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(71) Applicant: **3M INNOVATIVE PROPERTIES COMPANY** [US/US]; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

(72) Inventors: **LEE, Nicholas A.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **HAASE, Michael A.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

(74) Agent: **MOSHREFZADEH, Robert, S.** et al.; 3M Center, Office of Intellectual Property Counsel, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

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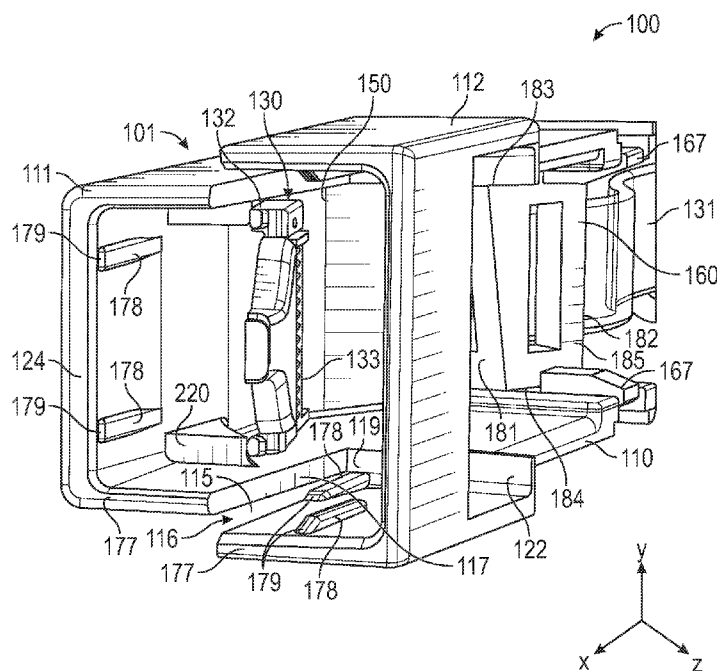


FIG. 1A

(57) Abstract: An optical assembly includes a hermaphroditic cassette comprising a hood that includes a narrower section and a wider section. The narrower and wider sections are separated by slots such that the narrower section fits at least partially within a wider section of an identical mating hood of a mating optical assembly and the wider section receives a narrower section of the mating hood. The hood has first and second stop features configured to engage with second and first stop features of the mating hood. The first stop feature comprises a mating end of the narrower section of the hood and the second stop feature comprises a stop surface disposed within the wider section of the hood. Engagement of the stop features of the hood with stop features of the mating hood is configured to stop relative translational movement of the hood and the mating hood along the mating axis during mating.

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OPTICAL ASSEMBLY WITH CASSETTE**TECHNICAL FIELD**

This disclosure relates generally to optical ferrules, optical assemblies, and optical connectors
5 that include optical ferrules.

BACKGROUND

Optical connectors can be used for optical communications in a variety of applications including telecommunications networks, local area networks, data center links, and internal links in computer
10 devices. There is interest in extending optical communication to applications inside smaller consumer electronic appliances such as laptops and even cell phones. Expanded optical beams may be used in connectors for these systems to provide an optical connection that is less sensitive to dust and other forms of contamination and so that alignment tolerances may be relaxed. Generally, an expanded beam is a beam that is larger in diameter than the core of an associated optical waveguide (usually an optical fiber,
15 e.g., a multi-mode fiber for a multi-mode communication system). The connector is generally considered an expanded beam connector if there is an expanded beam at a connection point. The expanded beam is typically obtained by diverging a light beam from a source or optical fiber. In many cases, the diverging beam is processed by optical elements such as a lens or mirror into an expanded beam that is approximately collimated. The expanded beam is then received by focusing of the beam via another lens
20 or mirror.

BRIEF SUMMARY

Embodiments are directed to optical assemblies that include optical ferrule cassettes and to tools and methods for installing optical ferrule subassemblies into the cassettes.

25 According to some embodiments an optical assembly includes a hermaphroditic cassette comprising a hood that includes a narrower section and a wider section. The narrower and wider sections are separated by slots such that the narrower section fits at least partially within a wider section of an identical mating hood of a mating optical assembly and the wider section receives a narrower section of the mating hood. The hood has first and second stop features configured to engage with second and first
30 stop features of the mating hood. The first stop feature comprises a mating end of the narrower section of the hood and the second stop feature comprises a stop surface disposed within the wider section of the hood. Engagement of the stop features of the hood with stop features of the mating hood is configured to stop relative translational movement of the hood and the mating hood along the mating axis during mating.

35 According to some aspects, each slot has an opening at a mating end of the hood and slot walls that extend to an end of the slot. Engagement of the stop features of the hood with stop features of the mating hood is configured to stop relative translational movement of the hood and the mating hood along the mating axis during mating before the ends of the first and second slots make contact with ends of the first and second slots of the mating hood.

Some embodiments are directed to an optical ferrule subassembly that comprises at least one optical waveguide. An optical ferrule is attached to the optical waveguide at a first location of the optical waveguide. A cable retainer attached to the optical waveguide at a second location of the optical waveguide. The cable retainer has first and second opposing sides that are non-parallel with each other,
5 the non-parallel sides disposed across the optical waveguide.

In some embodiments, the cable retainer has first and second opposing sides that extend laterally across the optical waveguide and third and fourth opposing sides that extend between the first and second sides, wherein the third side is shorter than the fourth side.

Some embodiments involve an optical assembly that includes one or more optical ferrule subassemblies that each comprises at least one optical waveguide, an optical ferrule attached to the optical waveguide at a first location, and a cable retainer attached to the optical waveguide at a second location. The cable retainer has two opposing sides that are non-parallel with each other extending laterally across the optical waveguide and two opposing sides that extend between the non-parallel sides. The optical assembly further includes a cassette configured to hold the optical ferrule subassemblies. The
10 cassette comprises one or more retainer mounts. Each retainer mount is configured to receive a cable retainer of one optical ferrule subassembly.

According to some embodiments, an optical assembly includes a cassette configured to contain one or more optical ferrule subassemblies. Each optical ferrule subassembly comprises at least one optical waveguide, an optical ferrule attached to the optical waveguide at a first location, and a cable
20 retainer attached to the optical waveguide at a second location. The cable retainer has two opposing sides that are non-parallel with each other extending laterally across the optical waveguide, and two opposing sides that extend between the two non-parallel sides. The cassette comprises one or more retainer mounts. Each retainer mount is configured to receive a cable retainer of at least one optical ferrule subassembly. Each retainer mount has a first surface extending from an inner wall of the cassette and
25 oriented at a non-perpendicular angle with respect to a mating axis of the cassette, the first surface configured to engage one of the non-parallel sides of the cable retainer.

In accordance with some embodiments, an optical assembly includes a cassette having sides that define an interior space configured to contain at least one optical ferrule subassembly. The at least one optical ferrule subassembly comprises at least one optical waveguide, an optical ferrule attached to the optical waveguide at a first location of the optical waveguide, and a cable retainer attached to the optical
30 waveguide at a second location of the optical waveguide. The cassette has one or more flexible latching members configured to hold the cable retainer within the interior space of the cassette.

Some embodiments are directed to an insertion tool for assembling an optical assembly that includes multiple optical ferrule subassemblies. The insertion tool has a base configured to support a
35 frame of the optical assembly. The frame is configured to hold one or more optical ferrule subassemblies. A plurality of teeth extend from the surface of the base. The teeth spaced apart from each other along a lateral axis of the base and have a pitch along the lateral axis that is equal to a pitch of the ferrule subassemblies of the frame.

Some embodiments involve an optical assembly that includes a frame configured to hold a plurality of ferrule subassemblies spaced apart from each other and disposed at least partially within an interior space of the frame. The frame has a base side extending from a mating end to an opposing non-mating end of the frame. Ferrule support features are spaced apart from each other along and proximate to a mating end of the frame. The ferrule support features are configured to support ferrules of optical ferrule subassemblies after the optical ferrule subassemblies are inserted into the frame and before mating with a mating optical assembly. The frame has holes in the base side spaced apart from each other along and proximate to the mating end of the frame. A pitch of the holes equal to a pitch of the ferrule support features.

A method of assembling ferrule subassemblies into a cassette involves inserting teeth of a ferrule installation tool into holes in a first side of the cassette. After inserting the teeth into the holes, optical ferrule subassemblies are placed into the cassette. Each optical ferrule subassembly has a ferrule attached to a first location of an optical waveguide and a cable retainer attached to a second location of an optical waveguide. Placement of each ferrule subassembly comprises positioning the ferrule in the cassette between adjacent pairs of teeth and positioning the cable retainer such that a side of the cable retainer engages with a surface extending from an inner surface of the cassette. Engagement of the cable retainer and the surface restricts motion of the cable retainer along a mating axis of the cassette.

According to some embodiments an assembly includes a frame configured to hold one or more optical ferrule subassemblies and a tool for installing multiple optical ferrule subassemblies into the frame. The frame includes a base side extending from a mating end to an opposing non-mating end of the frame. The base side has holes proximate the mating end and spaced apart from each other along the mating end. The installation tool comprises a base having a surface configured to support the frame. A plurality of teeth extend from the surface of the base and are spaced apart from each other along a lateral axis of the base. The teeth inserted into the holes in the frame.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1A is a perspective view of an optical assembly comprising a single piece cassette comprising a hood in accordance with some embodiments;

FIG. 1B is a perspective view of the hood of FIG. 1 absent the optical ferrule subassembly;

FIG. 2 is a perspective cut away view of the optical assembly of FIG. 1 after mating with a mating optical assembly;

FIGS. 3A and 3B are cutaway views of the hood before (FIG. 3A) and after (FIG. 3B) mating;

FIG. 4A shows an optical ferrule and identical mating optical ferrule suitable for use in an optical assembly that includes a cassette in accordance with some embodiments;

FIG. 4B is a cutaway view of a portion of optical ferrule focusing on the light redirecting member and attachment area in accordance with some embodiments;

FIG. 5 illustrates two mated optical ferrule subassemblies in accordance with some embodiments;

FIG. 6 is a top view of an optical ferrule subassembly comprising a trapezoidal cable retainer in accordance with some embodiments;

FIGS. 7 and 8 are perspective views that respectively illustrate two trapezoidal cable retainer configurations according to some embodiments;

FIG. 9 provides a perspective view of an optical assembly comprising a multi-piece cassette in accordance with some embodiments;

FIG. 10 is a perspective view of a ferrule installation tool in accordance with some embodiments;

FIG. 11 is an exploded illustration of a frame of a cassette that is suitable for being loaded with optical ferrule subassemblies using the ferrule installation tool of FIG. 10;

FIGS. 12A through 12D illustrate a process of loading optical ferrule subassemblies into a frame of a cassette in accordance with some embodiments;

FIG. 13 illustrates a ferrule installation tool having a lip in accordance with some embodiments.

FIGS. 14A and 14B illustrate insertion of a trapezoidal cable retainer of an optical ferrule subassembly into a retainer mount in accordance with some embodiments; and

FIGS. 15A and 15B illustrate insertion of a cable retainer having a curved side into a retainer mount in accordance with some embodiments.

The figures are not necessarily to scale. Like numbers used in the figures refer to like components. However, it will be understood that the use of a number to refer to a component in a given figure is not intended to limit the component in another figure labeled with the same number.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Embodiments described herein involve optical ferrules, optical assemblies, and optical connectors that include such optical ferrules. Optical ferrules used in many applications may be optically coupled to one waveguide or arrays of multiple parallel waveguides (typically 4, 8 or 12 or more parallel waveguides). The individual waveguides are typically made of glass with a protective buffer coating, and the parallel waveguides are enclosed by a jacket. Optical ferrules are useful for connecting optical waveguides to other optical waveguides or to optoelectronic components for in-line interconnects and/or printed circuit board (PCB) connections, e.g., backplane connections.

One type of ferrule is an expanded beam ferrule, in which light is coupled between waveguides in a beam that is larger in diameter than the core of an associated optical waveguide and typically somewhat less than the waveguide-to-waveguide pitch. The waveguides may comprise optical fibers, e.g., single-mode fibers for a single-mode communication system, or multi-mode fibers for a multi-mode communication system. These expanded beam optical ferrules can have non-contact optical coupling and can require reduced mechanical precision when compared with conventional optical ferrules.

Optical assemblies may include a cassette configured to hold one or more optical ferrule subassemblies that include an optical ferrule and at least one optical waveguide attached to the optical ferrule. The cassette can be a one-piece unit or a multi-piece unit. One or more cassettes can be mounted

within a connector housing. A cassette may provide mechanical protection and/or mating alignment for optical ferrule subassemblies mounted within the cassette.

Some embodiments described herein are directed to an optical assembly that includes a cassette and at least one optical ferrule subassembly. The cassette may comprise a hermaphroditic structure, referred to herein as a hood, which extends beyond the ends of the ferrules disposed within the cassette, thus protecting the ends of the ferrules from impact and abrasion.

FIG. 1A is a perspective view of an optical assembly **100** including a single piece cassette **101** comprising a hood **110**. An optical ferrule subassembly **130** is disposed within the hood **110**. FIG. 1B is a perspective view of the hood **110** absent the optical ferrule subassembly. FIG. 2 is a perspective cut away view of the optical assembly **100** after mating with a mating optical assembly **100m**. FIGS. 3A and 3B are cutaway views of the hood **110** before (FIG. 3A) and after (FIG. 3B) mating.

In the illustrated embodiments of FIGS. 1A through 3B, the single piece cassette **101** is a hood **110** that includes a narrower section **111** and a wider section **112**. As depicted in FIG. 1B, in some embodiments a first portion **111a** of the narrower section **111** extends beyond and behind the wider section **112** along the mating axis which is the x-axis in FIG. 1B. A second portion **111b** of the narrower section **111** is configured to fit within the wider section of a mating hood. The hood **110** and a mating hood can be identical and hermaphroditic as shown in FIGS. 1B through 3B. As in FIG. 3A and 3B, during mating, the wider section **112** of the hood **110** is configured to receive the second portion of the narrower section **111m** of the mating hood **100m** such that the narrower section **111m** fits at least partially within the wider section **112**.

As best seen in FIG. 1B, slots **115** are disposed between the narrower section **111** and the wider section **112** of the hood **110**. At least a portion of the narrower section **111** is separated from at least a portion of the wider section **112** by first and second slots **115** disposed on opposing sides of the hood **110**. Each of the first and second slots **115** has an opening **116** at a mating end **121** of the hood **110** and slot walls **117** that extend to an end **119** of the slot **115**. During mating, the first and second slots **115** are configured to slidably engage with second and first slots of the mating hood, allowing the narrower section **111** of the hood **110** to slide within the wider section of the mating hood and allowing the narrower section of the mating hood to slide within the wider section **112** of the hood **110**.

The hood **110** may include stop features **122**, **124** configured to stop translational movement of the hood **100** along the mating axis **198** of the cassette **101** during mating with the mating hood **110m**. The stop features stop the translational movement between the hood **110** and the mating hood **110m** along the mating axis **198** before the ends **119** of the first and second slots **115** make contact with the ends of the second and first slots of the mating hood. A first stop feature **124** may comprise a mating end of the narrower section **111** and a second stop feature **122** may comprise a one or more stop surfaces disposed in the wider section of the hood. As shown in FIGS. 3A and 3B, the stop surfaces **122** of the wider section **112** engage with a mating end **124m** of the narrow section **111m** of the mating hood **110m** and *vice versa*. First stop features **124**, **124m** can be designed to engage with second stop features **122m**, **122** to stop the relative translational motion of the hood **110** and the mating hood **110m** along the mating axis

198 before the slot ends 119 make contact with the slot ends of the mating hood. The stop features 122, 124 provide a fixed stop between the hood 110 and the mating hood 110m such that when the two hoods 110, 110m are fully nested within each other, as shown in FIG. 2 and FIG. 3B, the optical ferrules are correctly positioned relative to each other to provide the proper amount of overlap, providing a good
5 optical connection.

FIG. 4A shows an optical ferrule 400 and identical mating optical ferrule 400m suitable for use in an optical assembly that includes a cassette as discussed herein. FIG. 4B is a cutaway view of a portion 400-1 of optical ferrule 400 focusing on the light redirecting member 406 and attachment area 408. FIG. 4A shows an optical ferrule 400 and mating optical ferrule 400m prior to mating. The optical ferrule 400,
10 400m comprises a first surface 401, 401m that includes one or more substantially parallel grooves 405 oriented for receiving one or more optical waveguides 131. The first surface 401 also includes a light redirecting member 406 configured to be optically coupled to the optical waveguides 131. The term “optical waveguide” is used herein to refer to an optical element that propagates signal light. An optical waveguide comprises at least one core with a cladding, wherein the core and cladding are configured to
15 propagate light within the core, e.g., by total internal reflection. An optical waveguide may be, for example, a single or multi-mode waveguide, a single core fiber, a multi-core optical fiber, or a polymeric waveguide. A waveguide may have any suitable cross sectional shape, e.g., circular, square, rectangular etc.

Each groove 405 is configured to receive a different optical waveguide 131 of the array of one or
20 more optical waveguides. The optical waveguides 131 received by the grooves 405 can be permanently attached, e.g., using an adhesive, to the optical ferrule 400 at the grooves 405 which provide an attachment area 408 for the optical waveguides 131.

The optical ferrule 400 is configured to mate hermaphroditically with another optical ferrule 400m, which may be identical to the optical ferrule 400. The optical ferrules 400, 400m illustrated in
25 FIG. 4A include a mechanical mating tongue 416, 416m. In some embodiments, the mechanical mating tongue 416, 416m can have a tapering width along at least a portion of a length of the tongue portion as shown in the illustrations. The mechanical mating tongue 416, 416m can extend outwardly from a cassette frame as discussed below.

FIG. 4B illustrates the attachment of several optical waveguides 131 to optical ferrule at the
30 attachment area 408. Optical waveguides (optical fibers) 131 are aligned in grooves 405 to which they are permanently attached. The exit end of optical waveguides 131 is situated so as to be able to direct light emanating from the optical waveguide 131 into the input side or face of light redirecting member 406. Light redirecting member 406 includes an array of light redirecting elements 407, at least one for each of the optical waveguides (optical fibers) 131 attached to optical ferrule 400. For example, in
35 various embodiments each light redirecting element 407 comprises one or more of a prism, a lens, and a reflecting surface.

At the point of attachment, the fiber buffer coating and protective jacket (if any) of the optical waveguide may be stripped away to allow only the bare optical fiber to lie aligned and permanently

affixed to groove **405**. Light redirecting element **407** includes light input side **409** for receiving input light from first optical waveguide **131** disposed in and aligned by the groove **405**. Light redirecting element **407** also includes light redirecting side **411** that may include a curved surface for receiving light from the input side **409** along an input direction and redirecting the received light along a different
5 redirected direction. The light redirecting element **407** also includes output side **412** that receives light from light redirecting side **411** of light redirecting element **407** and transmits the received light as output light along an output direction toward a light redirecting member of a mating light coupling unit.

Although FIGS. 4A and 4B show an optical ferrule **400** that includes multiple light redirecting elements **407** that can be optically coupled to multiple optical waveguides **131**, it is also possible that an
10 optical ferrule includes just one light redirecting element that can be optically coupled to a single optical waveguide.

The optical ferrule **400** and mating optical ferrule **400m** have an opposing second surface **402**, **402m** that includes a mating surface **420m**. The features of the second surface **402**, **402m** of the optical ferrule **400** are best understood with reference to the identical mating optical ferrule **400m** shown in FIG.
15 4A. The mating surface **420m** includes an optically transmitting window **421m** for propagating an optical signal therethrough to an optically transmitting window of the optical ferrule. In some embodiments, the mating surface **420m** of the optical may comprise a main portion **423m** and one or more pads **422m** that extend away from the main portion **423** along the thickness axis (z-axis). For example, in some configurations, the pads **422m** may extend away from the main portion **423m** of the
20 mating surface **420m** by about 5 μm to about 10 μm .

In some embodiments, the mating surface may not include pads. When present, the one or more pads **422m** may collectively occupy less than a majority, e.g., less than 50%, less than 25%, or less than 10% of the surface area of the mating surface **420m**. Alternatively, the pads **422m** may individually or collectively occupy a substantial portion of the surface area of the mating surface, e.g., more than 10%,
25 more than 25%, or even more than 50% of the surface area of the mating surface **420m**.

In some embodiments, after mating, the pads of the mating optical ferrule rest on corresponding pads **422m** of the mating optical ferrule **400m**, providing a small gap between the main portions of the mating surfaces of the optical ferrule **400** and the mating optical ferrule **400m**. The small gap accommodates dust and/or other irregularities that may be present between the main portion of the mating
30 surface of the optical ferrule **400** and the main portion **423m** of the mating surface **420m** of the mating optical ferrule **400m**.

In some embodiments, when the mating surface of the optical ferrule **400** and the mating surface **420m** of the mating optical ferrule **400m** do not include pads, the main portion of the mating surface of the optical ferrule **400** and the main portion **423m** of the mating surface **420m** of the mating optical
35 ferrule **400m** may be in contact after the optical ferrules **400**, **400m** are mated.

Additional information regarding features and operation of optical ferrules, optical ferrule subassemblies and optical connectors is discussed in concurrently filed and commonly owned U.S. Patent

Application S/N _____, having Attorney Docket 80762US002 and entitled “Optical Ferrule having Compound Stops” which is incorporated herein by reference.

FIG. 5 illustrates two mated optical ferrule subassemblies **530, 530m**. The ferrule subassemblies **530, 530m** comprise optical waveguides **531, 531m** attached to optical ferrules **532, 532m** at first attachment areas **508, 508m**. The optical waveguide is attached to a cable retainer at a second attachment area **508', 508m'**; the cable retainer is subsequently attached to the cassette. The length of the optical waveguides **531, 531m** between the first attachment area **508, 508m** of the optical ferrule **500, 500m**, and the second attachment area **508', 508m'** is configured to allow a bend **511, 511m** to develop in the optical waveguides **531, 531m** when the second attachment area **508', 508m'** is secured within a cassette. The bend **511, 511m** contributes to a predetermined mating spring force at a predetermined angle and location of the optical ferrule **532, 532m** that holds the optical ferrule **532** and mating optical ferrule **532m** in mating alignment and in optical communication in the mated position. In some embodiments, the second attachment area **508', 508m'** may comprise a cable retainer **560, 560m** attached to the waveguides **531, 531m**. The cable retainer **560, 560m** is configured to be received and secured by a retainer mount within the cassette such that the second attachment area **508', 508m'** is secured within the cassette as discussed in more detail herein. Additional information regarding optical cable assemblies and housings that include cable retainers and mounts is described in commonly owned U.S. Patent Application S/N 62/240,008, filed October 12, 2015 which is incorporated herein by reference.

In some embodiments, the cable retainer may have two opposing sides that are non-parallel with each other. In some embodiments, the cable retainer may have two opposing sides wherein one of the sides is shorter than the other side. The sides of the cable retainer may be substantially straight, or one or more of the sides may be curved.

FIG. 6 is a top view of an optical ferrule subassembly **630** comprising a cable retainer **660** in accordance with some embodiments. The subassembly **630** includes at least one optical waveguide **631** and an optical ferrule **632** attached to the optical waveguide **631** at a first attachment location **608**. The optical ferrule subassembly **630** includes a cable retainer **660** attached to the waveguide **631** at a second attachment location **608'**. The cable retainer **660** has two opposing sides **683, 684** that are substantially parallel with each other and two opposing sides **681, 682** that are non-parallel with each other. The parallel sides **683, 684** are disposed along a longitudinal axis **699** of the optical waveguide **631** and the non-parallel sides **681, 682** are disposed laterally across the optical waveguide **631**. Side **683** is shorter than side **684** and side **682** is shorter than **681**. Surface **641** and an opposing surface (not shown) extend between sides **681, 682, 683, and 684**. In the illustrated embodiment, the cable retainer **660** has a trapezoidal shape, although other shapes are also possible.

FIGS. 7 and 8 are perspective views that respectively illustrate two trapezoidal cable retainer configurations according to some embodiments. FIG. 7 shows a cable retainer **760** comprising two opposing surfaces **785, 786**, two opposing sides **783, 784** that are substantially parallel with each other, and two opposing sides **781, 782** that are non-parallel with each other. The parallel sides **783, 784** are disposed along a longitudinal axis **199** of the optical waveguide, (not shown in FIG. 7). The non-parallel

sides **781**, **782** extend laterally across the optical waveguide. Openings in the non-parallel sides **781**, **782** and one of the parallel sides **783** form a three sided slot **761** that extends through the cable retainer **760** along the axis **199** and is configured to receive the optical waveguide.

FIG. 8 shows a cable retainer **860** comprising two opposing surface **885**, **886**, two opposing sides **883**, **884** that are substantially parallel with each other, and two opposing sides **881**, **882** that are non-parallel with each other. The parallel sides **883**, **884** are disposed along a longitudinal axis **199** of the optical waveguide (not shown in FIG. 8) and the non-parallel sides **881**, **882** are disposed laterally across the optical waveguide. Openings in the non-parallel sides **881**, **882** form a four sided slot **861** that extends through the cable retainer **860** along the axis **199** and is configured to receive the optical waveguide.

Referring again to FIGS. 1A and 1B, the hood **110** may include one or more flexible latching members **165** that form a cable retainer mount configured to hold the cable retainer **160** within the hood **110**. Each flexible latching member **165** comprises an elongated flexible arm portion **166** and a finger portion **167** at the end of the arm portion **166**. The flexible latching members **165** are configured to flex away from each other to receive the cable retainer **160**, and to flex toward each other when the cable retainer **160** is disposed within the hood **110**. When the cable retainer **160** is received by the latching member **165** within the hood each elongated flexible arm portion **166** extends along one of the parallel sides **183**, **184** of the cable retainer **160** and the finger portion **167** extends along the surface **185** of the cable retainer **160**. According to some implementations, the cable retainer **160** may be trapezoidal in shape as previously discussed in connection with FIGS. 7 and 8. The optical waveguide **131** runs through a slot in the cable retainer **160**.

According to some implementations, the hood **110** includes a first protrusion **201** extending from an inner surface **211** of a first side **212** of the hood **110** as best seen in FIG. 1B. The first protrusion **201** has a first surface **202** arranged to engage with one of the non-parallel sides **181** of the cable retainer **160**. According to some implementations, the hood **110** includes a second protrusion **203** extending from an inner surface **213** of an opposing second side **214** of the hood **110**, the second protrusion **203** having a second surface **204** configured to engage the non-parallel side **181** of the cable retainer **160**. The latching members **165** secure the cable retainer **160** within the hood **110** and prevent motion of the cable retainer **160** along the z-axis shown in FIG. 1B. Engagement of the side **181** of the cable retainer **160** with first and second surfaces **202**, **204** of first and second protrusions **201**, **203** limit movement of the cable retainer **160** along the x axis as shown in FIG. 1B.

In some embodiments, the hood **110** may include one or more curved alignment shoulders **220** within the hood **110** as shown, for example in FIGS. 1A, 1B, and 2. The curved alignment shoulders **220** are configured to support the optical ferrule **132** before the optical assembly **100** mates with a mating optical assembly. Once the two ferrules of the optical assembly **100** and the mating optical assembly come into contact, they nestle against each other, rising off curved alignment shoulders **220** within the hood **110** and providing a stable optical interconnect.

As shown in FIGS. 1A through 3B, the hood **110** may include one or more ribs **178** extending from the inner surfaces **211**, **213**, **215** of the hood **110** and running generally along axis **198** at a mating end **121** of the hood **110**. The ribs **178** facilitate alignment of the hood **110** with the mating hood during mating. The lead-in edges **179** of the ribs **178** may be chamfered. Lead-in chamfered edges **177** at the mating end of the narrower **111** and/or wider **112** sections of the hood **110** and/or at the lead-in edges **179** of the ribs **178** can reduce sticking between the mating hoods during mating. The lead-in chamfers **177**, **179** and ribs **178** can guide the alignment of the hoods **110**, **110m** during mating even if the initial positioning of the centerlines of the hoods **110**, **110m** is somewhat inaccurate.

FIG. 1A illustrates an optical assembly **100** comprising a single piece cassette **101** wherein the single piece is a hood **110**. In other implementations, as illustrated in FIG. 9, a cassette **901** may be a multi-piece article. Cassette **901** includes a frame **902** disposed within a hood **910**. One or more optical ferrule subassemblies **930** comprising at least an optical ferrule **932** and one or more optical waveguides **931** are disposed within the frame **902**. The mating ends of the optical ferrules **932** may extend out of the frame **902** and the hood **910** may extend over the ends of the optical ferrules **932** to mechanically protect the ferrules **932** from impact and abrasion. The hood **910** includes a narrower section, a wider section, and slots such that the narrower section can slide within a wider section of a mating hood as previously discussed in connection with FIGS. 1A through 3B. The hood **910** may include stop features that stop the translational motion of the cassette along the mating axis during mating as discussed herein.

The one or more optical ferrule subassemblies **930** disposed within the frame **902** may be the same or similar to those previously discussed and may include a cable retainer. In some configurations, the frame **902** may include a retainer mount configured to receive and secure the cable retainer of the optical ferrule subassembly **930**. Additional features of the frame of an optical assembly are discussed in connection with FIG. 11.

An optical connector can include one or more single or multi-piece cassettes having optical ferrule subassemblies disposed within the cassettes. The cassettes may be configured to be inserted into a single or a multi-piece connector housing. The cassette may be standardized across a broad range of optical connector configurations whereas the connector housing may be designed to be specific to a particular application. The use of standardized format cassettes that hold the optical ferrule subassemblies and can be inserted into housings having a number of different configurations simplifies manufacture of the optical connectors.

Assembly of an optical connector can involve loading optical ferrule subassemblies (optical ferrule and cable retainer attached to an optical waveguide) into a cassette. In the example of the cassette **101** illustrated in FIG. 1A, the optical ferrule subassembly **130** is loaded from the “bottom” of the hood **110** which is shown at the right side of the page in FIG. 1A). Installation of the optical ferrule subassembly involves resting the optical ferrule **132** on the curved alignment shoulders **220** and bending the optical waveguide **131** while pressing the cable retainer **160** into the flexible arms **166** of the retainer mount **165**. With reference to FIG. 6, an optical ferrule subassembly has a longitudinal axis **699**, a lateral axis **698**, and a thickness axis **697**. In the embodiment illustrated in FIG. 1A, the optical ferrule

subassembly **130** is inserted into the hood **110** generally along the thickness axis of the optical ferrule subassembly.

The frame **902** has a removable cover **903**. In the example cassette **901** of FIG. 9, the cover **903** is removed and the optical ferrule assemblies are loaded into the frame **902** of the cassette **901** from the left “side” shown in FIG. 9. Referring back to FIG. 6, which discusses the axes of an optical ferrule subassembly, the optical ferrule subassembly **932** is inserted into the frame generally along the lateral axis **698** of the optical ferrule subassembly. After the optical ferrule subassemblies are loaded into the frame **902**, the frame **902** with the optical ferrule subassemblies installed therein is inserted into the hood **903**.

Installing the optical ferrule subassemblies from the side along the lateral axis of the ferrule subassemblies involves resting the ferrule on the curved alignment shoulders at the mating end of the cassette while bending the waveguide and inserting the cable retainer into a retainer mount in the cassette. However, loading multiple optical ferrule subassemblies from the side can be challenging because, for example, the optical ferrule can be accidentally moved too far forward or backward such that it falls off the curved alignment shoulders. Some embodiments are directed to a ferrule installation tool that facilitates installation of the optical ferrule subassemblies into the frame of the cassettes. The tool assists the assembler in locating the ferrule on the correct set of alignment shoulders within the frame and holding the ferrule in place while the cable retainer is placed into the retainer mount.

FIG. 10 illustrates a ferrule installation tool **1000** in accordance with some embodiments. The ferrule installation tool **1000** includes a substantially flat base **1001** and optionally includes first and second corner supports **1002** extending from the surface of the base **1001**. For example, in some configurations the corner supports **1002** can be L-shaped as shown in FIG. 10. The corner supports **1002** are spaced apart by a distance that allows the mating end of a frame of a cassette to be inserted between the first and second corner supports **1002**. A plurality of teeth **1003** extend from the surface of the base **1001**. The teeth **1003** are spaced apart from each other on the base between the corner supports **1002**. The pitch of the teeth **1003** is equal to the pitch of the optical ferrule subassemblies when they are installed in the frame. As illustrated in FIG. 10, in some configurations, the bottom of each tooth **1003** where the tooth **1003** is attached to the base **1001** may be wider than the tip of the tooth **1003**.

A frame **1100** suitable for being loaded with optical ferrule subassemblies using the ferrule installation tool **1000** shown in FIG. 10 is illustrated in the exploded view of FIG. 11. The frame **1100** has a first side **1101** extending between the mating end **1111** and the non-mating end **1112** of the frame **1100**. Frame **1100** has a second side **1102** that includes a removable cover, the second side **1102** opposing the first side **1101**. The second side **1102** extends between the mating end **1111** and the non-mating end **1112** of the frame **1100**. Third **1103** and opposing fourth **1104** sides extend between the mating end **1111** and the non-mating end **1112** of the frame **1100** and between the first **1101** and second **1102** sides. The first **1101**, second **1102**, third **1103**, and fourth **1104** sides define an interior space **1190** of the frame **1100** into which the optical ferrule subassemblies are inserted. The frame **1100** includes

holes **1120** through the first side **1101** proximate the mating end **1111**. The holes **1120** are spaced apart from each other between the third **1103** and fourth **1104** sides.

The frame **1100** is configured to hold a plurality of optical ferrule subassemblies **1230** (not shown in FIG. 11 but shown in FIG. 12A - 12C) that are spaced apart from each other and disposed at least partially within the interior space **1190** of the frame **1100**. Each optical ferrule subassembly **1230** includes at least one optical waveguide **1231**, an optical ferrule **1232** attached to the optical waveguide **1231** at a first location **1208** of the optical waveguide **1231**, and a cable retainer **1260** attached to the optical waveguide **1208'** at a second location of the optical waveguide **1231**. After they are loaded into the frame **1100**, the ferrule subassemblies **1230** are spaced apart within the interior space **1190** of the frame **1100** at a pitch that is equal to a pitch of the spaced apart holes **1120** in the first **1101** side of the frame **1100**.

The frame **1100** includes retainer mounts **1165** configured to secure the cable retainers **1160** of the optical ferrule **1130** subassembly within the frame **1100**. Each retainer mount comprises first and second walls **1166**, **1167** extending from the inner surface **1101a** of the first side **1101** of the frame **1100**. The walls **1166**, **1167** have first and second surfaces **1166a**, **1167a** that face each other. The inner surface **1166a** of wall **1166** may be oriented at a non-perpendicular angle with respect to the x-axis which is the mating axis of the frame **1100**. For example, the angle of the surface **1166a** may be about 70 degrees to about 85 degrees or about 80 degrees with respect to the x-axis. The inner surface **1167a** of wall **1167** may be oriented substantially perpendicular to the x-axis.

The frame **1100** may include ferrule support **1140**, such as the curved alignment shoulders previously discussed, or other features that support the ferrules **1232** prior to mating. A frame **1100** that is configured to hold multiple optical ferrule subassemblies may also include at least one support brace **1150** and/or a rib **1151**. The support brace **1150** extends between the first **1101** and second sides **1102** at the mating end **1111** of the frame **1100** and reduces flexing of the frame **1100** at the mating end **1111**. The brace **1150** may be positioned at about the mid-point of the mating end **1111**, such that half of the optical ferrule subassemblies **1130** (e.g., 4, 5, 6, 7, 8 or more) are inserted on one side of the support bar **1150** and the other half of the optical ferrule subassemblies **1130** are inserted on another side of the support bar **1150**. The support rib **1151** is disposed behind the support brace **1150** in the location of the retainer mounts **1165**.

FIGS. 12A through 12C illustrate the process of loading a frame **1100** with optical ferrule subassemblies **1230** using the ferrule installation tool **1000** in accordance with some embodiments. The process initially involves inserting the teeth **1003** of the ferrule installation tool **1000** into the holes **1120** in the first side **1101** of the cassette frame **1100**. The base **1001** of the ferrule installation tool **1000** supports the first side **1101** of the cassette frame **1100**.

The frame **1100** is positioned between the first and second L-shaped corner supports **1002** of the ferrule installation tool **1000**. The third **1103** and fourth **1104** sides of the frame **1100** are adjacent to the long side of the L-shaped corner supports **1002** and the mating edge **1111** of the frame **1100** is adjacent to the short side of the corner supports **1002**. With the third and fourth **1103**, **1104** sides of the frame

adjacent the long sides of the corner supports **1002** and the mating edge **1111** of the frame **1100** adjacent to the short sides of the corner supports **1002**, lateral translational motion of the frame **1100** along the y axis and forward motion along the x axis is restricted by the corner supports **1002**.

After positioning frame **1100** in the installation tool **1000**, the optical ferrule subassemblies **1230** are then placed into the frame **1100**. In FIG. 12A, the frame **1100** has been placed into the installation tool **1000**. A ferrule **1232** of at least one optical ferrule subassembly **1230** is positioned between adjacent sets of teeth **1003** of the ferrule installation tool **1000** and is placed on the ferrule support features **1140** which extend from the inner surface of the first side **1101** of the frame **1100**. In some implementations, the ferrule support features **1140** may comprise the curved alignment shoulders discussed previously.

As illustrated in FIG. 12A, the ferrule **1232** is inserted into the frame **1100** before insertion of the cable retainer **1260** into the frame **1100**. After the ferrule **1232** is inserted between the teeth **1003** and onto the support features **1140** of the frame **1100**, the cable retainer **1260** is inserted between the walls **1166**, **1167** of the frame's retainer mount **1165**.

The cable retainer **1260** may have a trapezoidal shape as illustrated in FIGS. 7 and 8. In many embodiments, the retainer mount has about the same shape as the cable retainer. Trapezoidal cable retainers have a long side **1263** that is substantially parallel to a short side **1264**. As illustrated in FIG. 12B, in implementations that include a trapezoidal cable retainer **1260**, the short side **1264** is inserted between the walls **1166**, **1167** of the retainer mount **1165** before the long side **1263**. Positioning the cable retainer **1260** can involve rotating the optical ferrule subassembly **1230** around the y-axis which is substantially perpendicular with the mating axis (x-axis) of the frame **1160**.

As the cable retainer **1260** is installed in the retainer mount **1166**, the non-parallel sides **1261**, **1262** of the cable retainer **1260** engage the surfaces **1166a**, **1167a** of the walls **1166**, **1167**. Inserting the short side **1264** of the trapezoidal cable retainer **1260** first before inserting the long side **1263** eases insertion of the cable retainer **1260** into the retainer mount **1165**. Insertion of the cable retainer **1260** into the retainer mount **1165** forms a bend in the optical waveguide **1231**.

FIGS. 14A through 15B illustrate in more detail insertion of a cable retainer **1460** of an optical ferrule subassembly **1430** into a retainer mount **1465**. FIG. 14A shows an optical ferrule subassembly **1430** comprising an optical ferrule **1432** attached to optical waveguides **1431** at a first attachment location **1408**. A cable retainer **1460** is attached to the optical waveguides **1431** at a second attachment location **1408'**. In the illustrated embodiment, the cable retainer **1460** has a trapezoidal shape. The cable retainer **1460** has first and second **1481**, **1482** opposing sides that are non-parallel to each other and third and fourth opposing sides **1483**, **1484** that are substantially parallel to one another. First and second sides **1481**, **1482** extend laterally across the optical waveguides **1431**. Third and fourth sides **1483**, **1484** extend along the longitudinal axis **1499** of the waveguide **1431**. As depicted in FIGS. 14A and 14B, the sides **1481**, **1482**, **1483**, **1484** of the cable retainer **1460** are substantially straight in this embodiment. Side **1483** is shorter than side **1484** and side **1482** is shorter than **1481**.

The retainer mount **1465** includes first and second walls **1466**, **1467** that extend from an inner surface **1401a** of the side **1401** of the frame. The first wall **1466** has a first surface **1466a** and the second

wall **1467** has a second surface **1467a** that faces the first surface **1466a**. The first surface **1466a** is oriented at a non-perpendicular angle, α , with respect to the mating axis **1498** of the frame (x-axis in FIGS. 14A and 14B) wherein α is sufficient to allow insertion of the cable retainer **1460** into the retainer mount **1465** by rotating the optical ferrule subassembly **1430** around a rotation point **1491** located on or near the optical ferrule **1432**. For example α may be between about 70 degrees to about 85 degrees or about 80 degrees with respect to the mating axis **1498** of the frame. The second surface **1467a** is oriented about perpendicular with respect to the mating axis **1498**. To facilitate rotational insertion of the cable retainer **1460** into the retainer mount **1465**, the first distance **d1** between the first surface **1466a** and the second surface **1467a** at a location nearer to the inner surface **1401a** of the frame side **1401** is smaller than a second distance **d2** at a location farther from the inner surface **1401a** of the frame side **1401**. For example, **d1** may be at the bottom surface of the retainer mount **1465** (at the inner surface **1401a** of the frame side **1401**) and **d2** may be at the top surface of the retainer mount **1465**.

As illustrated in FIGS. 14A and 14B, installation of the cable retainer **1460** into the retainer mount **1465** involves rotating the optical ferrule subassembly **1430** around the z axis which is perpendicular to the mating axis **1498** wherein the point of rotation **1491** is located on or proximate to the ferrule **1432**. The smaller of the parallel sides **1483** of the cable retainer **1460** is inserted into the retainer mount **1465** first, and the optical cable subassembly **1430** is rotated until the cable retainer **1460** is disposed within the retainer mount **1465**. When fully inserted, the first surface **1466a** of the retainer mount **1465** is adjacent to the non-parallel side **1481** that is disposed laterally across the waveguides **1431** at a non-perpendicular angle with respect to the longitudinal axis **1499** of the waveguides **1431**. The second surface **1467a** of the retainer mount **1465**, which is behind the first surface **1466a** along the mating axis **1498**, is adjacent to the non-parallel side **1482** that is substantially perpendicular to the longitudinal axis **1499** of the waveguide **1431**. FIG. 14B shows the cable retainer **1460** after it is fully installed in the retainer mount **1465**. Insertion of the cable retainer **1460** into the retainer mount **1465** prevents movement of the cable retainer **1460** along the mating axis **1498** and secures the second attachment area **1408'** of the optical waveguide **1431** within the frame.

The cable retainer need not be trapezoidal and may have curved sides as illustrated in FIGS. 15A and 15B. The retainer mount **1565** has a shape that accommodates the shape of the cable retainer **1560**. FIG. 15A shows an optical ferrule subassembly **1530** comprising an optical ferrule **1532** attached to optical waveguides **1531** at a first attachment location **1508**. A cable retainer **1560** is attached to the optical waveguides **1531** at a second attachment location **1508'**. In the illustrated embodiment, the cable retainer **1560** is not a trapezoid, having one curved side **1581**. Second side **1582** opposes the curved side **1581** and third and fourth opposing sides **1583**, **1584** are substantially parallel to one another. First and second sides **1581**, **1582** extend laterally across the optical waveguides **1531**. Third and fourth sides **1583**, **1584** extend along the longitudinal axis **1599** of the waveguide **1531**. Side **1583** is shorter than side **1584**.

The retainer mount **1565** includes first and second walls **1566**, **1567** that extend from an inner surface **1501a** of the side **1501** of the frame. The first wall **1566** has a first surface **1566a** that has the

same curvature as the first side **1581** of the cable retainer **1560**. The second wall **1567** has a second surface **1567a** that faces the first surface **1566a**. A line **1590** drawn from the base to the tip of surface **1566a** makes a non-perpendicular angle, α , with respect to the mating axis **1598** of the frame (x-axis in FIGS. 15A and 15B) wherein α is sufficient to allow insertion of the cable retainer **1560** into the retainer mount **1565** by rotating the optical ferrule subassembly **1530** around a rotation point **1591** located on or near the optical ferrule **1532**. For example α may be between about 70 to about 85 degrees or about 80 degrees with respect to the mating axis **1598** of the frame. The second surface **1567a** is oriented about perpendicular with respect to the mating axis **1598**. To facilitate rotational insertion of the cable retainer **1560** into the retainer mount **1565**, the first distance **d1** between the first surface **1566a** and the second surface **1567a** at a location nearer to the inner surface **1501a** of the frame side **1501** is smaller than a second distance **d2** at a location farther from the inner surface **1501a** of the frame side **1501**.

As illustrated in FIGS. 14A and 14B, installation of the cable retainer **1560** into the retainer mount **1565** involves rotating the optical ferrule subassembly **1530** around the z axis which is perpendicular to the mating axis **1598** wherein the point of rotation **1591** is located on or proximate to the ferrule **1532**. The smaller of the parallel sides **1583** of the cable retainer **1560** is inserted into the retainer mount **1565** first, and the optical cable subassembly **1530** is rotated around point **1599** until the cable retainer **1560** is disposed within the retainer mount **1565**. When fully inserted, the first surface **1566a** of the retainer mount **1565** is adjacent to the curved side **1581** that is disposed laterally across the waveguides **1531**. The second surface **1567a** of the retainer mount **1565**, which is behind the first surface **1566a** along the mating axis **1598**, is adjacent to the second side **1582** that is substantially perpendicular to the longitudinal axis **1599** of the waveguide **1531**. FIG. 15B shows the cable retainer **1560** after it is fully installed in the retainer mount **1565**. Insertion of the cable retainer **1560** into the retainer mount **1565** prevents movement of the cable retainer **1560** along the mating axis **1598** and secures the second attachment area **1508'** of the optical waveguide **1531** within the frame.

Returning now to FIG. 12C, after installation of the optical ferrule subassemblies **1230**, the frame **1100** and the optical ferrule subassemblies **1230** installed therein are lifted from the base **1001** of the ferrule installation tool **1000**, which removes the teeth **1003** of the ferrule installation tool **1000** from the holes **1120** in the frame **1100** as illustrated in FIG. 12D. The frame **1100** with the optical ferrule assemblies **1230** installed therein may be inserted into a hood as illustrated in FIG. 6 and the cassette, comprising the frame and hood, may be installed into an optical connector.

According to some aspects, the ferrule installation tool includes a lip that extends along the base of the installation tool. When corner supports are present, the lip **1301** may extend between the corner supports **1002** as illustrated in FIG. 13. During installation of the optical ferrule subassemblies, the lip **1301** restrains movement of the ferrules **1232** along the x-axis and restricts extension of the optical waveguides during installation of the optical ferrule subassemblies into the frame **1100**.

Additional information regarding optical ferrules, optical assemblies, and optical connectors that may be used in conjunction with the approaches described herein is provided in the following commonly owned U.S. Patent Applications which are incorporated herein by reference: U.S. Patent Application S/N

62/240,000, filed October 12, 2015; U.S. Patent Application S/N 62/240,069, filed October 12, 2015; U.S. Patent Application S/N 62/240,066, filed October 12, 2015; U.S. Patent Application S/N 62/240,008, filed October 12, 2015; and U.S. Patent Application S/N : 62/239,996, filed October 12, 2015.

5 Unless otherwise indicated, all numbers expressing feature sizes, amounts, and physical properties used in the specification and claims are to be understood as being modified in all instances by the term “about.” Accordingly, unless indicated to the contrary, the numerical parameters set forth in the foregoing specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings disclosed herein. The
10 use of numerical ranges by endpoints includes all numbers within that range (e.g. 1 to 5 includes 1, 1.5, 2, 2.75, 3, 3.80, 4, and 5) and any range within that range.

Various modifications and alterations of the embodiments discussed above will be apparent to those skilled in the art, and it should be understood that this disclosure is not limited to the illustrative embodiments set forth herein. The reader should assume that features of one disclosed embodiment can
15 also be applied to all other disclosed embodiments unless otherwise indicated. It should also be understood that all U.S. patents, patent applications, patent application publications, and other patent and non-patent documents referred to herein are incorporated by reference, to the extent they do not contradict the foregoing disclosure.

CLAIMS

1. An optical assembly, comprising:

a hermaphroditic cassette comprising:

5 a hood that includes a narrower section and a wider section and separated by slots such that the narrower section fits at least partially within a wider section of an identical mating hood of a mating optical assembly and the wider section receives a narrower section of the mating hood; and

10 first and second stop features configured to engage with second and first stop features of the mating hood, the first stop feature comprising a mating end of the narrower section of the hood and the second stop feature comprising a stop surface disposed within the wider section of the hood, engagement of the stop features of the hood with stop features of the mating hood configured to stop relative translational movement of the hood and the mating hood along the mating axis during mating.

- 15 2. An optical assembly, comprising:

a cassette comprising:

20 a hood that includes a narrower section and a wider section, the narrower section extending beyond and behind the wider section and configured to fit at least partially within a wider section of a mating hood of a mating optical assembly and the wider section configured to receive a narrower section of the mating hood;

25 first and second slots disposed on opposing sides of the hood, the first and second slots separating at least a portion of the narrower section from at least a portion of the wider section, each slot having an opening at a mating end of the hood and slot walls that extend to an end of the slot, the first and second slots configured to engage with second and first slots of the mating hood; and

30 first and second stop features configured to engage with second and first stop features of the mating hood, the first stop feature comprising a mating end of the narrower section of the hood and the second stop feature comprising a stop surface disposed within the wider section of the hood, engagement of the stop features of the hood with stop features of the mating hood configured to stop relative translational movement of the hood and the mating hood along the mating axis during mating before the ends of the first and second slots make contact with ends of the first and second slots of the mating hood.

- 35 3. An optical ferrule subassembly, comprising:

at least one optical waveguide;

an optical ferrule attached to the optical waveguide at a first location; and

a cable retainer attached to the optical waveguide at a second location, the cable retainer having first and second opposing sides that are non-parallel with each other, the non-parallel sides disposed across the optical waveguide.

- 5 4. An optical ferrule subassembly, comprising:
 at least one optical waveguide;
 an optical ferrule attached to the optical waveguide at a first location; and
 a cable retainer attached to the optical waveguide at a second location, the cable retainer having
first and second opposing sides that extend laterally across the optical waveguide and third and fourth
10 opposing sides that extend between the first and second sides, wherein the third side is shorter than the
fourth side.
5. An optical assembly, comprising:
 one or more optical ferrule subassemblies, each optical ferrule subassembly comprising:
15 at least one optical waveguide;
 an optical ferrule attached to the optical waveguide at a first location; and
 a cable retainer attached to the optical waveguide at a second location, the cable retainer
having two opposing sides that are non-parallel with each other extending laterally across the
optical waveguide and two opposing sides that extend between the non-parallel sides; and
20 a cassette configured to hold the optical ferrule subassemblies, the cassette comprising one or
more retainer mounts, each retainer mount configured to receive a cable retainer of one optical ferrule
subassembly.
6. An optical assembly, comprising:
25 a cassette configured to contain one or more optical ferrule subassemblies, each optical ferrule
subassembly comprising at least one optical waveguide, an optical ferrule attached to the optical
waveguide at a first location, and a cable retainer attached to the optical waveguide at a second location,
the cable retainer having two opposing sides that are non-parallel with each other extending laterally
across the optical waveguide, and two opposing sides that extend between the two non-parallel sides, the
30 cassette comprising one or more retainer mounts, each retainer mount configured to receive a cable
retainer of at least one optical ferrule subassembly, each retainer mount comprising a first surface
extending from an inner wall of the cassette and oriented at a non-perpendicular angle with respect to a
mating axis of the cassette, the first surface configured to engage one of the non-parallel sides of the cable
retainer.
- 35 7. An optical assembly, comprising:
 a cassette comprising:

sides that define an interior space configured to contain at least one optical ferrule subassembly comprising:

at least one optical waveguide;

an optical ferrule attached to the optical waveguide at a first location of the optical waveguide; and

a cable retainer attached to the optical waveguide at a second location of the optical waveguide; and

one or more flexible latching members configured to hold the cable retainer within the interior space of the cassette.

8. An insertion tool for assembling an optical assembly that includes multiple optical ferrule subassemblies, the tool comprising:

a base configured to support a frame of the optical assembly, the frame configured to hold one or more optical ferrule subassemblies; and

a plurality of teeth extending from the surface of the base, the teeth spaced apart from each other along a lateral axis of the base, the teeth having a pitch along the lateral axis that is equal to a pitch of the ferrule subassemblies of the frame.

9. An optical assembly, comprising:

a frame configured to hold a plurality of ferrule subassemblies spaced apart from each other and disposed at least partially within an interior space of the frame, the frame comprising:

a base side extending from a mating end to an opposing non-mating end of the frame;

ferrule support features spaced apart from each other along and proximate to a mating end of the frame, the ferrule support features configured to support ferrules of optical ferrule subassemblies after the optical ferrule subassemblies are inserted into the frame and before mating with a mating optical assembly; and

holes in the base side spaced apart from each other along and proximate to the mating end of the frame, a pitch of the holes equal to a pitch of the ferrule support features.

10. An assembly, comprising:

a frame configured to hold one or more optical ferrule subassemblies, the frame comprising:

a base side extending from a mating end to an opposing non-mating end of the frame; and

holes in the base side proximate the mating end and spaced apart from each other along the mating end; and

a tool for installing multiple optical ferrule subassemblies into the frame, the tool comprising:

a base having a surface configured to support the frame; and

a plurality of teeth extending from the surface of the base and spaced apart from each other along a lateral axis of the base, the teeth inserted into the holes in the frame.

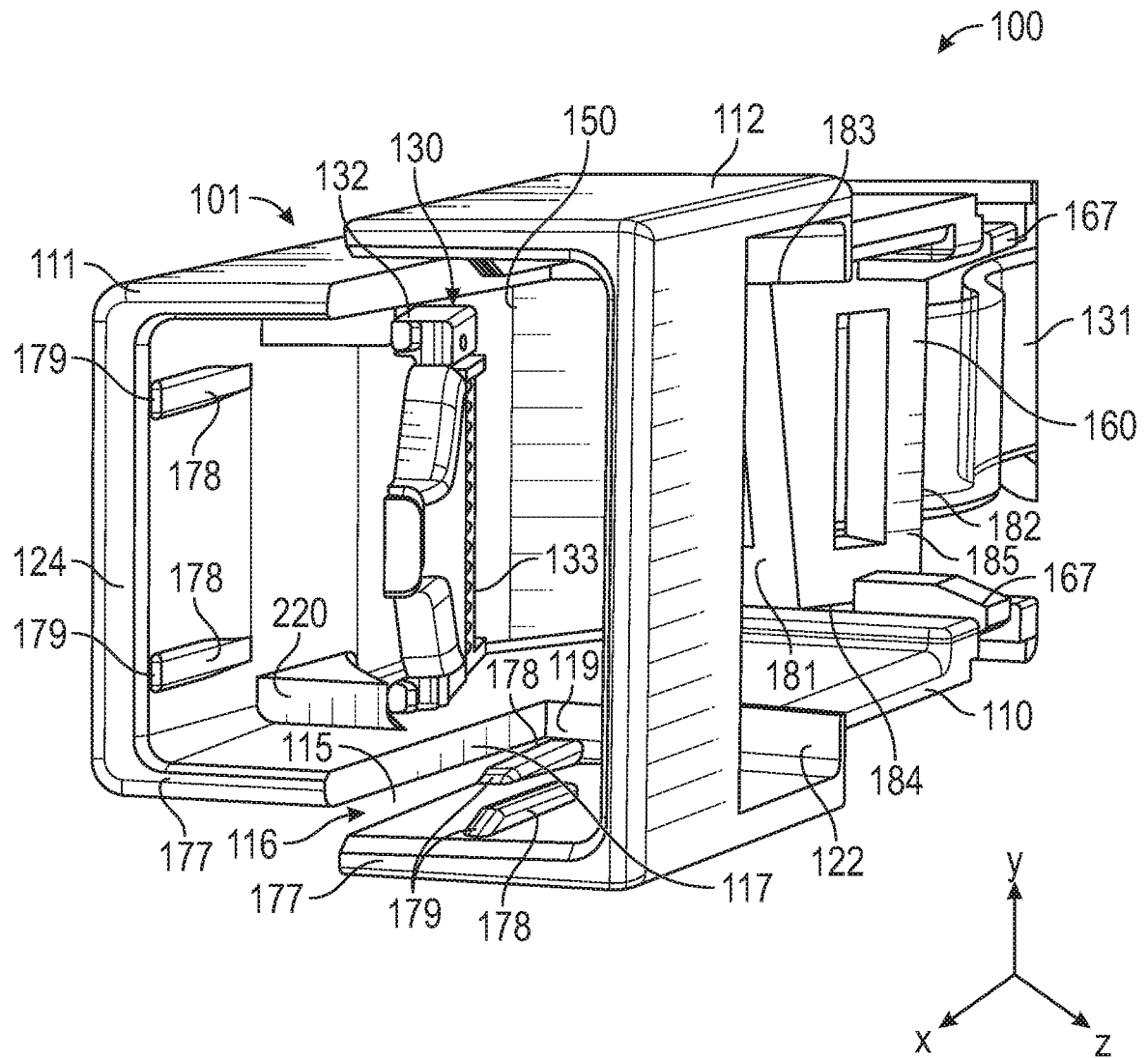


FIG. 1A

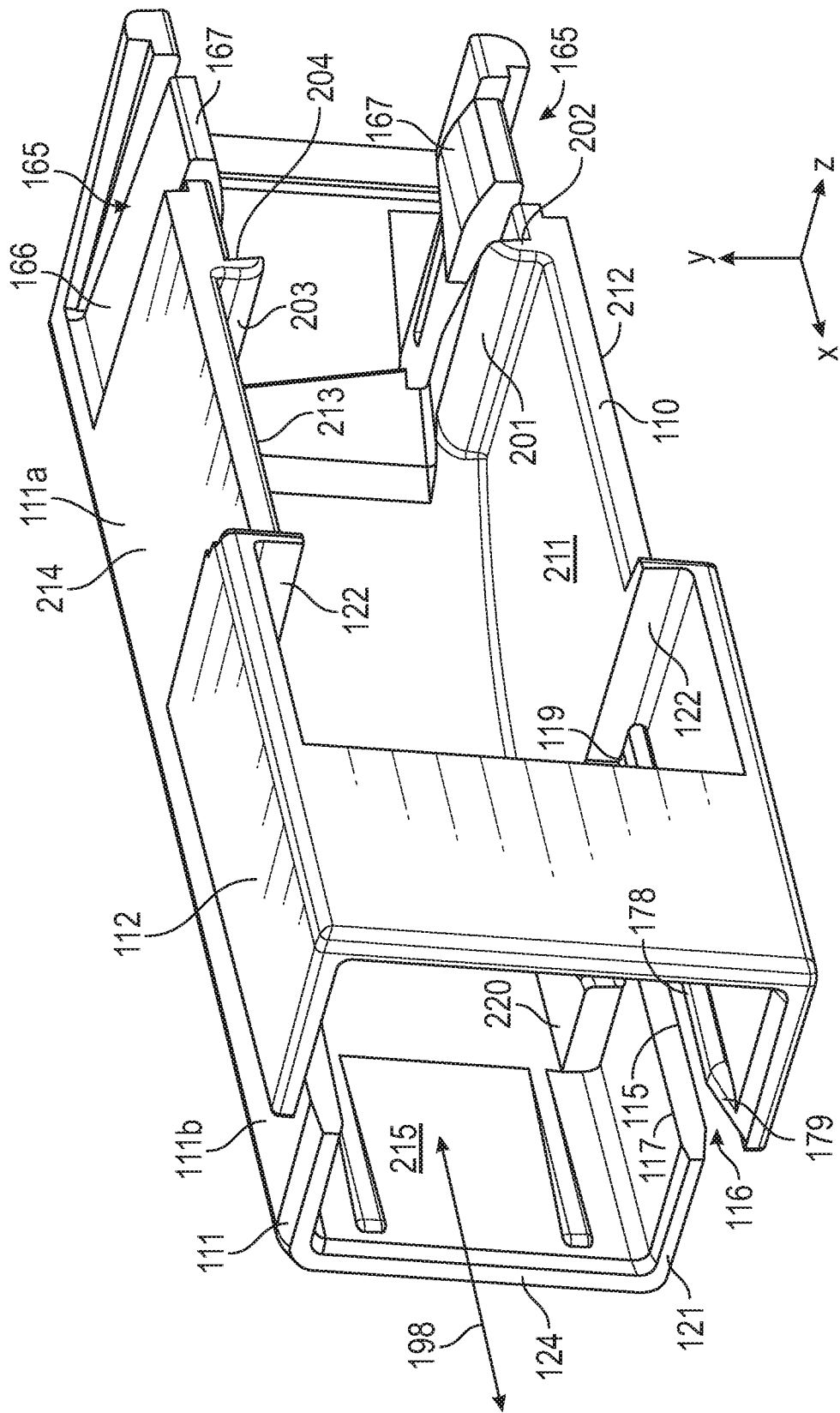


FIG. 1B

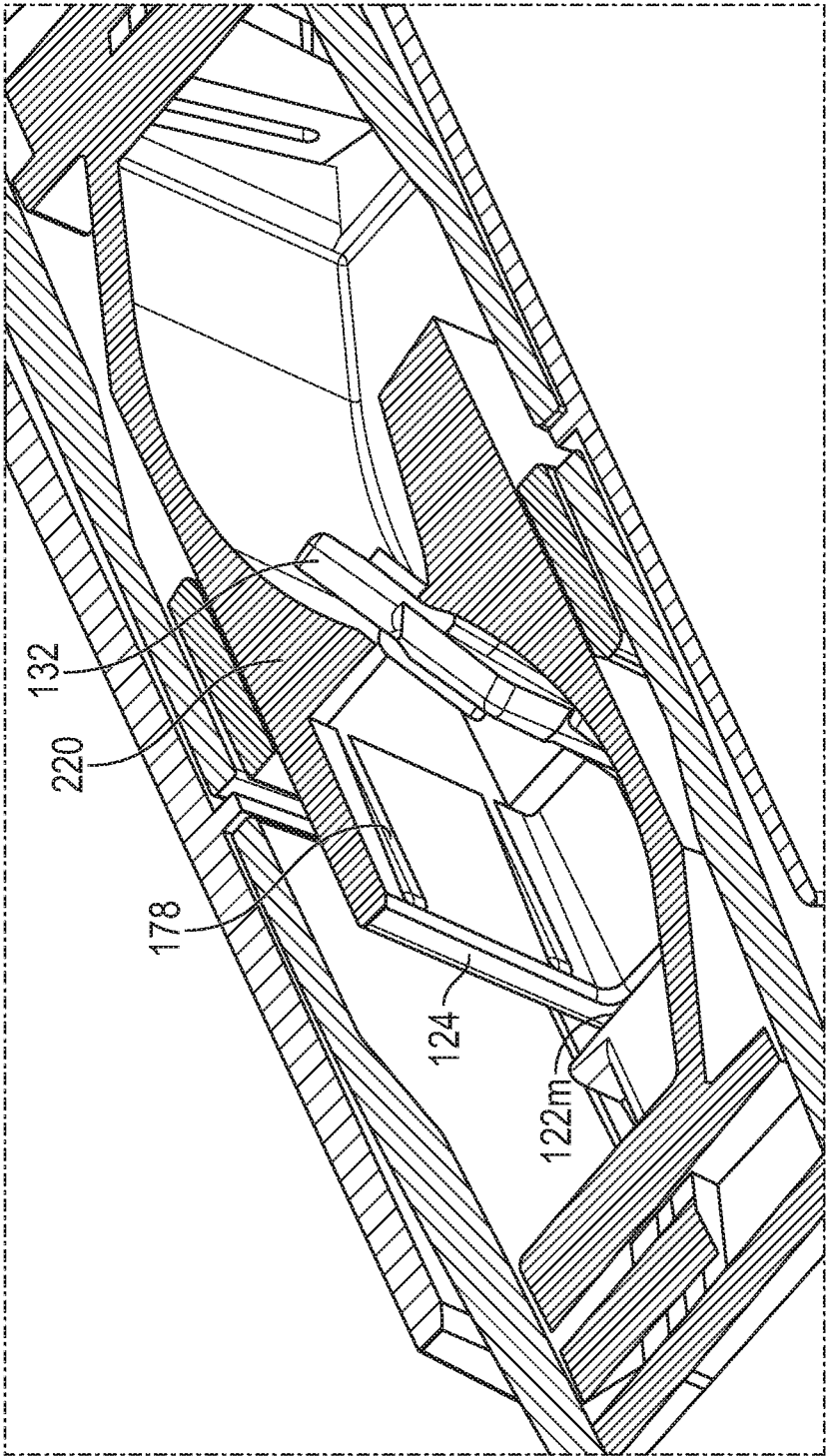


FIG. 2

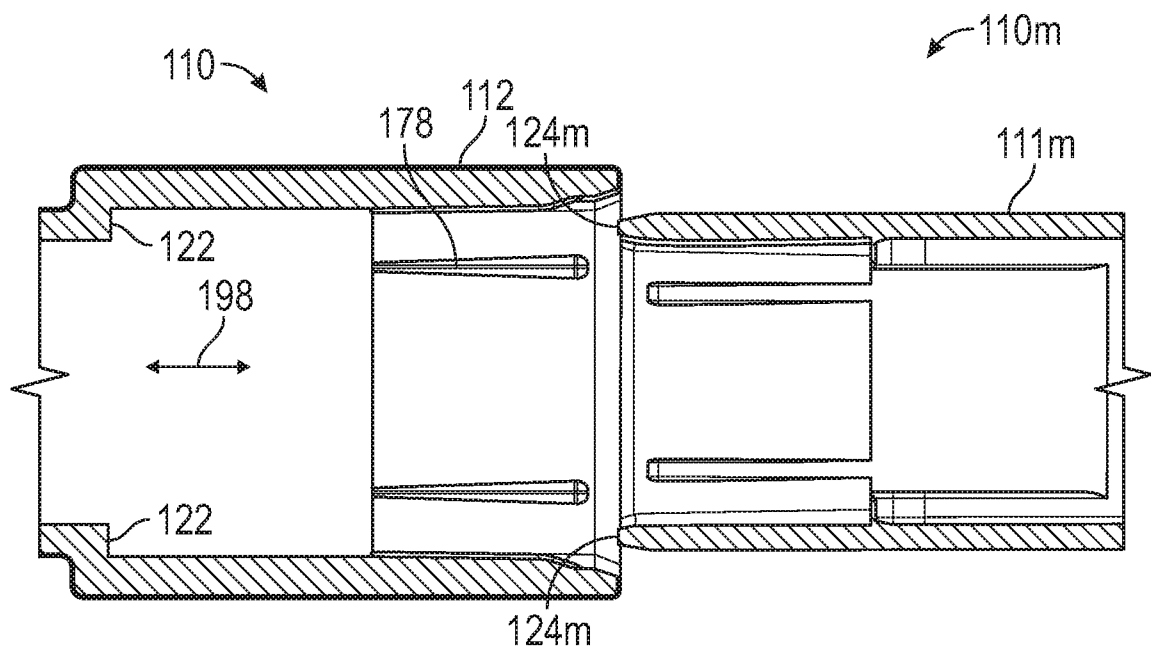


FIG. 3A

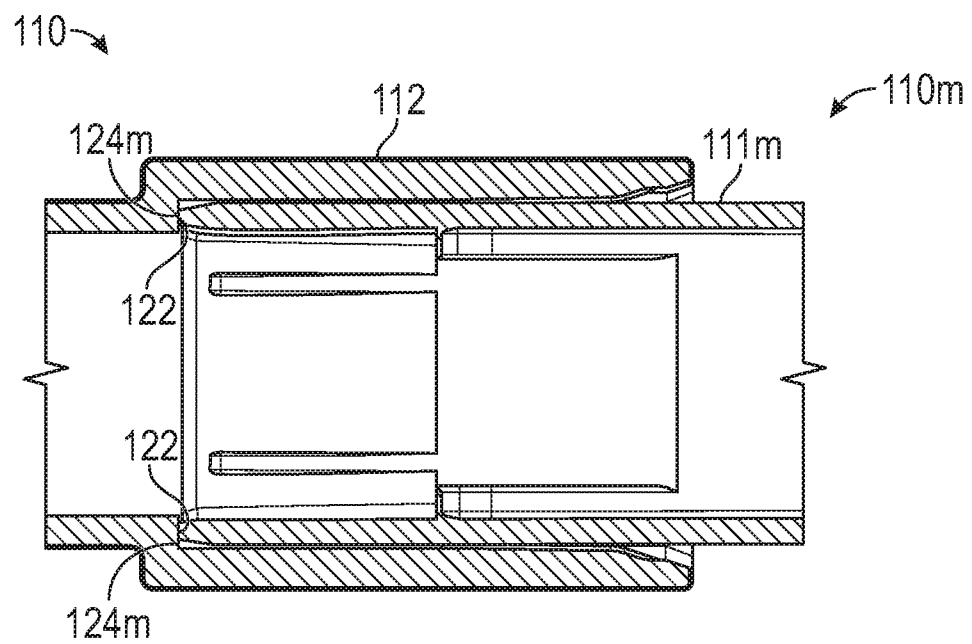


FIG. 3B

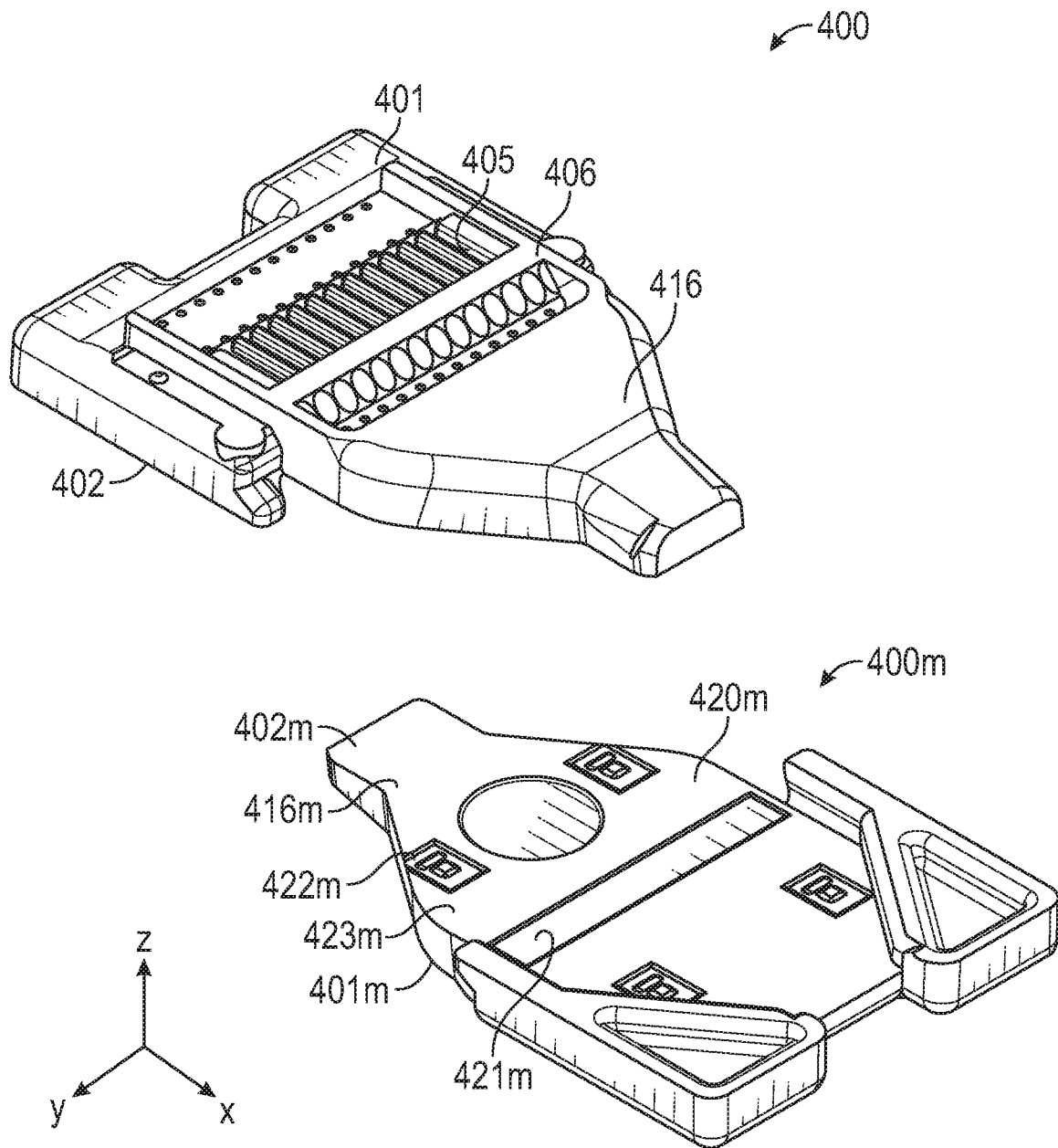


FIG. 4A

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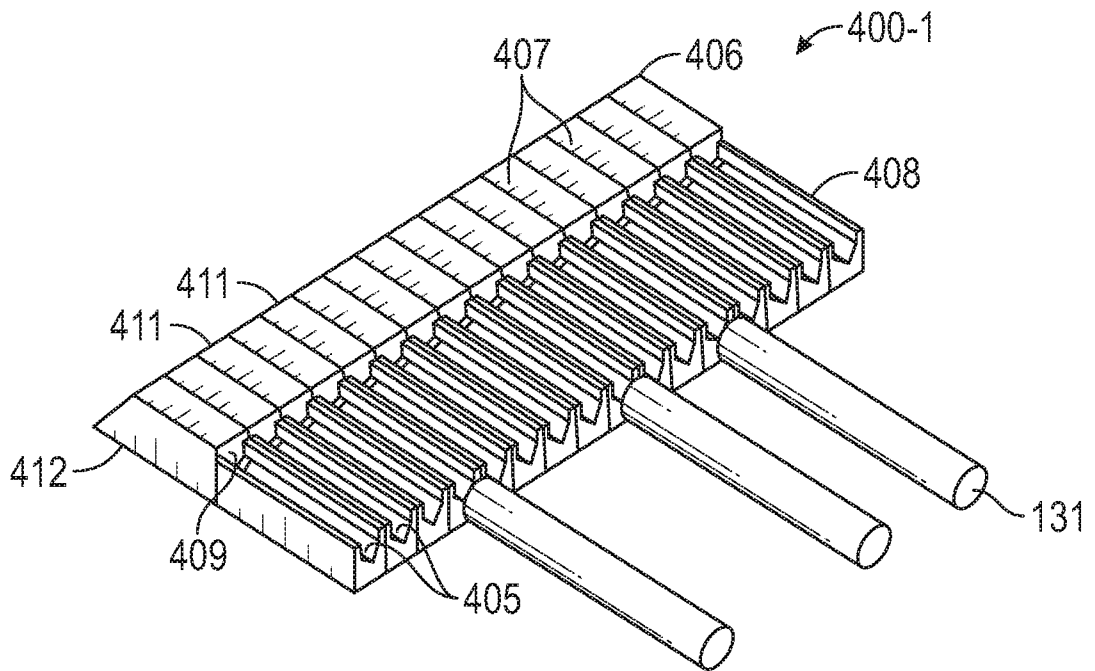


FIG. 4B

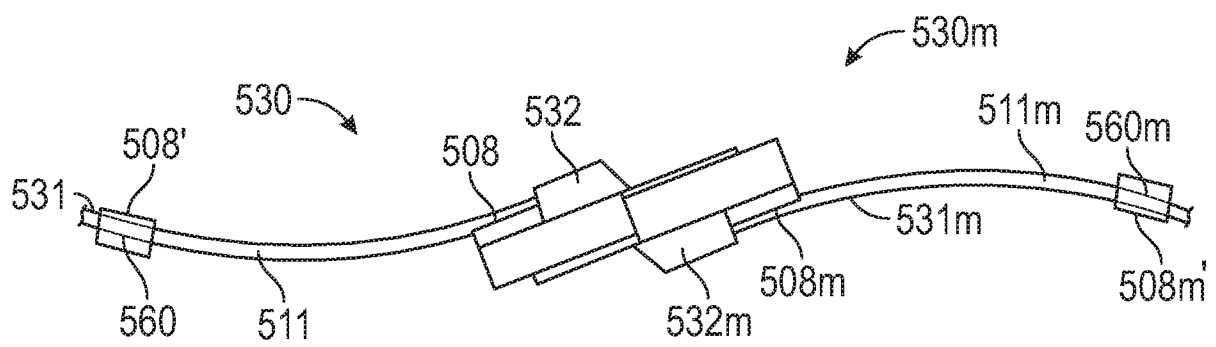


FIG. 5

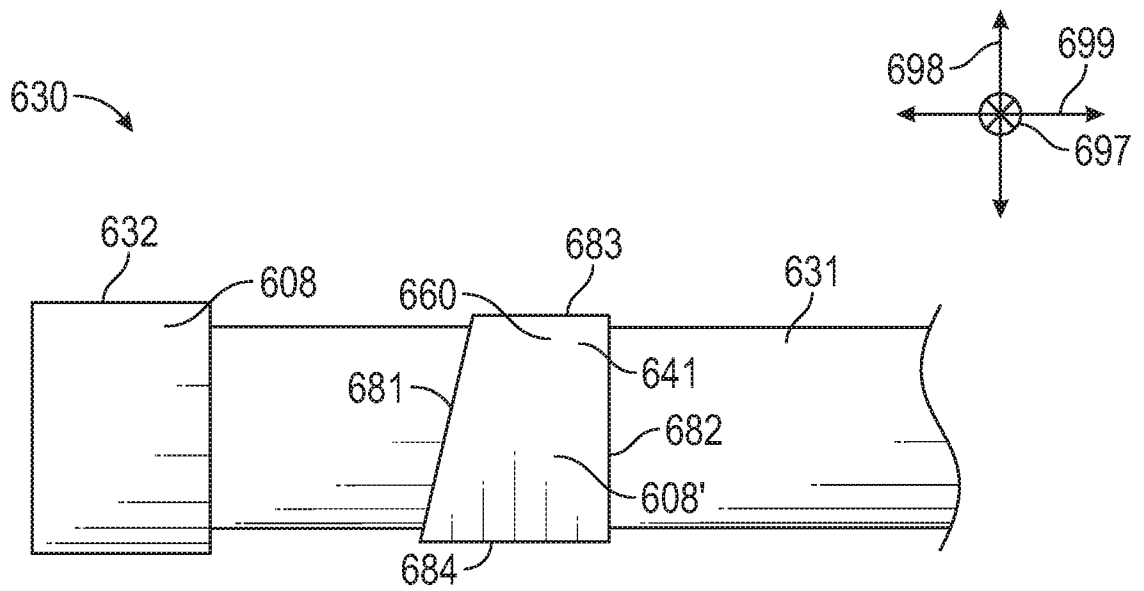


FIG. 6

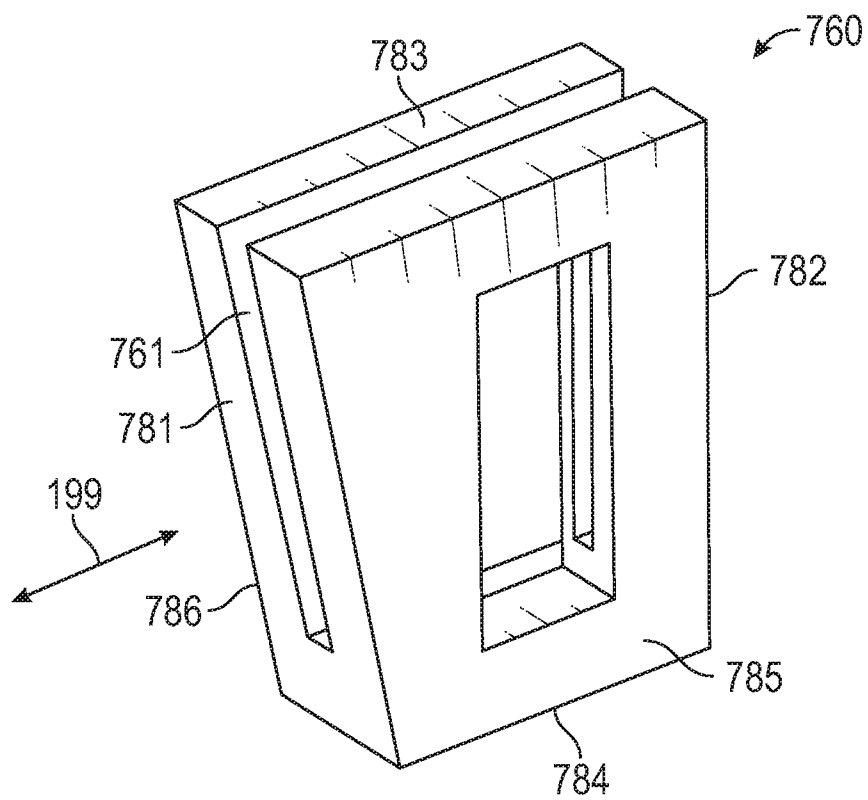


FIG. 7

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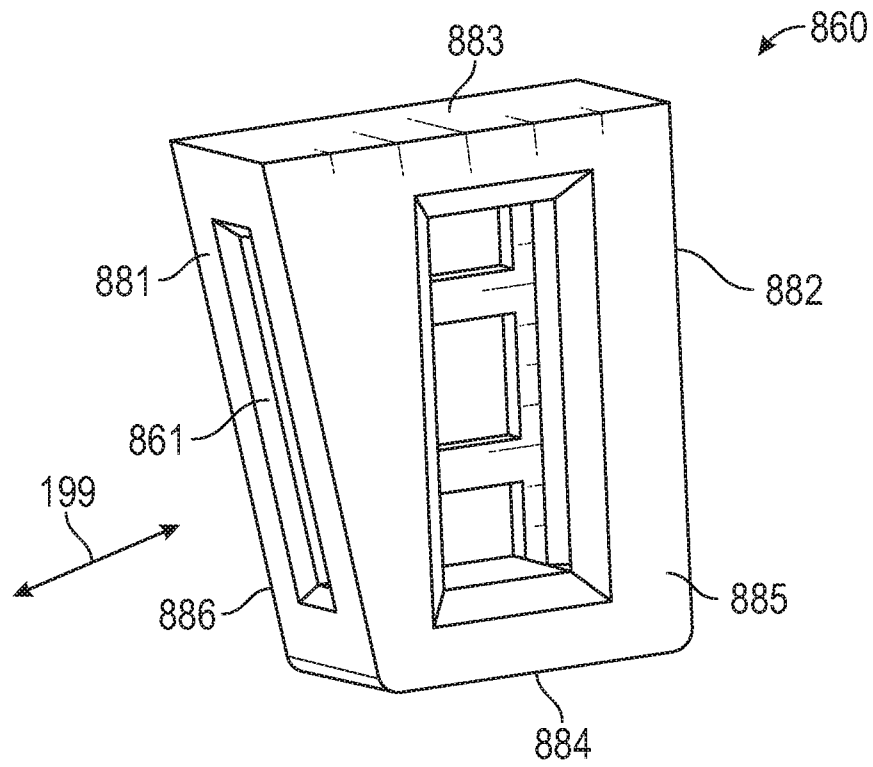


FIG. 8

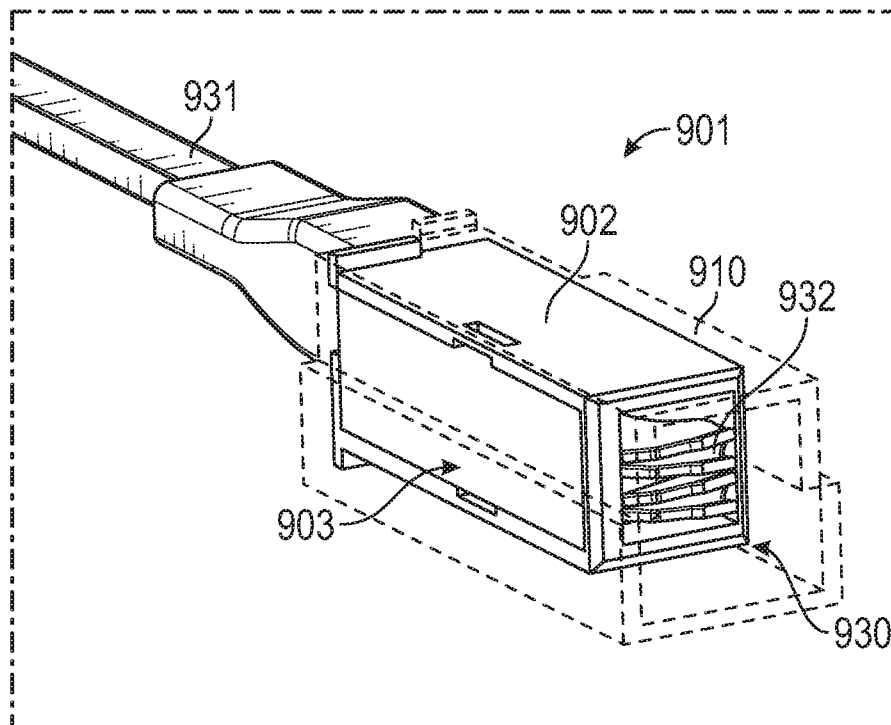


FIG. 9

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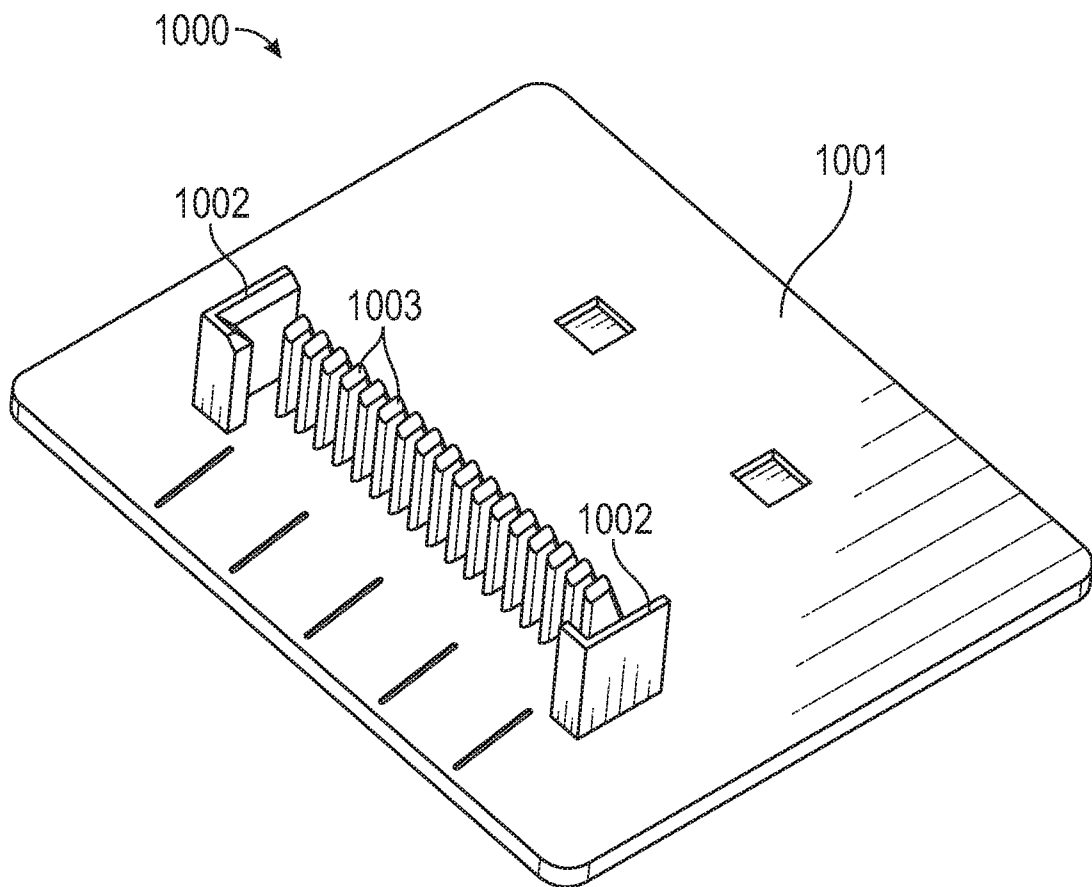


FIG. 10

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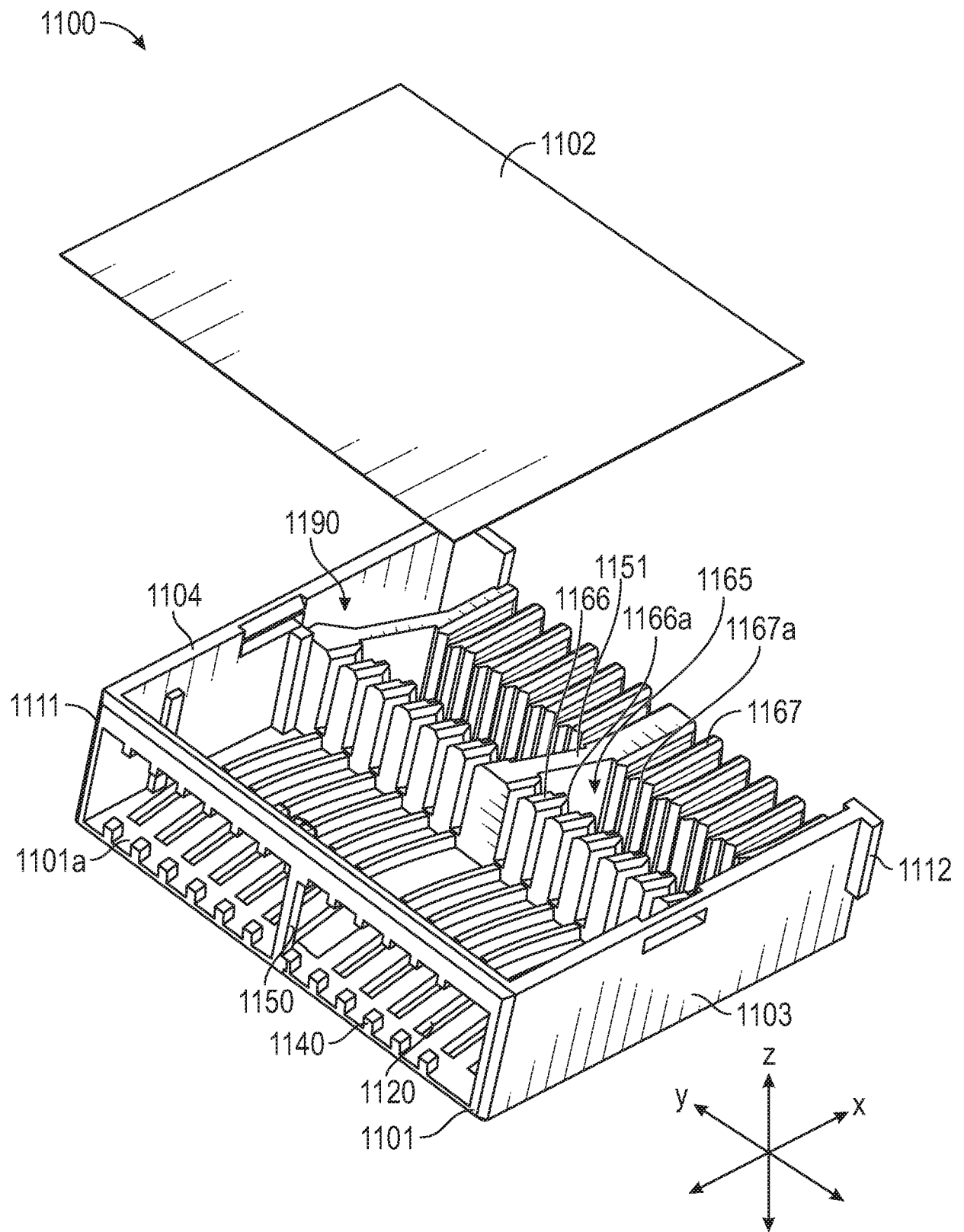


FIG. 11

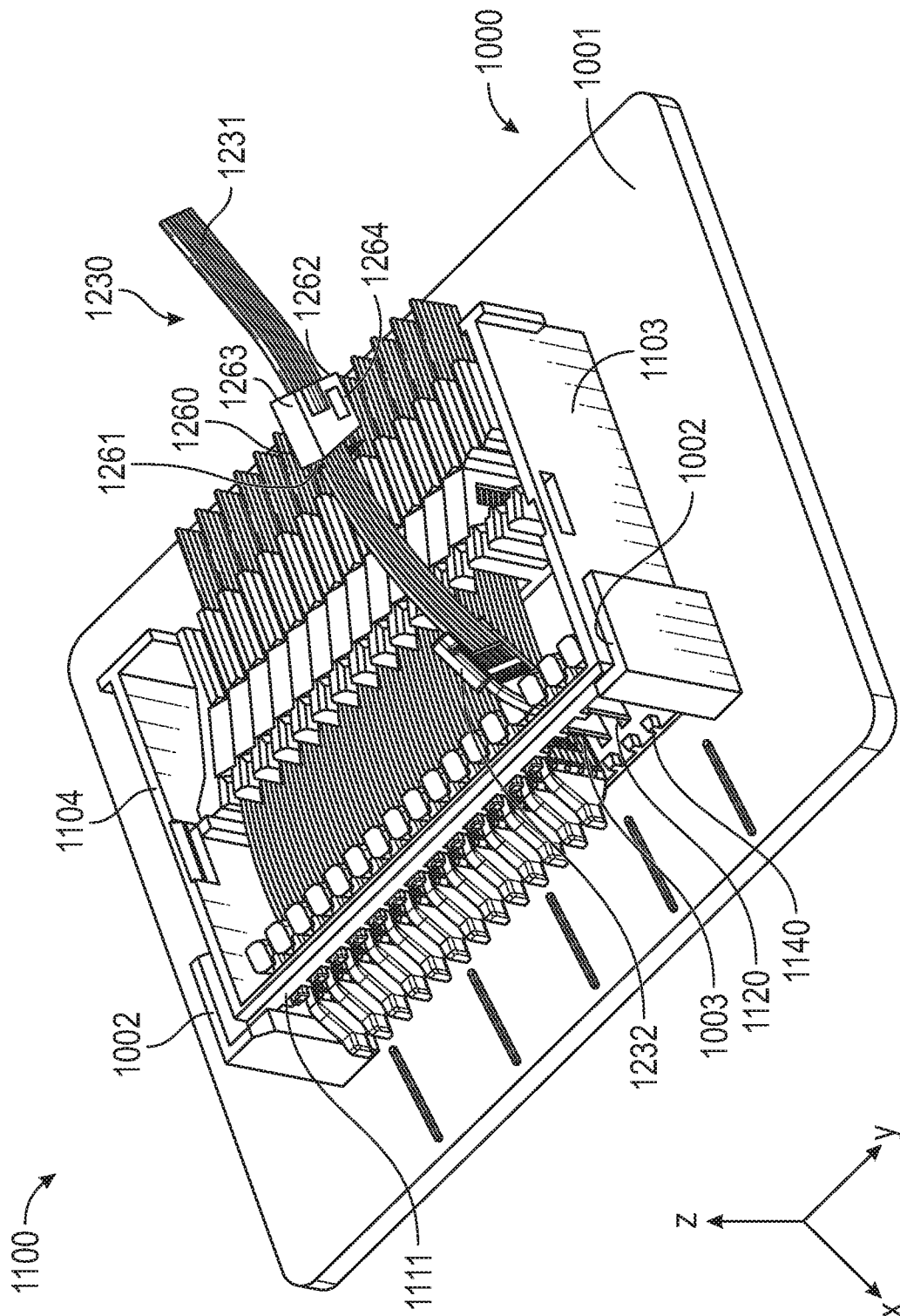


FIG. 12A

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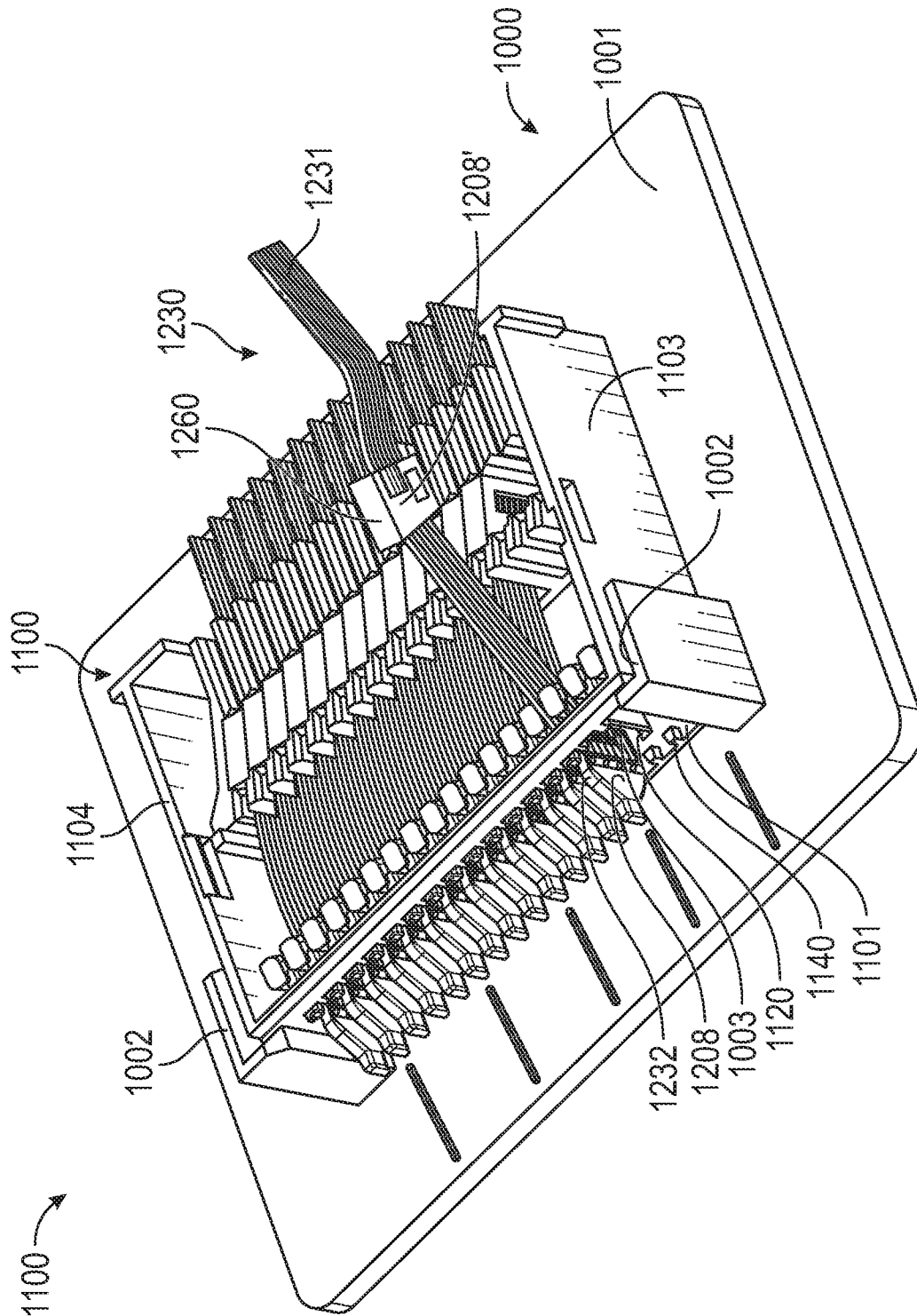


FIG. 12B

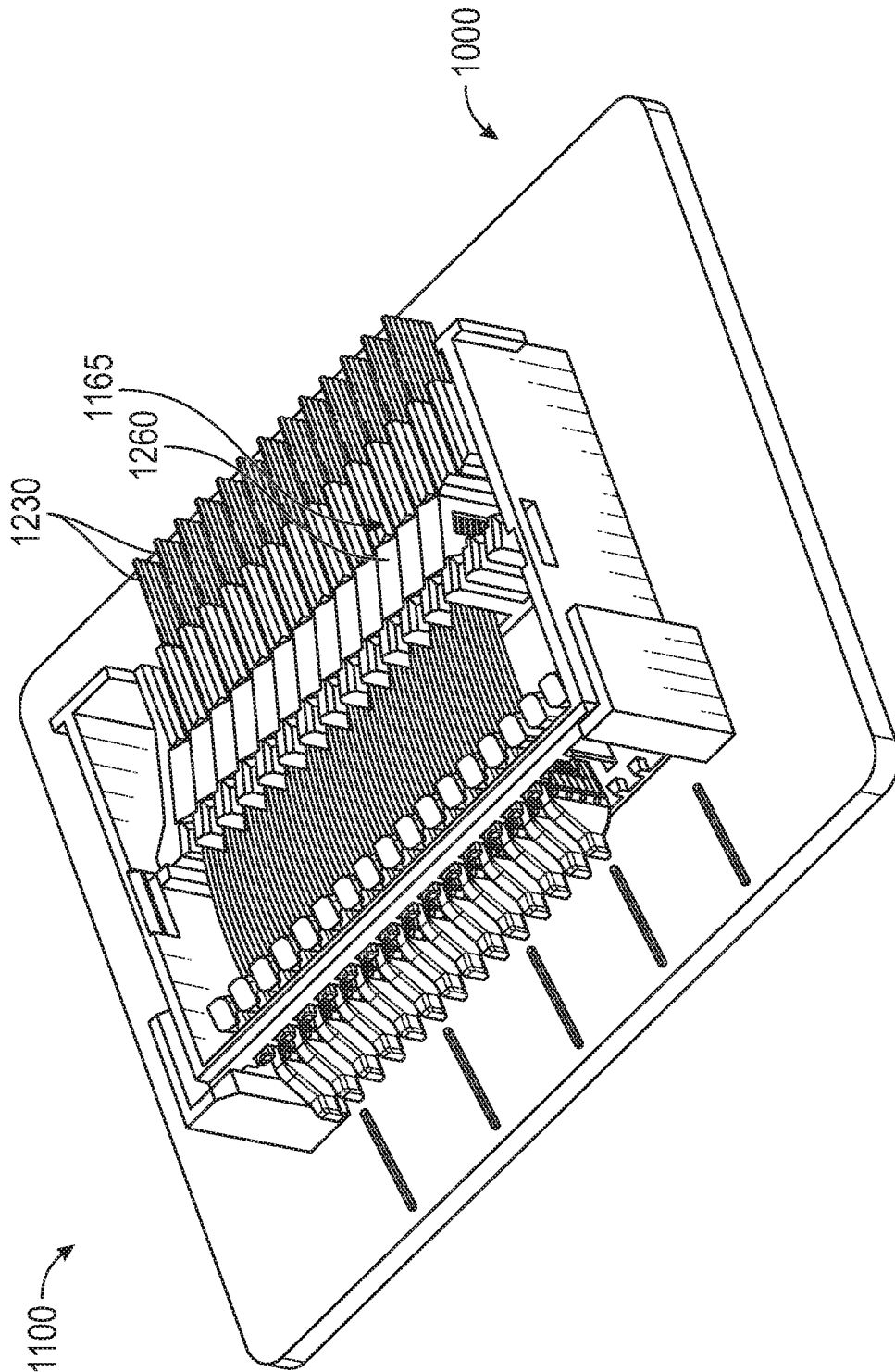


FIG. 12C

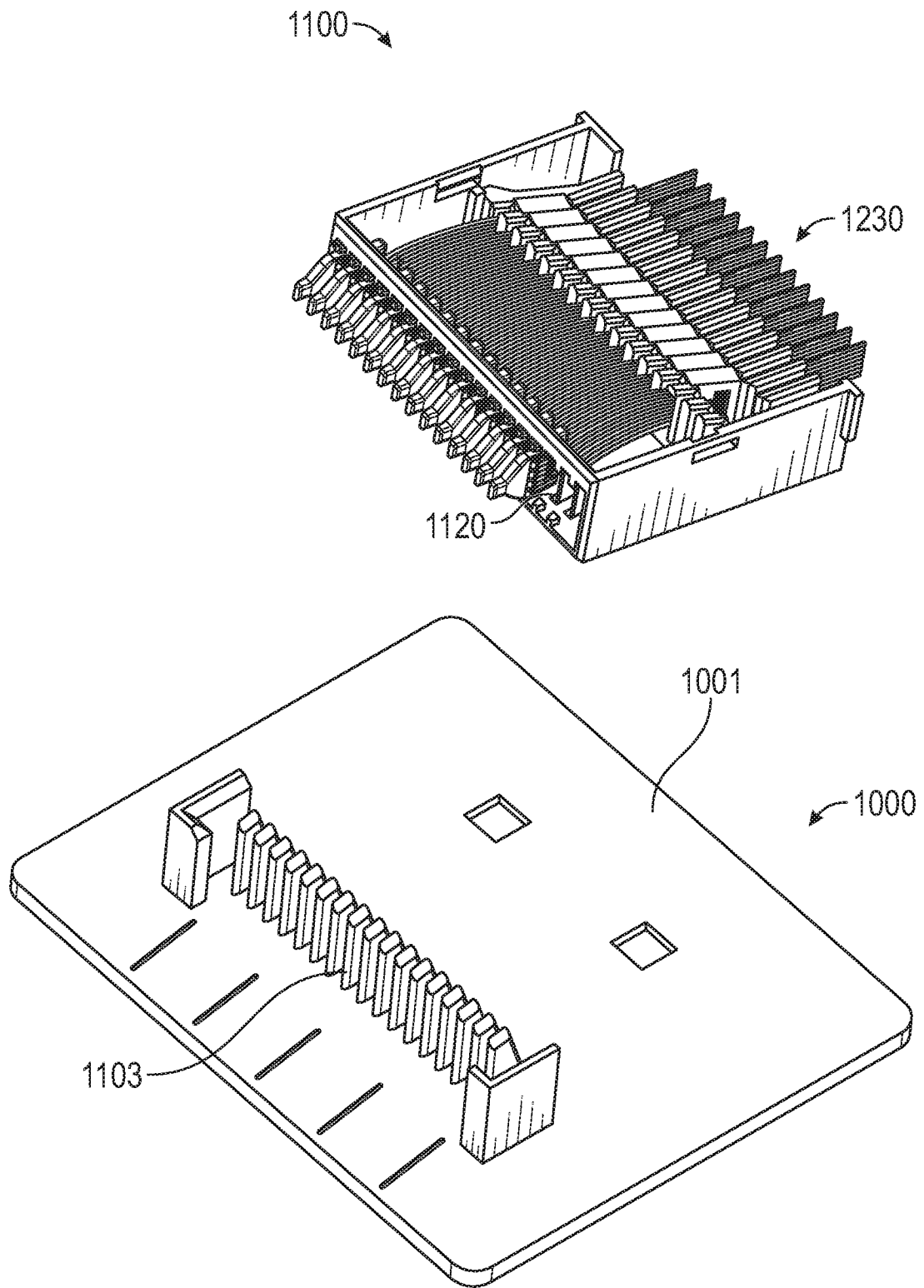


FIG. 12D

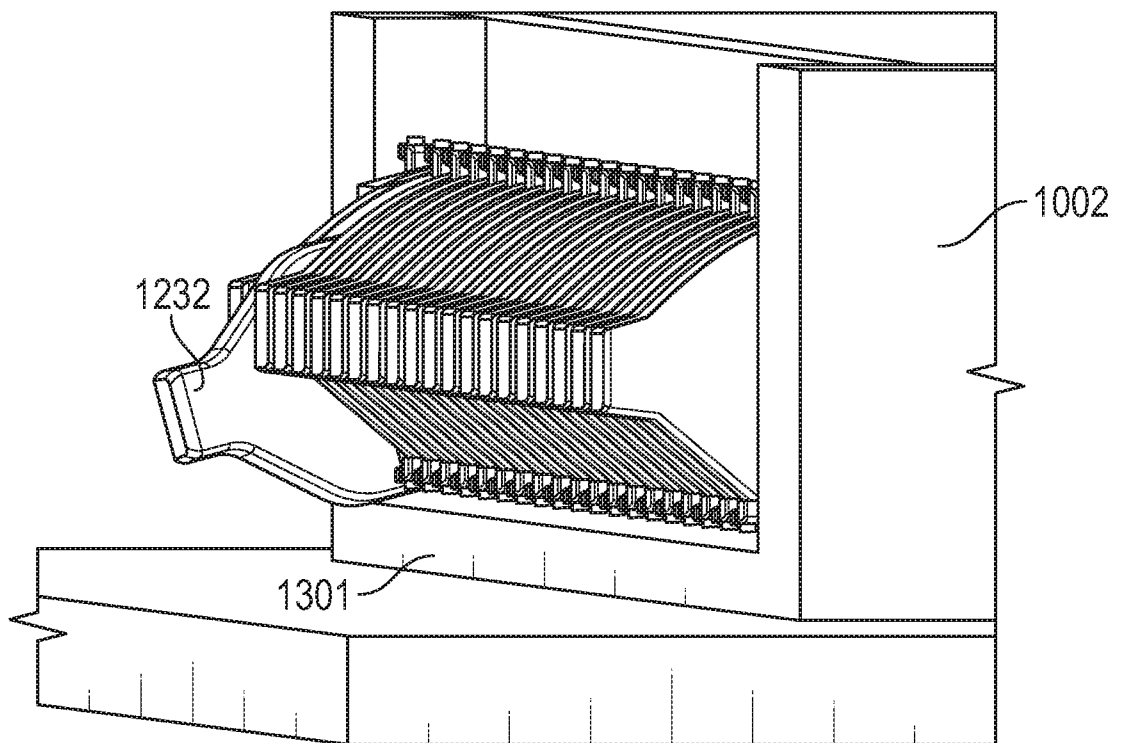


FIG. 13

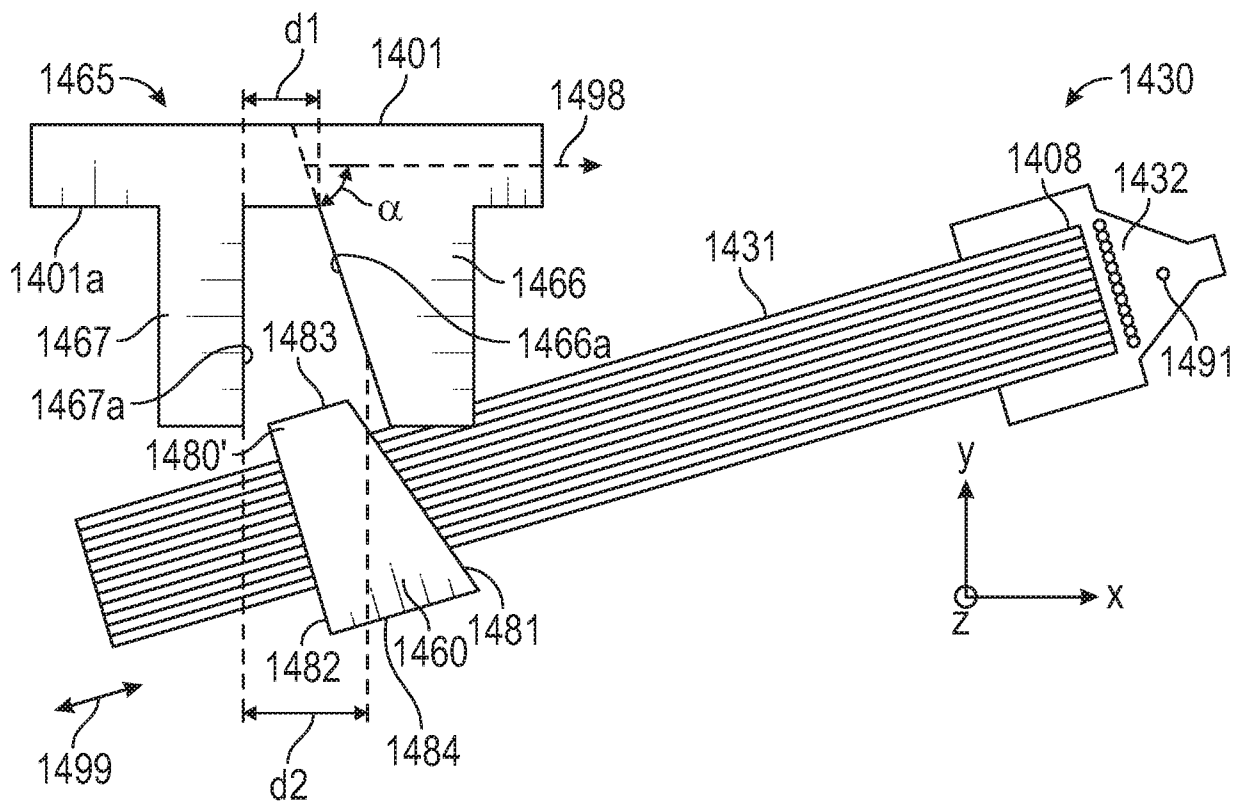


FIG. 14A

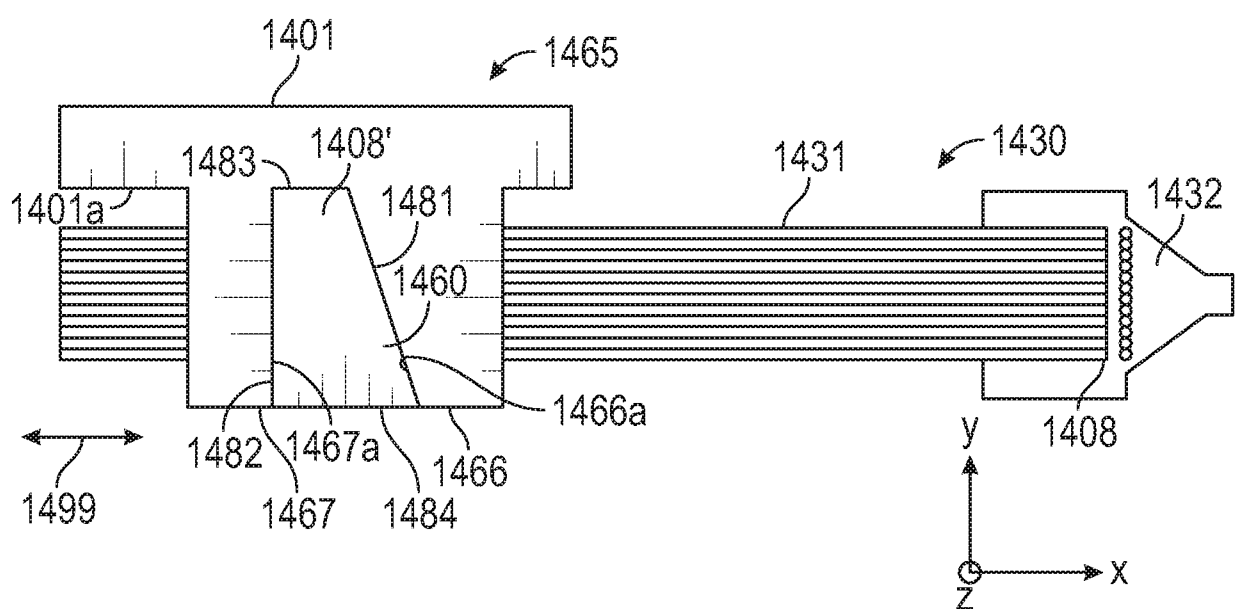


FIG. 14B

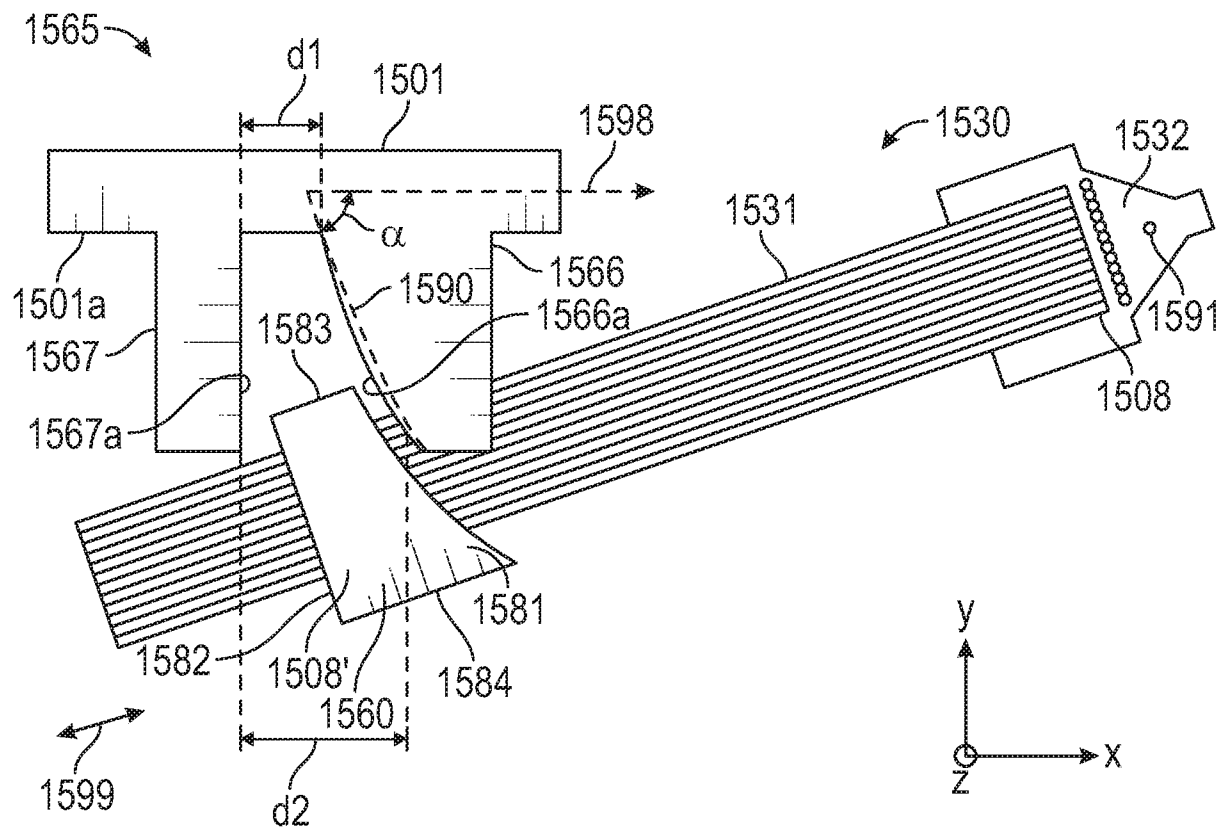


FIG. 15A

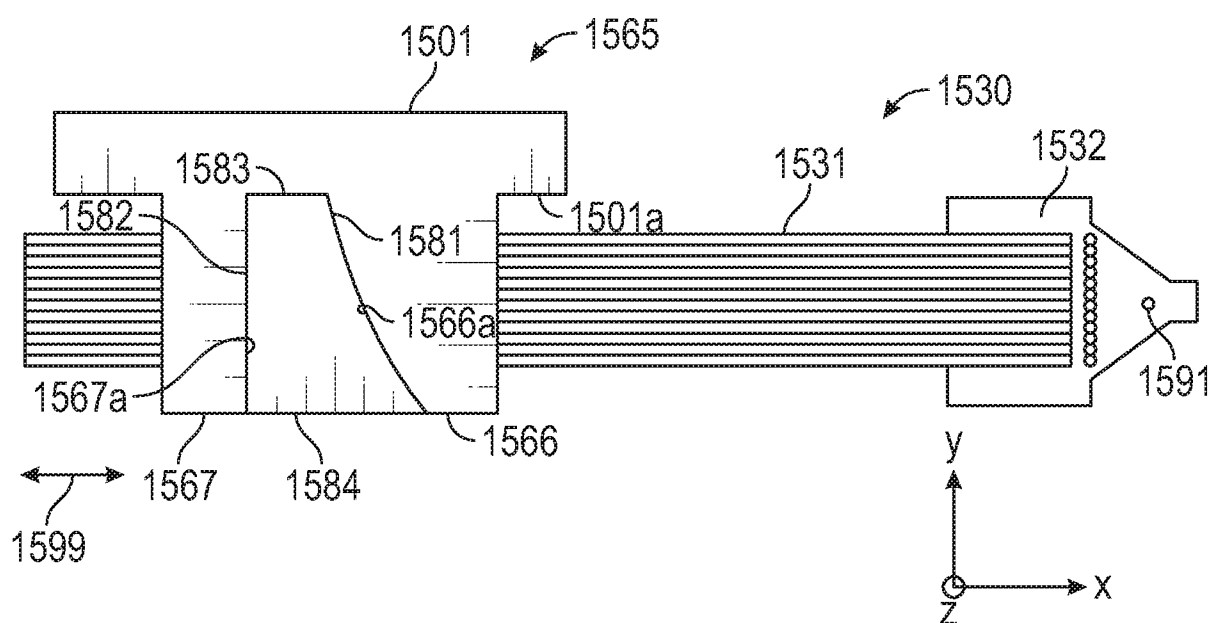


FIG. 15B

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2019/055366

A. CLASSIFICATION OF SUBJECT MATTER		
Int.Cl. G02B6/36(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)		
Int.Cl. G02B6/36-6/43, G02B6/46, H01S5/02, H01R13/46		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Published examined utility model applications of Japan 1922-1996 Published unexamined utility model applications of Japan 1971-2019 Registered utility model specifications of Japan 1996-2019 Published registered utility model applications of Japan 1994-2019		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2002-311295 A (YAZAKI CORPORATION) 2002.10.23, paragraphs [0016]-[0024], figures 1-5 (No Family)	1-10
X A	WO 2017/066139 A1 (3M INNOVATIVE PROPERTIES COMPANY) 2017.04.20, page 18, lines 4-16, figures 24B, 25 & JP 2018-534634 A, paragraphs [0069]-[0071], figures 24B, 25 & US 2018/0284357 A1 & KR 10-2018-0067578 A & CN 108351472 A	3-5 1-2, 6-10
☒ 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
08.10.2019		15.10.2019
Name and mailing address of the ISA/JP		Authorized officer
Japan Patent Office		YAMAMOTO, Kiichi
3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan		2L 4086
		Telephone No. +81-3-3581-1101 Ext. 3295

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2019/055366

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5689598 A (SIECOR CORPORATION) 1997.11.18, column 3, line 66 - column 5, line 52, figures 1-5 & JP 10-104467 A, paragraphs [0009]-[0015], figures 1-5	1-10
A	US 5600747 A (THE FURUKAWA ELECTRIC CO., LTD.) 1997.02.04, figures 5, 10-13, 22-23 & JP 8-106029 A, figures 5, 10-13, 22-23 & EP 696748 A2 & CN 1117592 A	1-10
A	US 2012/0099819 A1 (RADIALL) 2012.04.26, (whole document) & EP 2444827 A1	1-10
A	WO 2017/116933 A2 (3M INNOVATIVE PROPERTIES COMPANY) 2017.07.06, (whole document) & JP 2019-500654 A & CN 108463753 A & TW 201737568 A	1-10
A	JP 60-057807 A (NISSAN MOTOR CO., LTD.) 1985.04.03, (whole document) (No Family)	1-10
A	JP 2004-085714 A (MITSUBISHI ELECTRIC CORPORATION) 2004.03.18, (whole document) (No Family)	1-10
A	JP 6-250028 A (FUJITSU LIMITED) 1994.09.09, (whole document) (No Family)	1-10
A	US 5671311 A (THE WHITAKER CORPORATION) 1997.09.23, (whole document) & JP 8-211251 A & EP 713111 A1 & KR 10-1996-0018634 A	1-10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2019/055366

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

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

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

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

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

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

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

D1: JP 2002-311295 A (YAZAKI CORPORATION)
2002.10.23, paragraphs [0016]-[0024], figures 1-5 (No Family)

The claims can be grouped into three inventions as below.

(Continued in extra sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

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.

Continuation of: Box No. III

(Invention 1) claims 1-2

Claims 1-2 include "slots separating at least a portion of a narrower section from at least a portion a wider section" as a special technical feature, over the prior art in light of the disclosure of document D1. Thus claims 1-2 are grouped into Invention 1.

(Invention 2) claims 3-7

Claims 3-7 involve neither the same nor corresponding special technical features with claims 1-2 in Invention 1.

Further, claims 3-7 are not dependent claims of claim 1. Those claims 3-7 are neither substantially identical, nor similarly closely related, with any claim grouped into Invention 1.

Therefore, claims 3-7 cannot be grouped into Invention 1.

Then, claims 3-7 include "at least one optical waveguide, an optical ferrule attached to the optical waveguide at a first location, and a cable retainer attached to the optical waveguide" as a special technical feature, over the prior art in light of the disclosure of D1. Thus claims 3-7 are grouped into Invention 2.

(Invention 3) claims 8-10

Claims 8-10 involve neither the same nor corresponding special technical features with claims 1-2 in Invention 1 or claims 3-7 in Invention 2.

Further, claims 8-10 are not dependent claims of claims 1-2 or claims 3-7. Those claims 8-10 are neither substantially identical, nor similarly closely related, with any claim grouped into Invention 1 or Invention 2.

Claims 8 and 10 include "a tool for installing multiple optical ferrule subassemblies into a frame" as a special technical feature, over the prior art in light of the disclosure of D1. Claim 9 is an invention for which an examination may be made without substantially conducting additional prior art searches as a result of examining claims 8 and 10. Thus claims 8-10 are grouped into Invention 3.