0062] FIG. 9 is a flowchart illustrating an example method 240 of using the offset measuring device 210 to measure a position of each alignment pin hole 124 before and after polishing the forward end face 120 of the ferrule 100. As described above, the offset measuring device 210 is configured to determine an angle or inclination of the alignment pin hole 124 relative to at least one of the reference surfaces 202, 204 and 206 of the ferrule 100.

[0063] At operation 242, the ferrule 100 is placed in the offset measuring device 210 to arrange at least one of the reference surfaces 202, 204 and 206 of the ferrule 100 at a predetermined position therein. In particular, the ferrule 100 is received to the ferrule alignment portion 214 of the offset measuring device 210. As described with reference to FIGS. 10-13, the ferrule alignment portion 214 is configured to align at least one of the reference surfaces 202, 204 and 206 therewith such that the ferrule 100 is placed in the ferrule alignment portion 214 of the offset measuring device 210 in the same position every time that the ferrule 100 is arranged therein. An example configuration of alignment of the ferrule 100 with the ferrule alignment portion 214 is described and illustrated in more detail with reference to FIG. 10.

[0064] At operation 244, a first position of the alignment pin hole 124 at the forward end face 120 of the ferrule 100 is determined relative to at least one of the reference points 216 of the offset measuring device 210. The first position of the alignment pin hole 124 indicates a position of the alignment pin hole 124 relative to at least one of the reference points 216 before the forward end face 120 of the ferrule 100 is polished. In some examples, the first position of the alignment pin hole 124 is determined as a vectorized position of the alignment pin hole axis A_A relative to at least one of the reference points 216 of the offset measuring device 210. The first position of the alignment pin hole 124 can be reduced in various manners, such as a Cartesian coordinate system including an X-axis distance and a Y-axis distance.

[0065] At operation 246, a predetermined amount of material is removed from the forward end face 120 of the ferrule 100 to form a butt end face 170 of the ferrule 100. In some examples, the butt end face 170 is angled about 8 degrees relative to the forward end face 120.

[0066] At operation 248, the polished ferrule 100 is placed in the offset measuring device 210 in the same manner as in the operation 242. In particular, the at least one reference surfaces 202, 204 and 206 of the ferrule 100 is arranged at the same position in the offset measuring device 210 as arranged at the operation 242.

[0067] At operation 250, a second position of the alignment pin hole 124 at the butt end face 170 of the ferrule 100 is determined relative to the same reference point(s) 216 of the offset measuring device 210 as used at the operation 244. The second position of the alignment pin hole 124 presents a position of the alignment pin hole 124 relative to the same reference point(s) 216 after the forward end face 120 of the ferrule 100 is polished to form the butt end face 170. Similarly to the first position of the alignment pin hole 124, the second position of the alignment pin hole 124 can be determined as a vectorized position of the alignment pin hole axis A_A relative to at least one of the reference points 216 of the offset measuring device 210. The second position of the alignment pin hole 124 can be reduced in various manners, such as a Cartesian coordinate system including an X-axis distance and a Y-axis distance.

[0068] At operation 252, an angle of the alignment pin hole 124 within the ferrule 100 can be calculated based upon the first and second positions of the alignment pin hole 124 relative to the reference point(s) 216 of the offset measuring device 210.

[0069] FIG. 10 is a perspective view of the offset measuring device 210 of FIG. 7, illustrating an example ferrule alignment portion 214. The ferrule alignment portion 214 has one or more positioning surfaces for arranging the ferrule 100 in the ferrule alignment portion 214 at a same position every time that the ferrule 100 is placed therein.

[0070] In some examples, the ferrule alignment portion 214 of the offset measuring device 210 has a first positioning surface 302, a second positioning surface 304, and a third positioning surface 306.

[0071] The first positioning surface 302 is configured to be at least partially abutted with the first reference surface 202 of the ferrule 100 (e.g., the lower surface 112 thereof) when the ferrule 100 is placed in the ferrule alignment portion 214 of the offset measuring device 210. The first positioning surface 302 operates to align the ferrule 100 in a Y-axis direction 312 with respect to the offset measuring device 210.

[0072] The second positioning surface 304 is configured to be at least partially abutted with the second reference surface 204 of the ferrule 100 (e.g., the shoulder 118 thereof) when the ferrule 100 is placed in the ferrule alignment portion 214 of the offset measuring device 210. The second positioning surface 304 operates to align the ferrule 100 in a Z-axis direction 314 with respect to the offset measuring device 210. In the illustrated example, the second positioning surface 304 is at least partially defined by the rear wall 220 of the offset measuring device 210.

[0073] The third positioning surface 306 is configured to be at least partially abutted with the third reference surface 206 of the ferrule 100 (e.g., the side surface 114 thereof) when the ferrule 100 is placed in the ferrule alignment portion 214 of the offset measuring device 210. The third positioning surface 306 operates to align the ferrule 100 in an X-axis direction 310 with respect to the offset measuring device 210.

[0074] Referring to FIGS. 11-13, an example method of arranging the ferrule 100 in the offset measuring device 210 by using the first, second, and third positioning surfaces 302, 304, and 306 of the ferrule alignment portion 214.

[0075] FIG. 11 illustrates that the ferrule 100 is aligned with the offset measuring device 210 in the Y-axis direction 312. The ferrule 100 is placed in the ferrule alignment portion 214 such that the first reference surface 202 (e.g., the lower surface 112) of the ferrule 100 is abutted with the first positioning surface 302 of the ferrule alignment portion 214. The first reference surface 202 of the ferrule 100 lies on the first positioning surface 302 of the ferrule alignment portion 214. A force F1 can be applied to the ferrule 100 against the ferrule alignment portion 214 in the Y-axis direction 312 to ensure the abutment between the first reference surface 202 and the first positioning surface 302.

[0076] FIG. 12 illustrates that the ferrule 100 is aligned with the offset measuring device 210 in the Z-axis direction 314. The ferrule 100 is placed in the ferrule alignment portion 214 such that the second reference surface 204 (e.g. the shoulder 118) of the ferrule 100 is abutted with the second positioning surface 304 of the ferrule alignment portion 214. The second reference surface 204 of the ferrule 100 lies on the second positioning surface 304 of the ferrule alignment portion 214. A force F2 can be applied to the ferrule 100 against the ferrule alignment portion 214 in the Z-axis direction 314 to ensure the abutment between the second reference surface 204 and the second positioning surface 304.

[0077] FIG. 13 illustrates that the ferrule 100 is aligned with the offset measuring device 210 in the X-axis direction 310. The ferrule 100 is placed in the ferrule alignment portion 214 such that the third reference surface 206 (e.g. the side surface 114) of the ferrule 100 is abutted with the third positioning surface 306 of the ferrule alignment portion 214. The third reference surface 206 of the ferrule 100 lies on the third positioning surface 306 of the ferrule alignment portion 214. A force F3 can be applied to the ferrule 100 against the ferrule alignment portion 214 in the X-axis direction 310 to ensure the abutment between the third reference surface 206 and the third positioning surface 306.

[0078] As illustrated in FIGS. 11-13, the ferrule 100 can be placed in the ferrule alignment portion 214 and aligned with the offset measuring device 210 in three directions including the X-axis, Y-axis, and Z-axis directions 310, 312 and 314. As described, the alignment of the ferrule 100 with the offset measuring device 210 is performed by arranging the reference surfaces 202, 204 and 206 of the ferrule 100 with the positioning surfaces 302, 304 and 306 of the ferrule alignment portion 214 of the offset measuring device 210. A position of the alignment pin hole 124 can be measured using the reference points 216 fixed at the offset measuring device 210. Since the ferrule 100 is aligned with the offset measuring device 210 by the reference surfaces 202, 204 and 206 of the ferrule 100, the positions of each alignment pin hole 124 measured with respect to the reference points 216 of the offset measuring device 210 are correlated with the positions of the alignment pin hole 124 measured with respect to at least one of the reference surfaces 202, 204 and 206 thereof.

[0079] Referring to FIGS. 14-17, another example method of determining an angle of an alignment pin hole 124 of a fiber optic ferrule 100 relative to a reference point of the ferrule. As described above, the reference point of the ferrule 100 can be at least one of the reference surfaces 202, 204 and 206 of the ferrule 100. In some embodiments, the reference point of the ferrule 100 for determining the angle of the alignment pin hole 124 is the shoulder 118. In this example, the method does not require measuring the alignment pin holes 124 before and after polishing the forward end face 120 of the ferrule 100.

[0080] FIG. 14 schematically illustrates an example offset measuring device 400 for determining an angle of the alignment pin hole 124 of the ferrule 100 relative to at least one of the references surfaces 202, 204 and 206 of the ferrule 100. In some embodiments, the offset measuring device 400 includes a device body 402, a ferrule alignment portion 404, and one or more measuring pins 406.

[0081] The device body 402 is configured to support the ferrule 100 for measurement of the alignment pin holes 124. In some embodiments, the device body 402 is configured similarly to the device body 212. However, the device body 402 does not require the reference points 216 to measure an angle of the alignment pin holes 124, as described below.

[0082] The ferrule alignment portion 404 is defined by the device body 402 and configured to receive and arrange the ferrule 100 at a predetermined position. Similarly to the ferrule alignment portion 214 of the offset measuring device 210, the ferrule alignment portion 214 operates to always arrange the ferrule 100 in the same position, thereby allowing the alignment pin holes 124 to be reliably measured relative to at least one of the references surfaces 202, 204 and 206.

[0083] The measuring pins 406 are configured to be inserted into the alignment pin holes 124, respectively. In some embodiments, the measuring pin 406 is dimensioned to be interference-fit into the alignment pin hole 124. As described in FIGS. 15A and 15B, the measuring pin 406 is slidably engaged within the alignment pin hole 124.

[0084] FIGS. 15A and 15B illustrate a method of measuring an angle of the alignment pin hole 124 relative to at least one of the reference surfaces 202, 204 and 206 of the ferrule 100. For clarify purposes, the device body 402 is not illustrated in FIGS. 15A and 15B. Once secured to the device body 402, the ferrule 100 stays in the device body 402 throughout the measuring process, and does not have to be removed from the device body 402 during the measuring process, in contrast to the first example method as described in FIGS. 7-13.

[0085] When the ferrule 100 is secured in place within the device body 402, the measuring pin 406 is inserted into the alignment pin hole 124 in a first position, as illustrated in FIG. 15A. In some embodiments, the measuring pin 406 is arranged to protrude from the end face 120 of the ferrule 100 at a first length (L1) in the first position, as illustrated in FIG. 15A. Then, a position of the measuring pin 406 (e.g., a center C_M of the measuring pin 406 or an axis A_M of the measuring pin 406) is measured (i.e., a first position measurement (P1)) relative to a predetermined reference. Once the first position of the measuring pin 406 is detected, the measuring pin 406 is displaced within the alignment pin hole 124 into a second position, as illustrated in FIG. 15B. In some embodiments, the measuring pin 406 is arranged to protrude from the end face 120 of the ferrule 100 at a second length (L2) different from the first length (L1). The first and second lengths (L1 and L2) can be measured with respect to any preset reference, and the difference (L1-L2) between the first and second lengths is used as described below. In the illustrated example of FIG. 15B, the second length (L2) is determined to be zero, and therefore, the measuring pin 406 is pushed toward the alignment pin hole 124 so as to be flush with the end face 120 of the ferrule 100. In other embodiments, the second length (L2) is positive so that the measuring pin 406 extends from the end face 120 of the ferrule 100. In yet other embodiments, the second length (L2) is negative so that the measuring pin 406 is pushed back into the alignment pin hole 124. Once the measuring pin 406 has been moved within the alignment pin hole 124, a position of the measuring pin 406 is again measured (i.e., a second position measurement (P2)) relative to the predetermined reference used for the first position measurement (P1) above.

[0086] In some examples, the measuring pin 406 includes a through-hole 408 that is used as a reference to measure the position of the measuring pin 406 in the first and second positions. In the illustrated example, the through-hole 408 is configured to be concentric to the measuring pin 406 (i.e., aligned with the center C_M or the axis A_M of the measuring pin 406). In other examples, however, the through-hole 408 can be off the center C_M or the axis A_M of the measuring pin 406. For example, the off-centric through-hole 408 can be used as a reference for measuring the positions of the measuring pin 406 while the orientation of the measuring pin 406 remains the same in the first and second positions. Other configurations of the through-hole 408 of the measuring pin 406 can be used in still other examples. In yet other examples, other reference features can be provided to the measuring pin 406.

[0087] FIG. 16 illustrates a method of calculating a tilt angle of the alignment pin hole 124. After the first and second positions are measured as illustrated in FIGS. 15A and 15B, the angle of the alignment pin hole 124 can be calculated a change in the alignment pin hole 124, using trigonometric functions. For example, the first position measurement (P1) (e.g., obtained from the center C_M of the measurement pin 406), the second position measurement (P2) (e.g., obtained from the center C_M of the measurement pin 406), and a difference (L1-L2) between the first and second length (L1 and L2) are used to calculate the angle (A) of the alignment pin hole 124 as follows:

$$A = \sin^{-1}\left(\frac{L1-L2}{P1-P2}\right).$$

[0088] Other methods of calculating the angle of the alignment pin hole 124 is also possible in other embodiments.

[0089] FIG. 17 schematically illustrates an example of the offset measuring device 210 and the offset measuring device 400. In particular, the offset measuring device 210 and the offset measuring device 400 includes a clamping device 420 configured to hold the ferrule 100 within the ferrule alignment portions 214 and 404 defined by the device bodies 212 and 402, respectively. An example method of securing the ferrule 100 into the ferrule alignment portion 214 and 404 is illustrated with reference to FIGS. 11-13.

[0090] The various examples and teachings described above are provided by way of illustration only and should not be construed to limit the scope of the present disclosure. Those skilled in the art will readily recognize various modifications and changes that may be made without following the example examples and applications illustrated and described herein, and without departing from the true spirit and scope of the present disclosure.

WHAT IS CLAIMED IS:

1. A method of determining an angle of a guide pin hole of a fiber optic ferrule relative to at least one reference surface of the ferrule, the method comprising:

placing the ferrule in an offset measuring device to arrange the at least one reference surface of the ferrule at a predetermined position of the offset measuring device;

determining a first position of the guide pin hole at a forward end face of the ferrule relative to a reference point formed in the offset measuring device;

removing a predetermined amount of material from the ferrule at the forward end face to form a butt end face of the ferrule;

placing the ferrule in the offset measuring device to arrange the at least one reference surface of the ferrule at the predetermined position of the offset measuring device;

determining a second position of the guide pin hole at the butt end face of the ferrule relative to the reference point formed in the offset measuring device; and

calculating an angle of the guide pin hole of the ferrule based upon the first and second positions of the guide pin hole.

2. The method of claim 1, wherein the steps of placing the ferrule in the offset measuring device comprise:

arranging the at least one reference surface of the ferrule against at least one positioning surface of the offset measuring device.

3. The method of claim 2, wherein arranging the at least one reference surface of the ferrule against at least one positioning surface of the offset measuring device comprises:

arranging a first reference surface of the ferrule against a first positioning surface of the hole inclination measuring device, the first reference surface being a first surface of the ferrule;

arranging a second reference surface of the ferrule against a second positioning surface of the hole inclination measuring device, the second reference surface being a second surface of the ferrule, the second surface being not parallel with the first surface of the ferule; and arranging a third reference surface of the ferrule against a third positioning surface of the hole inclination measuring device, the third reference surface being a third surface of the ferrule, the third surface being not parallel with the first and second surfaces of the ferrule.

4. The method of claim 3, wherein:

the first reference surface of the ferrule is a first main surface of a ferrule body opposite to a second main surface of the ferrule body through which an adhesive window is formed;

the second reference surface of the ferrule is a shoulder of an enlarged base, the enlarged base extending from an exterior surface of the ferrule body, and the shoulder being substantially parallel with the forward end surface of the ferrule; and

the third reference surface of the ferrule is a side surface of the ferrule body, the side surface being not parallel with the first main surface and the shoulder.

5. The method of claim 1, further comprising:

calculating an angle of a fiber hole of the ferrule relative to the guide pin hole.

6. The method of claim 5, wherein calculating an angle of a fiber hole of the ferrule relative to the guide pin hole comprises:

prior to removing a predetermined amount of material from the ferrule at the forward end face to form a butt end face of the ferrule, determining a first offset distance of the fiber hole relative to the guide pin hole at the forward end face of the ferrule;

after removing a predetermined amount of material from the ferrule at the forward end face to form a butt end face of the ferrule, determining a second offset distance of the fiber hole relative to the guide pin hole at the butt end face of the ferrule; and

calculating an angle of the fiber hole of the ferrule based upon the first and second offset distances of the fiber hole.

7. A system for measuring an angle of an alignment pin hole of a fiber optic ferrule, the system comprising:

a body configured to place the ferrule therein;

a ferrule alignment portion defined by the body and configured to arrange the ferrule in a same position every time that the ferrule is placed in the body; and

a reference point formed in the body and used to measure a position of the alignment pin hole on an end face of the ferrule therefrom.

8. The system of claim 7, wherein the ferrule alignment portion has at least one positioning surface configured to arrange at least one reference surface of the ferrule at a predetermined position relative to the body.

9. The system of claim 8, wherein:

the ferrule alignment portion has a first positioning surface, a second positioning surface, and a third positioning surface; and

when the ferrule is placed in the ferrule alignment portion, the first positioning surface is substantially abutted with a first reference surface of the ferrule, the second positioning surface is substantially abutted with a second reference surface of the ferrule, and the third positioning surface is substantially abutted with a third reference surface of the ferrule.

10. The system of claim 9, wherein the first, second, and third positioning surfaces are arranged to be not parallel with one another.

11. The system of claim 7, wherein the reference point is a hole formed in the body adjacent the ferrule alignment portion.

12. The system of claim 7, wherein the fiber optic ferrule comprises:

a ferrule body extending between a forward end and a rearward end and having a first main surface, a second main surface, and opposite side surfaces, the second main surface being opposite to the first main surface;

a forward end face defined by the ferrule body at the forward end and configured to be polished to form a butt end face;

one or more fiber holes defined in the ferrule body and configured to receive one or more optical fiber, respectively, the fiber holes being open at the forward end face;

one or more alignment pin holes being open at the forward end face and configured to receive one or more guide pins, respectively, to align two mating ferrules; and

an enlarged base provided to the rearward end of the ferrule body and extending from an exterior surface of the ferrule body, the enlarged base having a shoulder being substantially parallel with the forward end face.

13. The system of claim 12, wherein the fiber optic ferrule further comprises:

an adhesive window provided on the first main surface of the ferrule body and configured to receive adhesive to fix the optical fibers to the fiber holes.

14. The system of claim 12, wherein the fiber optic ferrule has at least one reference surface configured to be abutted with at least one positioning surface defined by the ferrule alignment portion.

15. The system of claim 14, wherein the fiber optic ferrule has a first reference surface, a second reference surface, and a third reference surface, the first reference surface being the second main surface of the ferrule body, the second reference surface being the shoulder, and the third reference surface being one of the side surfaces of the ferrule body.

16. A method of determining an angle of a guide pin hole of a fiber optic ferrule relative to at least one reference surface of a ferrule, the method comprising:

placing the ferrule in an offset measuring device to arrange the at least one reference surface of the ferrule at a predetermined position of the offset measuring device;

inserting a measuring pin into the guide pin hole in a first position;

determining a position of the measuring pin to generate a first position measurement of the measuring pin;

displacing the measuring pin within the guide pin hole into a second position;

determining a position of the measuring pin to generate a second position measurement of the measuring pin; and

calculating an angle of the guide pin hole of the ferrule based upon the first and second position measurements and a difference between the first and second positions of the measuring pin.

17. The method of claim 16, wherein:

the measuring pin is arranged to protrude from an end face of the ferrule at a first length in the first positon, and protrude from the end face of the ferrule at a second length in the second position; and

the difference between the first and second positions is defined as a difference between the first and second lengths.

18. A system for measuring an angle of a guide pin hole of a fiber optic ferrule, the system comprising:

a body configured to place the ferrule therein;

a ferrule alignment portion defined by the body and configured to arrange the ferrule in a predetermined position; and

a measuring pin configured to be inserted into the guide pin hole of the ferrule and configured to be arranged in a first position and a second position different from the first position, the measuring pin detectable in the first and second positions to provide first and second position measurements thereof.

19. The system according to claim 18, wherein the measuring pin is arranged to protrude from an end face of the ferrule at a first length in the first position, and protrude from an end face of the ferrule at a second length in the second position.

20. The system according to claim 18 or 19, wherein the measuring pin is interference-fit into the guide pin hole.

21. The system according to any one of claims 18-20, wherein the ferrule alignment portion has at least one positioning surface configured to arrange at least one reference surface of the ferrule at a predetermined position relative to the body.

22. The system according to claim 21, wherein the at least one reference surface of the ferrule includes a shoulder of the ferrule.

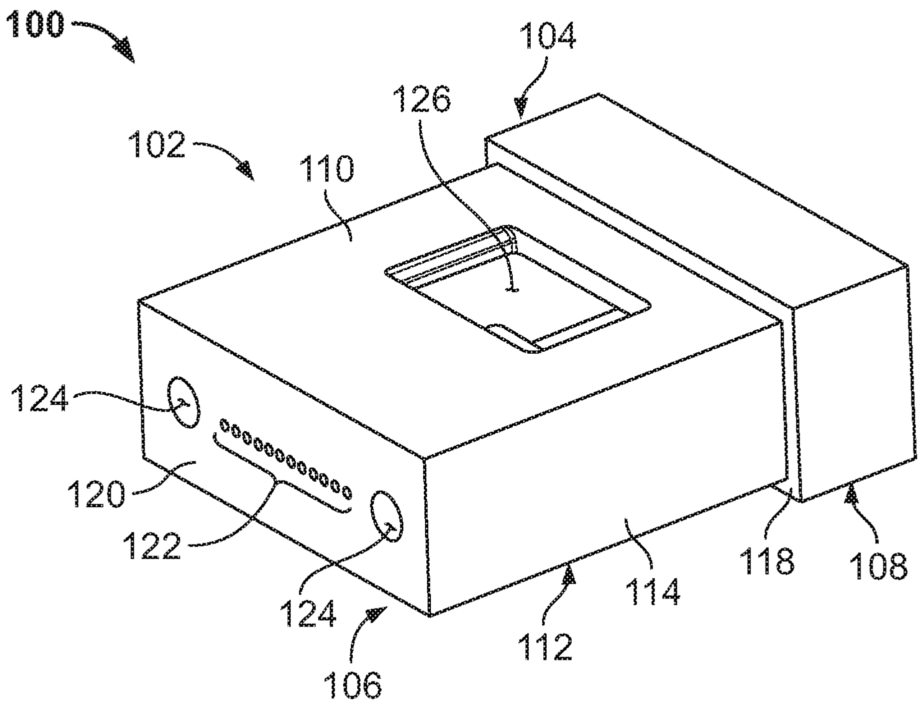


FIG. 1

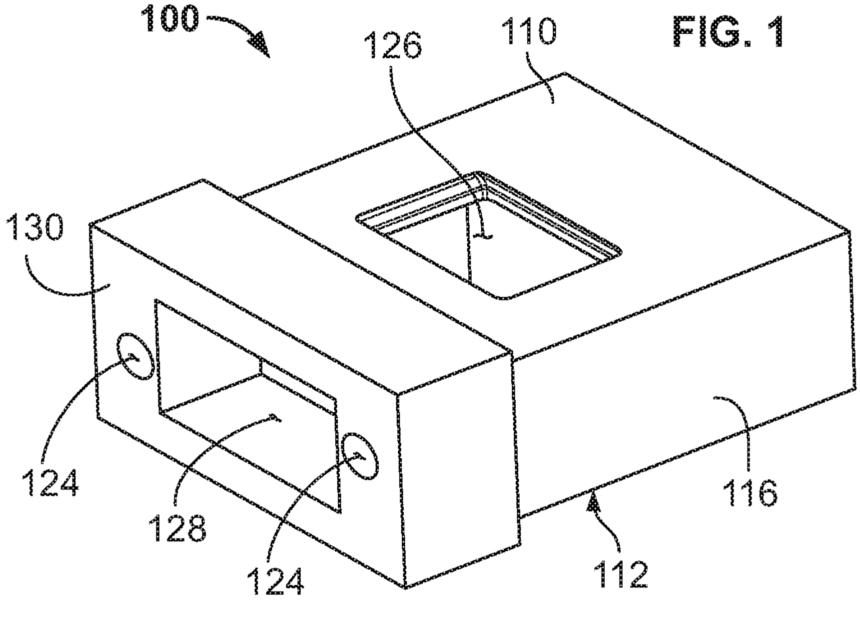


FIG. 2

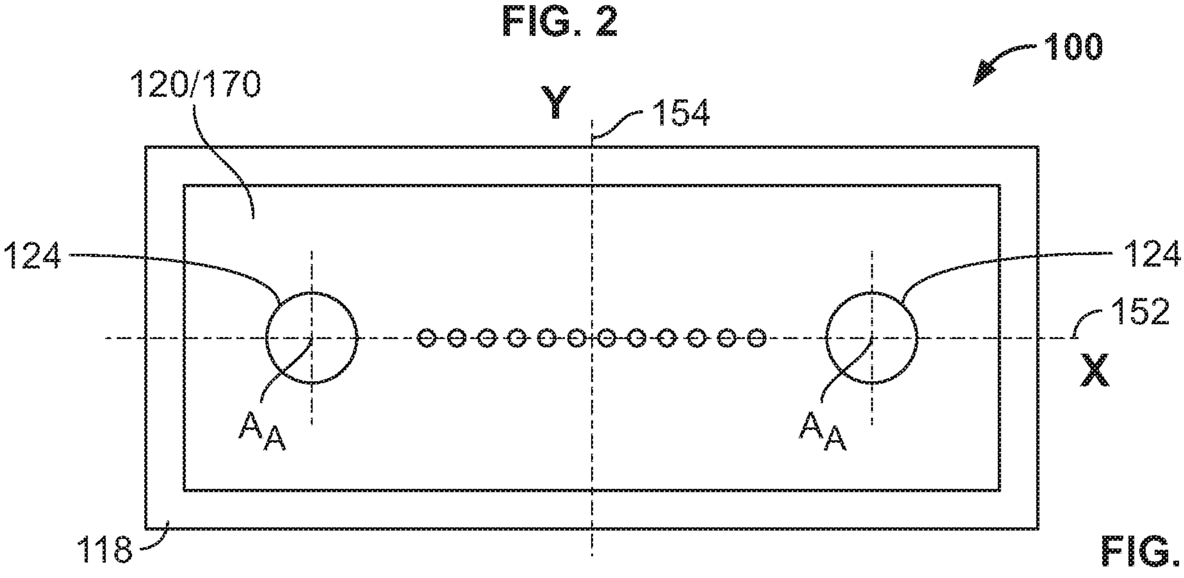


FIG. 3

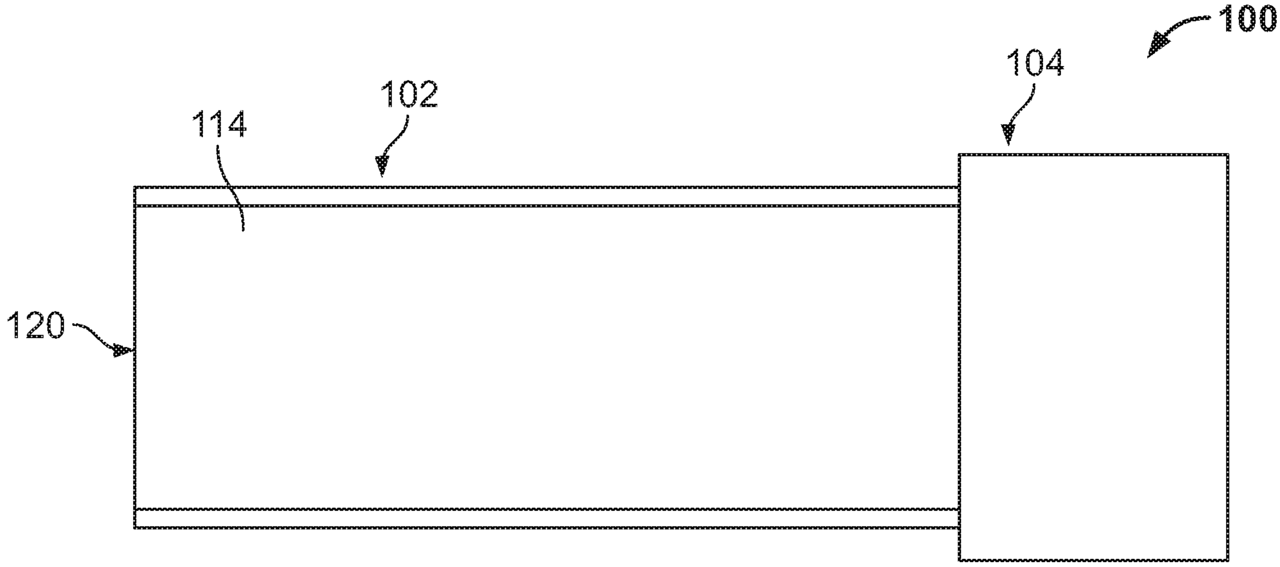


FIG. 4A

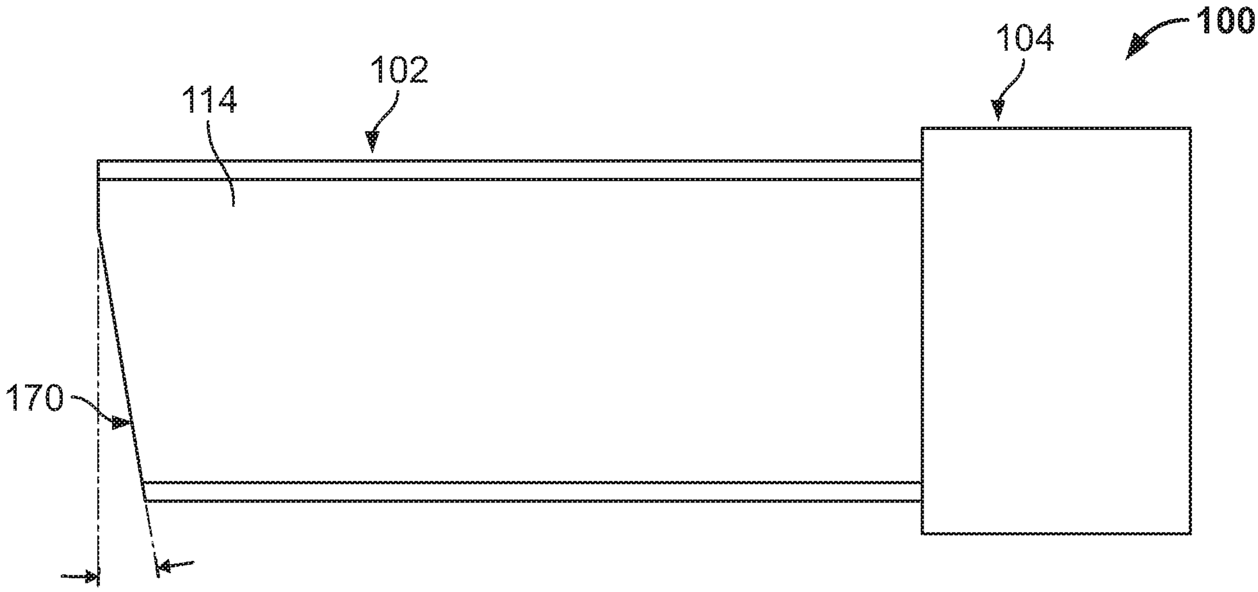


FIG. 4B

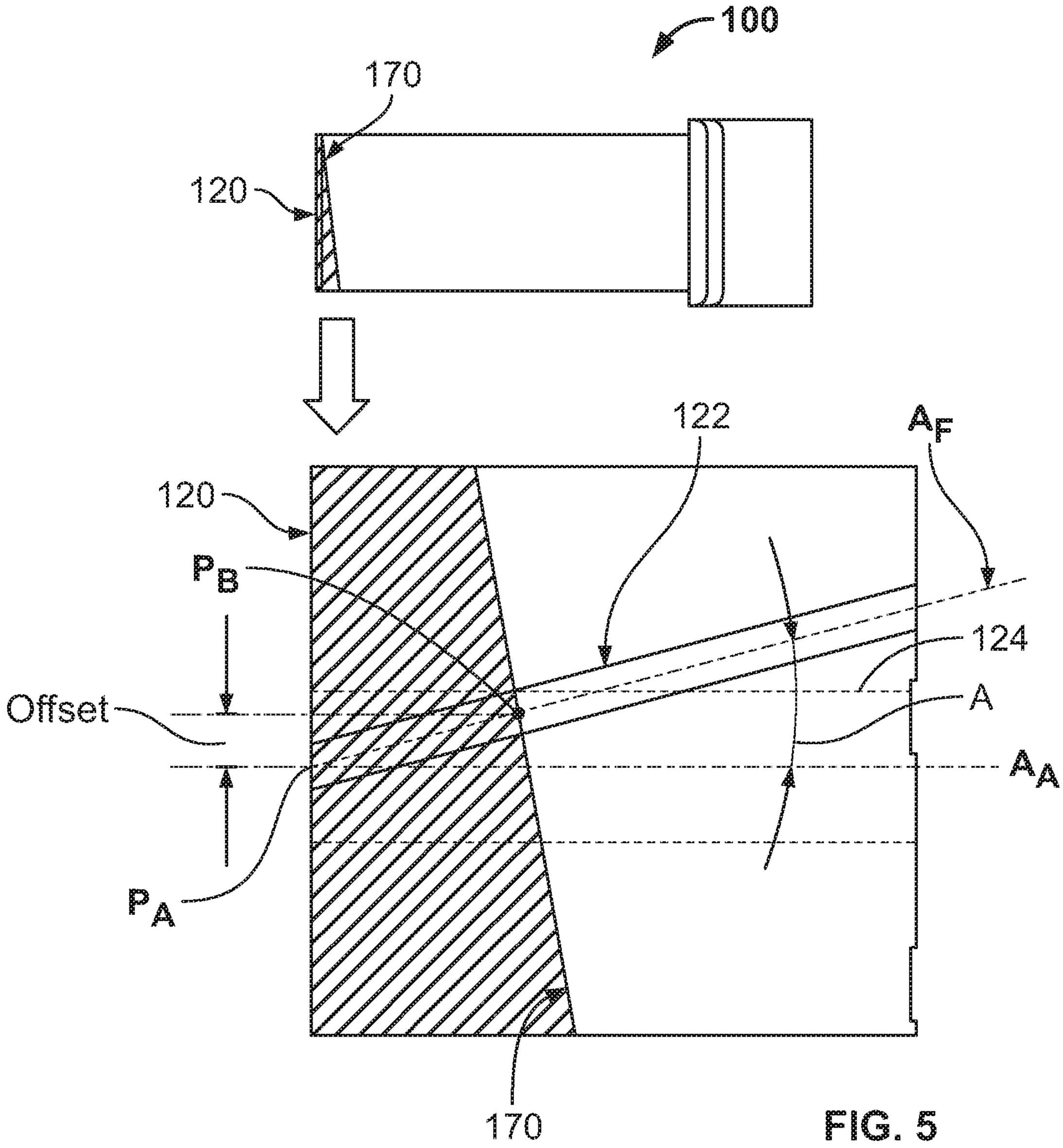

100
170
120
120
122
A_F
P_B
124
Offset
A
A_A
P_A
170

FIG. 5

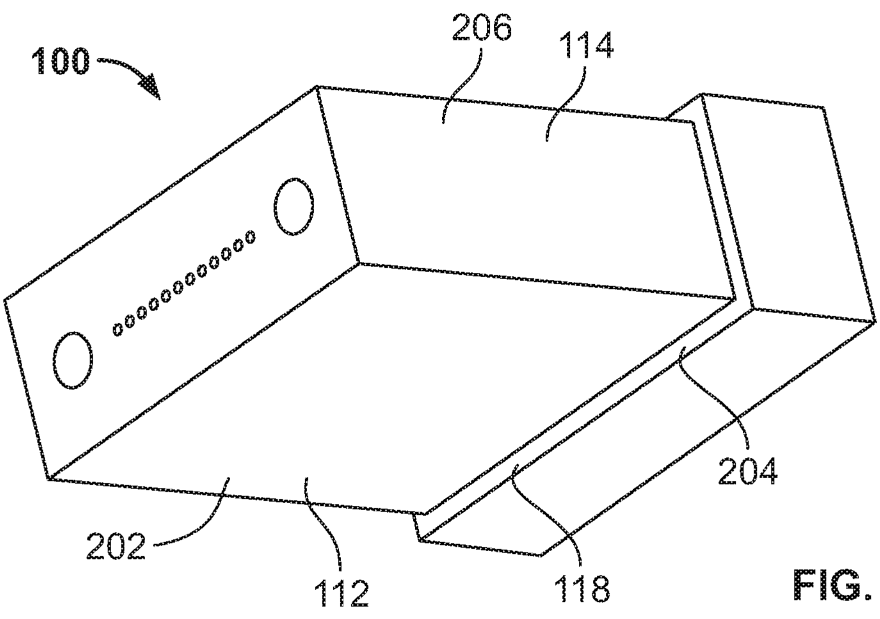

100
206
114
204
202
112
118

FIG. 6

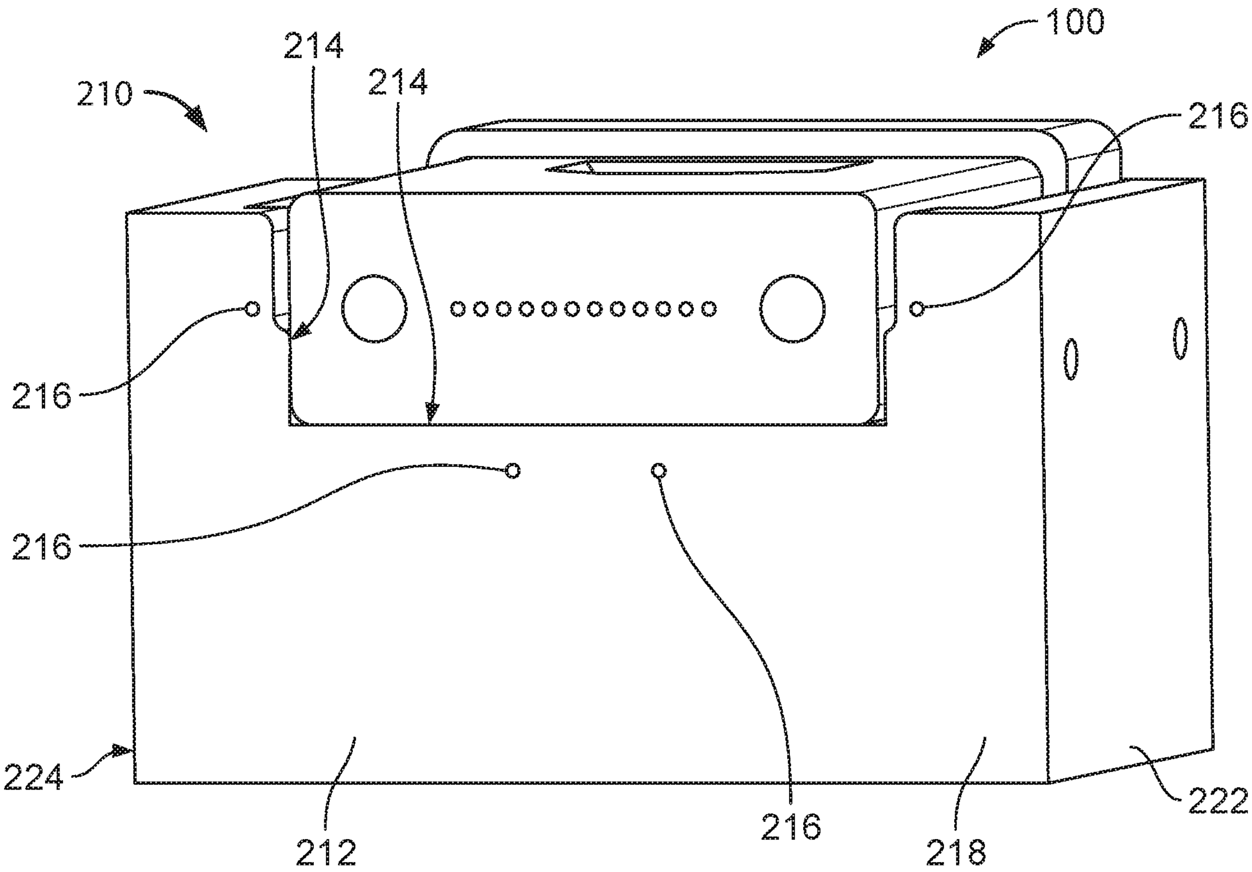

100
210
214
214
216
216
216
216
224
212
216
218
222

FIG. 7

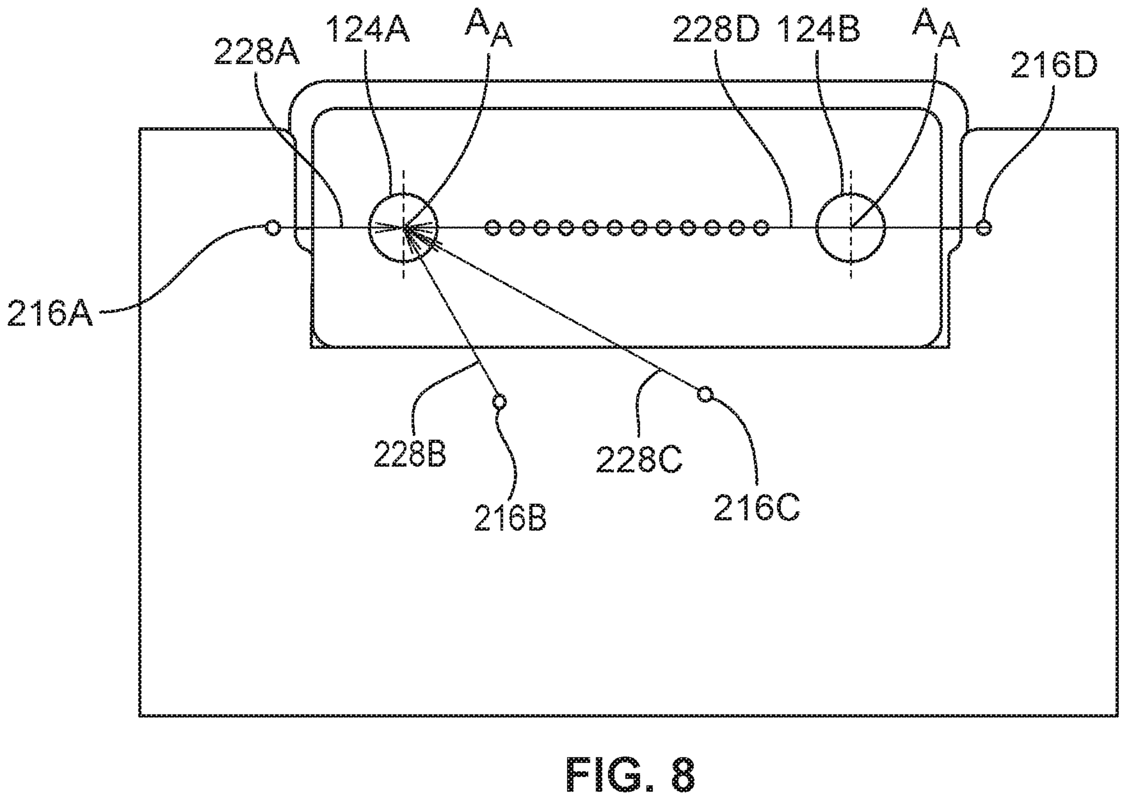

228A
124A
A_A
228D
124B
A_A
216D
216A
228B
228C
216B
216C

FIG. 8

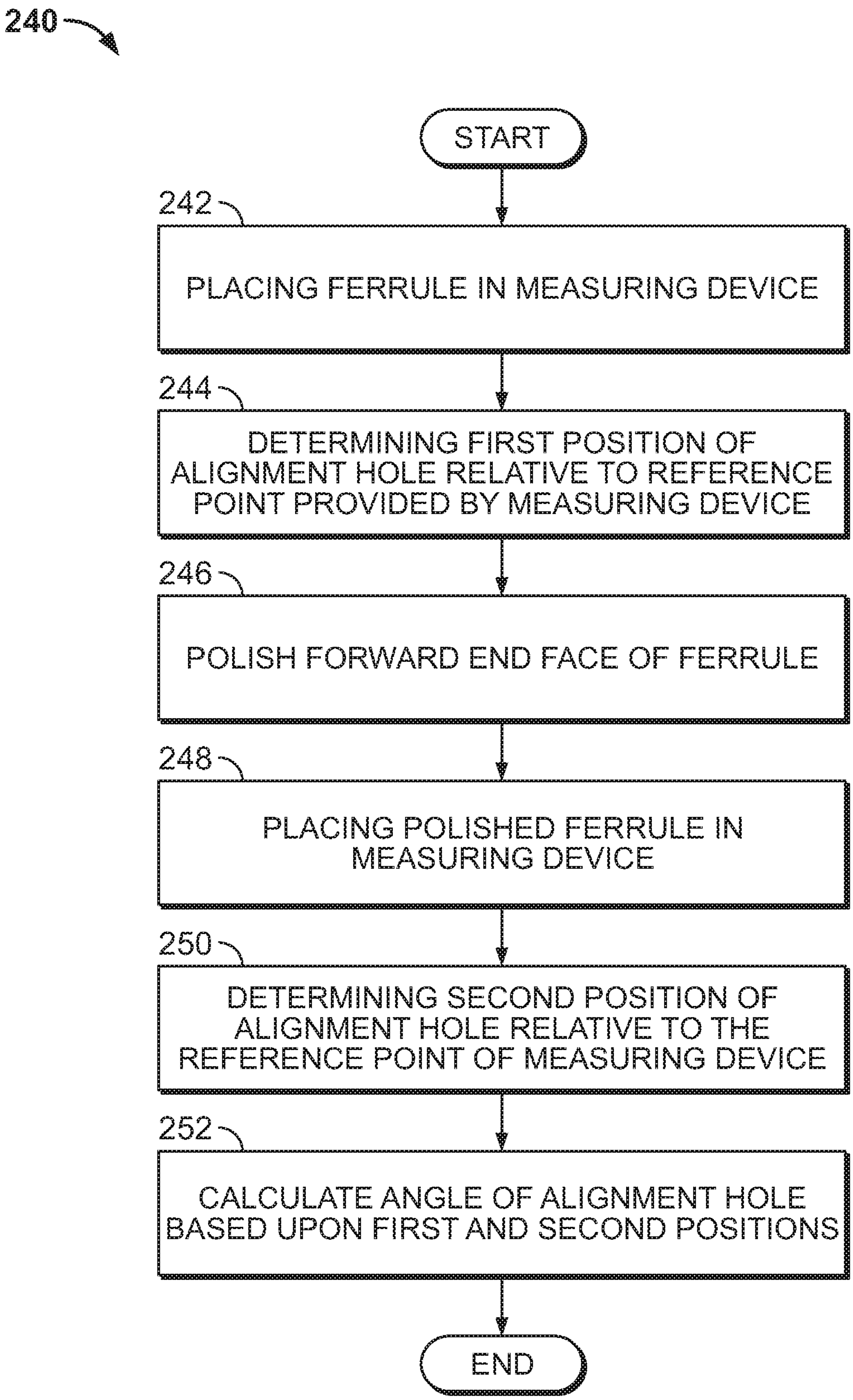

240
START
242
PLACING FERRULE IN MEASURING DEVICE
244
DETERMINING FIRST POSITION OF ALIGNMENT HOLE RELATIVE TO REFERENCE POINT PROVIDED BY MEASURING DEVICE
246
POLISH FORWARD END FACE OF FERRULE
248
PLACING POLISHED FERRULE IN MEASURING DEVICE
250
DETERMINING SECOND POSITION OF ALIGNMENT HOLE RELATIVE TO THE REFERENCE POINT OF MEASURING DEVICE
252
CALCULATE ANGLE OF ALIGNMENT HOLE BASED UPON FIRST AND SECOND POSITIONS
END

FIG. 9

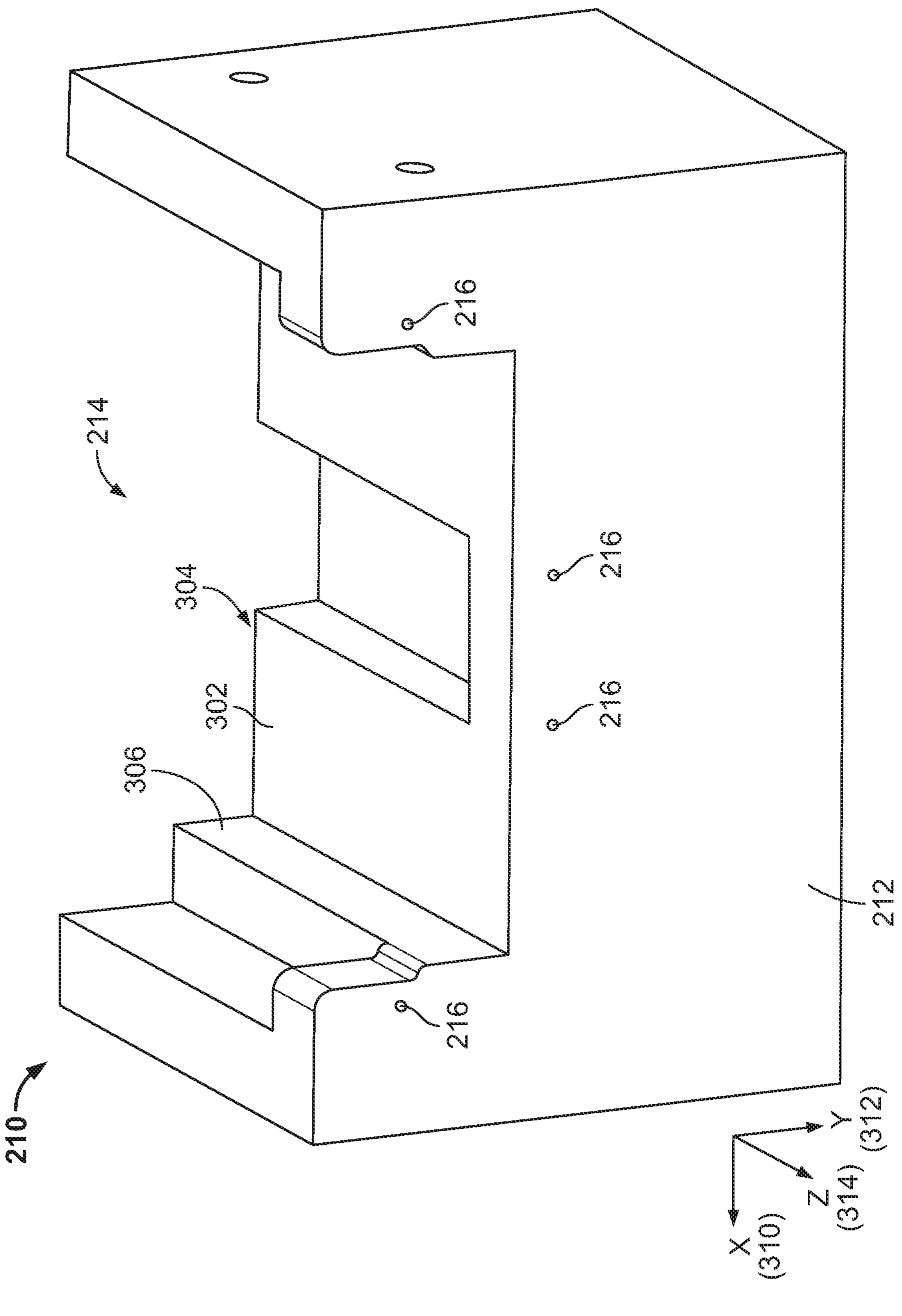


FIG. 10

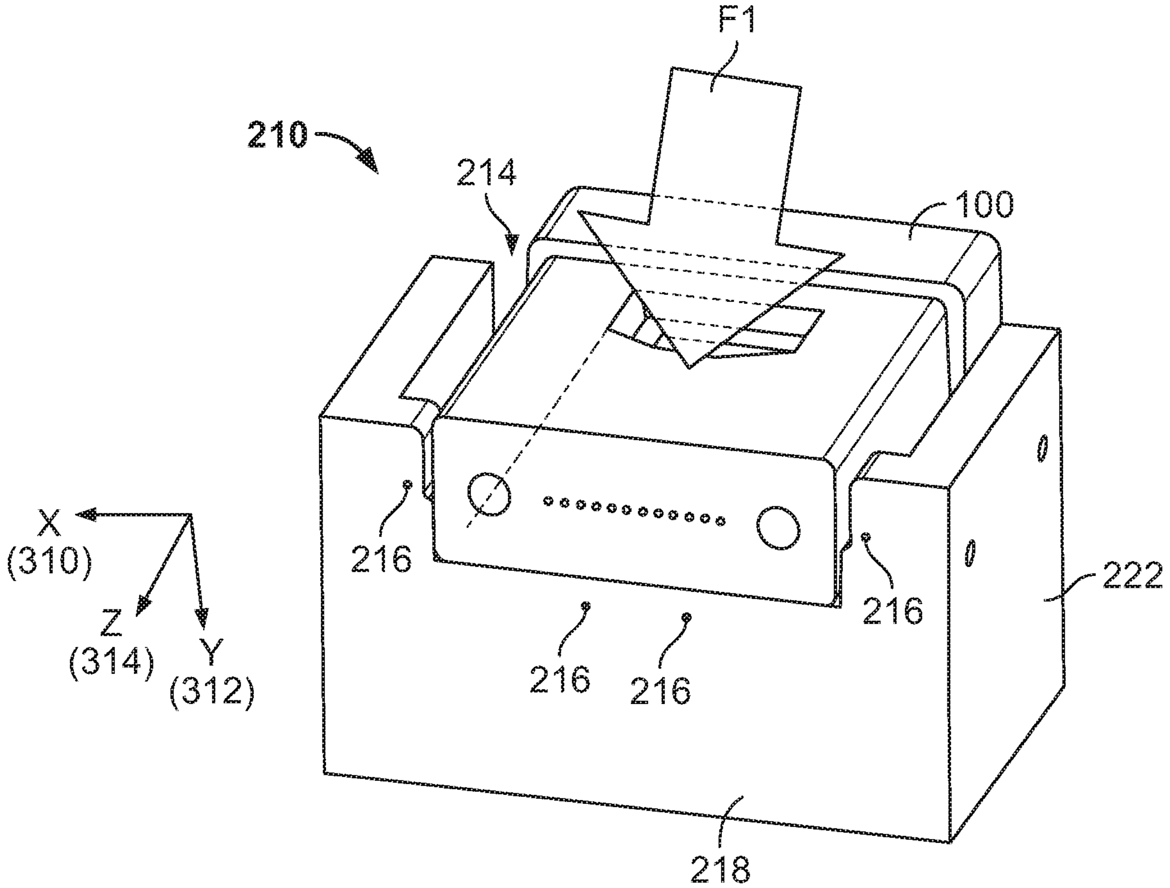

F1
210
214
100
X
(310)
Z
(314)
Y
(312)
216
216
216
216
222
218

FIG. 11

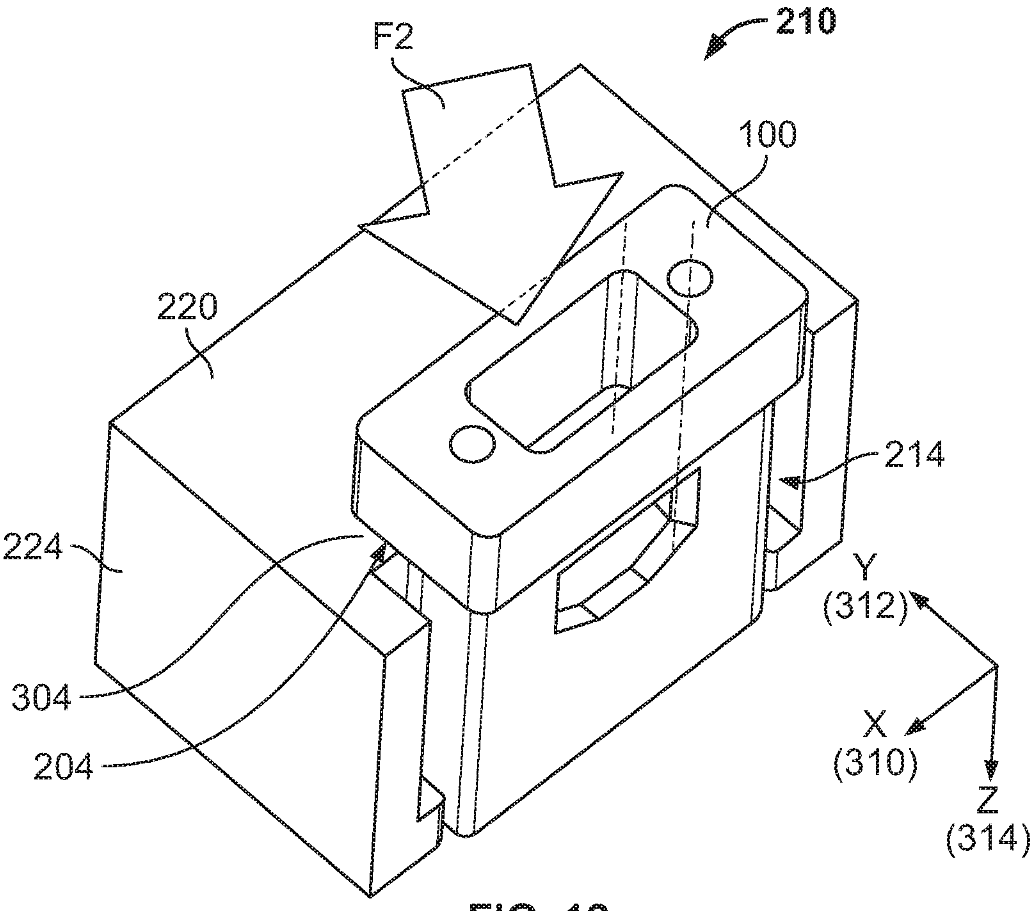
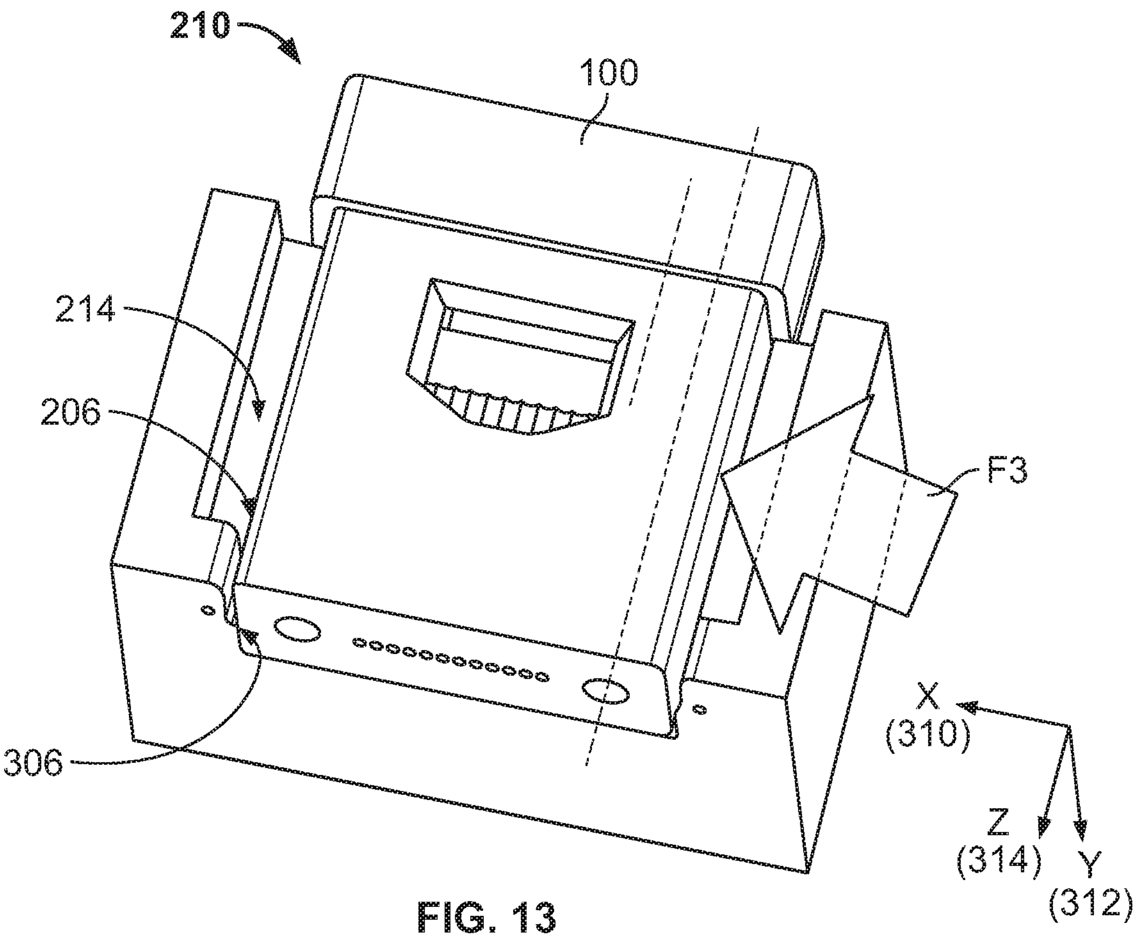

F2
210
100
220
214
224
304
204
Y
(312)
X
(310)
Z
(314)

FIG. 12


210
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214
206
306
F3
X
(310)
Z
(314)
Y
(312)

FIG. 13

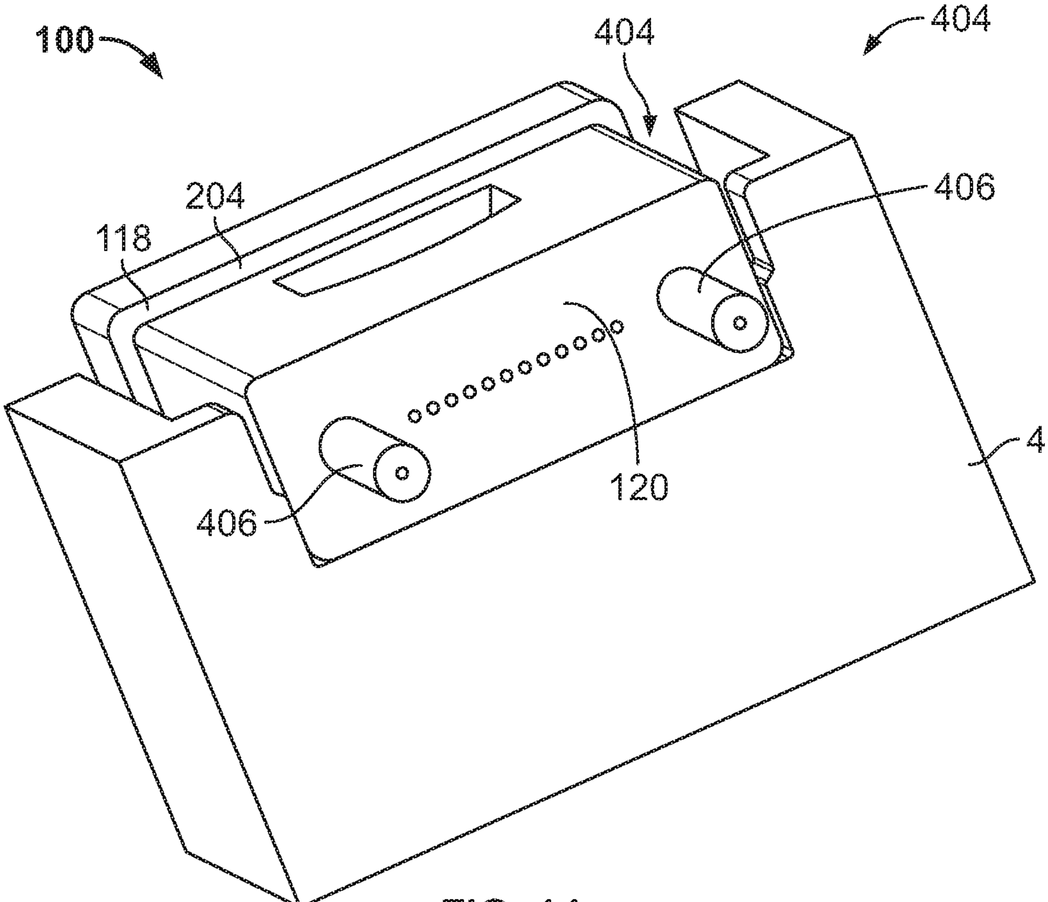
100
404
404
204
118
406
120
406
402

FIG. 14

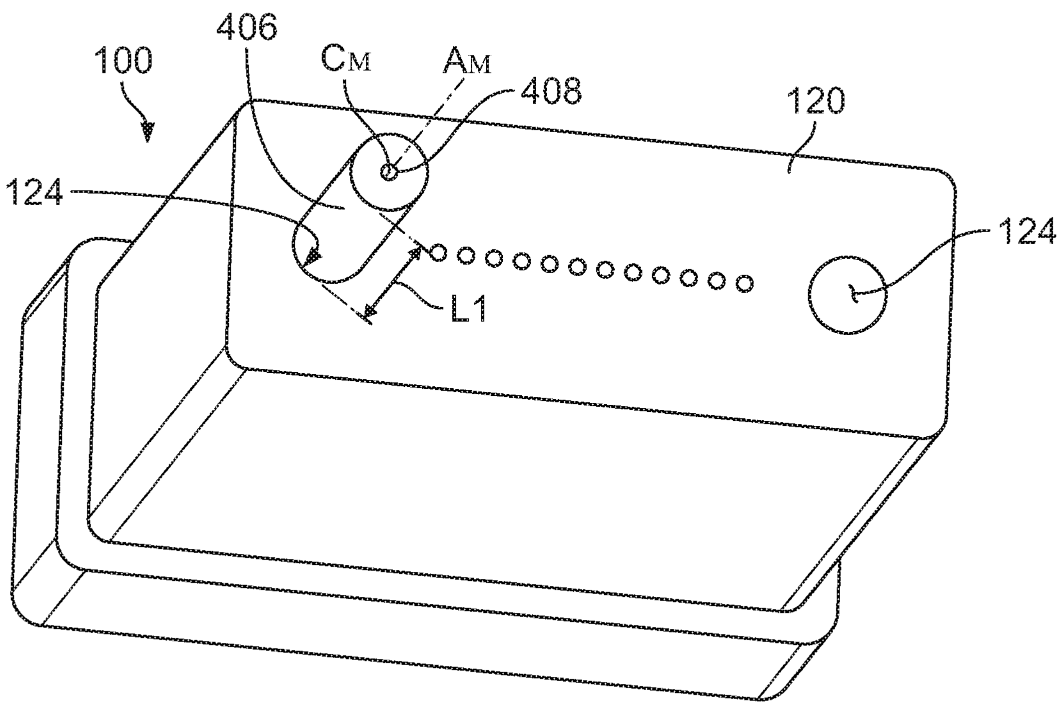

FIG. 15A

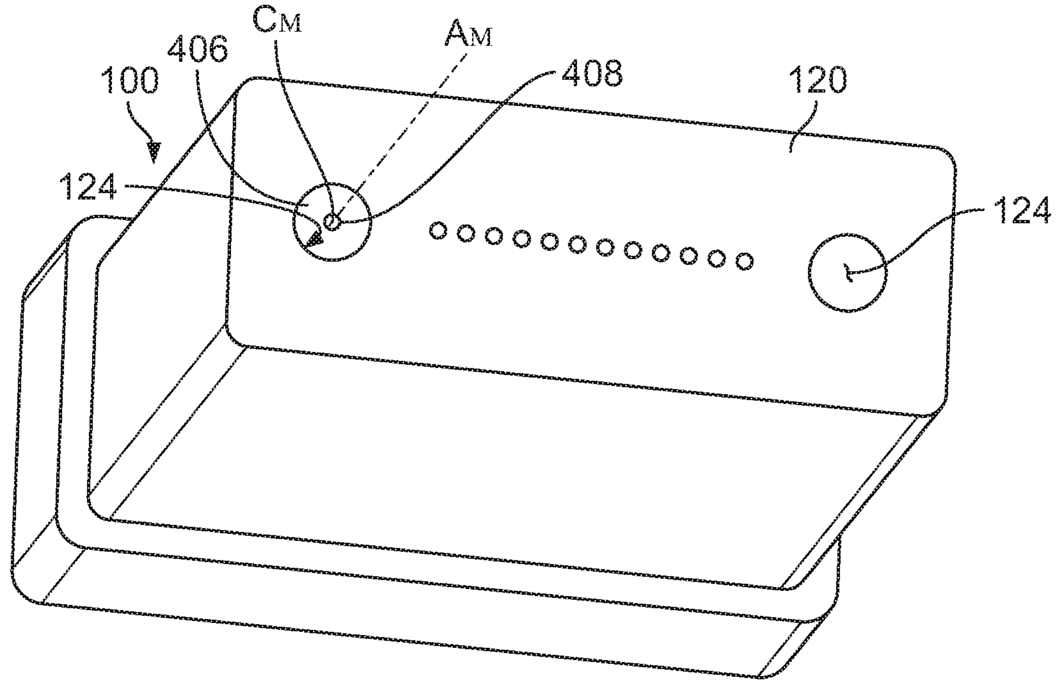

FIG. 15B

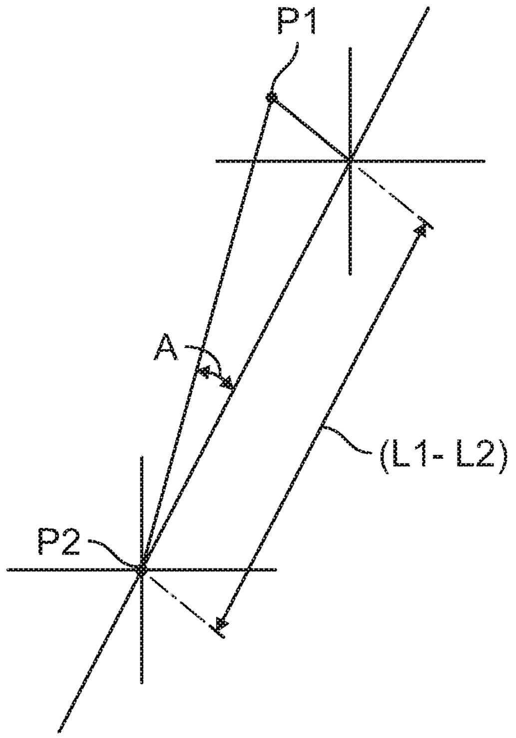

FIG. 16

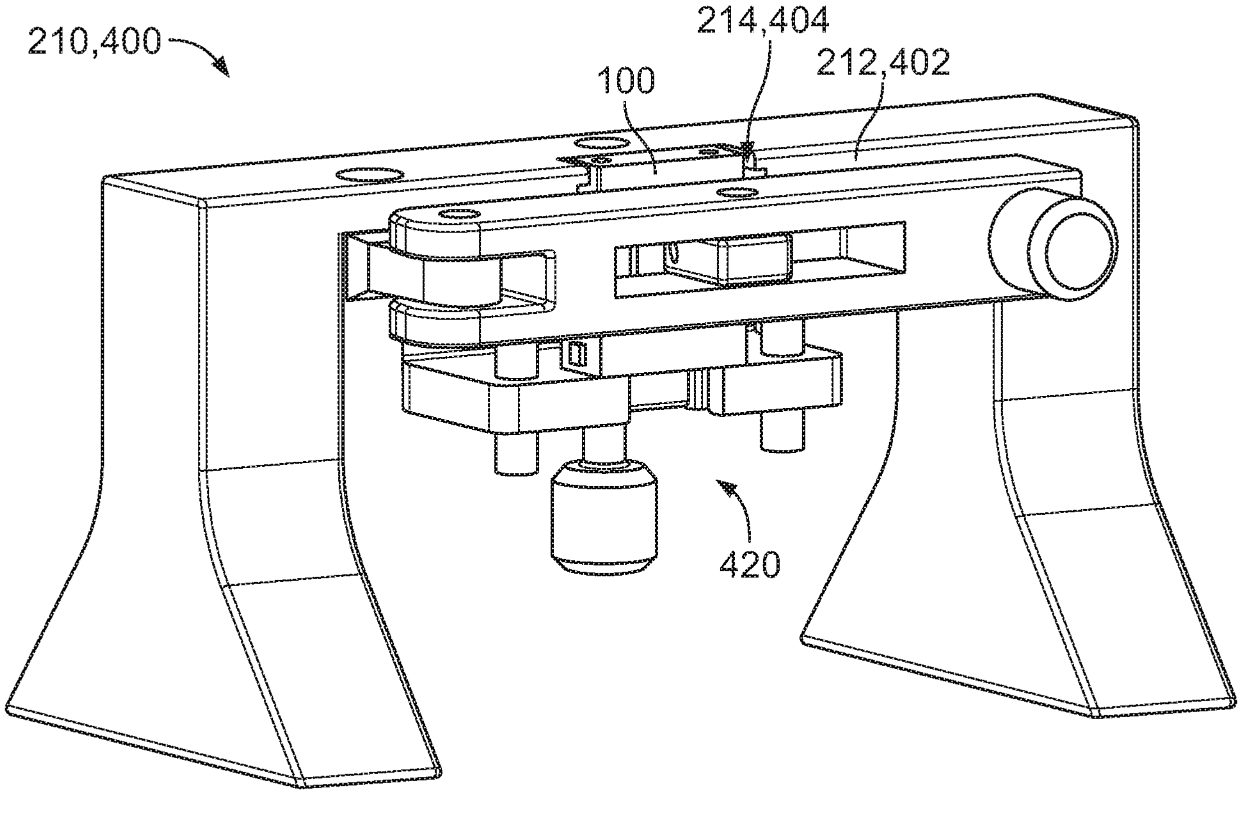

FIG. 17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/026455

A. CLASSIFICATION OF SUBJECT MATTER

G02B 6/40(2006.01)i, G02B 6/38(2006.01)i, G02B 6/27(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 6/40; G02B 6/38; G01N 21/01; G01M 11/00; B29D 11/00; G02B 6/36; G02B 6/27

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: measure, alignment, pin, hole, fiber, optic

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2008-0205824 A1 (JOSEPH TODD CODY et al.) 28 August 2008 See paragraphs [0004],[0031] and claim 1.	1-20
Y	US 2011-0228259 A1 (JEROEN ANTONIUS MARIA DUIS et al.) 22 September 2011 See paragraphs [0025]-[0026],[0029],[0031],[0040],[0046] and figure 6.	1-20
A	US 2002-0126961 A1 (KEN HIRABAYASHI et al.) 12 September 2002 See abstract and claims 1-5.	1-20
A	US 2011-0229090 A1 (MICAH C. ISENHOUR et al.) 22 September 2011 See abstract, claims 1-3 and figure 10.	1-20
A	EP 0488633 A2 (THE FURUKAWA ELECTRIC CO., LTD.) 03 June 1992 See abstract and claims 1-2.	1-20

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 July 2016 (25.07.2016)	**25 July 2016 (25.07.2016)**

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
Facsimile No. +82-42-481-8578

Authorized officer
KANG, Sung Chul
Telephone No. +82-42-481-8405

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/026455

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

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

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

2. ☒ Claims Nos.: 22
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claim 22 is regarded to be unclear because the claim refers to multiple dependent claim which does not comply with PCT Rule 6.4(a).

3. ☒ Claims Nos.: 21
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

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

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

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

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

Remark on Protest

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

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

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2016/026455

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