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- (71) **Applicant: TYCO ELECTRONICS (SHANGHAI) CO. LTD.** [CN/CN]; Level 1, No. 142 He Dan Road, Waigaoqiao Free Trade Zone, Shanghai, 200233 (CN).
- (71) **Applicant (for MG only): TYCO ELECTRONICS UK LTD** [GB/GB]; Faraday Road, Dorcan, Swindon Wiltshire SN3 5HH (GB).
- (72) **Inventors: TONG, Zhaoyang;** c/o Tyco Electronics (Shanghai) Co. Ltd., Level 1, No. 142 He Dan Road, Waigaoqiao Free Trade Zone, Shanghai, 200233 (CN). **LIU, Lei;** c/o Tyco Electronics (Shanghai) Co. Ltd., Level 1, No. 142 He Dan Road, Waigaoqiao Free Trade Zone, Shanghai, 200233 (CN). **LIN, Lin;** c/o Tyco Electronics (Shanghai) Co. Ltd., Level 1, No. 142 He Dan Road, Waigaoqiao Free Trade Zone, Shanghai, 200233 (CN).
- (74) **Agents: HEINZ-SCHAEFER, Marion et al.;** c/o Tyco Electronics UK Ltd, European Patent Department, Faraday Road, Dorcan, Swindon Wiltshire SN3 5HH (GB).

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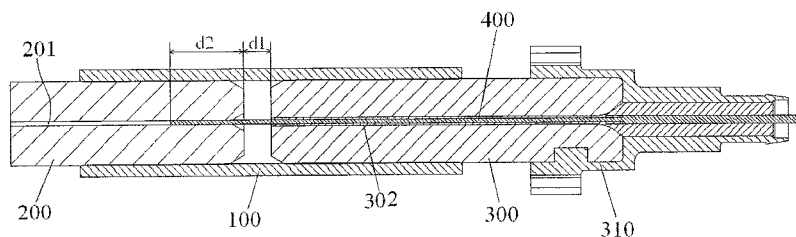
(54) **Title:** INDEXING TOOL, CALIBRATING METHOD, FERRULE ASSEMBLY AND FIBER OPTIC CONNECTOR

Fig.1

(57) **Abstract:** In an indexing tool for calibrating a position of an optical fiber (400) in a bore of a ferrule (300), the fiber extends outward from an end surface of the ferrule, the ferrule (300) has a first indexing feature, and the bore is positioned with respect to the first indexing feature. The indexing tool comprises: a second indexing feature (100) shaped to be complementary with the first indexing feature and capable of being mated with the first indexing feature to align them with each other; and an indexing element (200) having an alignment bore (201) for receiving the fiber extending outward from the ferrule, wherein the alignment bore is positioned with respect to the second indexing feature (100), such that when the first and second indexing features are mated and aligned with each other and the fiber (400) is received in the alignment bore (201), the position accuracy of the fiber in the bore of the ferrule with respect to the first indexing feature is calibrated to reach that of the fiber in the alignment bore with respect to the second indexing feature (100).

INDEXING TOOL, CALIBRATING METHOD, FERRULE ASSEMBLY AND FIBER OPTIC CONNECTOR

5 CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of Chinese Patent Application No. 201310203217.8 filed on May 28, 2013, Chinese Patent Application No. 201310203120.7 filed on May 28, 2013, Chinese Patent Application No. 201310226442.3 filed on June 7, 2013 and Chinese
10 Patent Application No. 201310226188.7 filed on June 7, 2013 in the State Intellectual Property Office of China, the whole disclosures of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

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Field of the Invention

Embodiments of the present invention relates to a technical field of fiber optic connector, more particularly, relates to an indexing tool and a method for calibrating a
20 position of an optical fiber in a bore of a ferrule, a ferrule assembly manufactured by the indexing tool and the calibrating method, and a fiber optic connector comprising the ferrule assembly.

Description of the Related Art

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A ferrule for a fiber optic connector is a high precision element manufactured by a precise machining technology, and the ferrule is a core component of the fiber optic connector. In prior art, steps of manufacturing the fiber optic connector generally comprising: obtaining a bare fiber by peeling an optical cable and cleaning the bare fiber;
30 inserting the bare fiber through a bore of the ferrule in which gel is prefilled; curing the gel to fix the bare fiber in the bore of the ferrule; and processing the ferrule and the fiber by grinding, polishing, testing, etc., to form a ferrule assembly. A manufacturing error is unavoidable during manufacturing the ferrule assembly. Furthermore, a personal error may be occurred in size for easily fitting/assembling the ferrule assembly, for example, in order
35 to easily insert the fiber through the bore of the ferrule, the diameter of the bore of the ferrule is formed to be larger than the outer diameter of the fiber, causing a size deviation distance between the outer diameter of the fiber and the inner diameter of the bore. Thereby, it is likely to occur various errors in the ferrule assembly, for example, a center axis of the

fiber is offset from a center axis of the bore of ferrule, a position of the bore is offset from an ideal position of the bore determined with reference to an indexing feature (for example, an outer cylinder of a single-fiber ferrule or a guide hole of a multi-fiber ferrule). As a result, an actual center axis of the fiber in the bore of the ferrule may be offset from an ideal center axis of the fiber determined with reference to the indexing feature of the ferrule due to these errors, increasing the insertion loss of coupling a pair of fiber optic connectors and decreasing the optical transmission performance of the fiber optic connectors.

A mode field diameter of a single-mode fiber is much less than a mode field diameter of a multi-mode fiber. Generally, the mode field diameter of the single-mode fiber is equal to about 1/6 to 1/5 of the mode field diameter of the multi-mode fiber, for example, a fiber core of a current standard single-mode fiber has a diameter of about 9 μ m, and a fiber core of a current standard multi-mode fiber has a diameter of about 50 μ m or 62.5 μ m. Thereby, the alignment accuracy of the single-mode fiber is required to be much higher than that of the multi-mode fiber. Accordingly, the precision of the ferrule for the single-mode fiber optic connector is much higher than that of the ferrule for the multi-mode fiber optic connector.

The single-mode ferrule and the multi-mode ferrule each comprises two different types—a ferrule with a single bore (also referred as a single-fiber ferrule) and a ferrule with a plurality of bores (also referred as a multi-fiber ferrule). Hereafter, it will describe precision requirements on the two types of single-mode and multi-mode ferrules.

(i) The single-mode single-bore and multi-mode single-bore ferrules

The precision requirements on the single-mode single bore ferrule mainly comprise a high size precision on the diameter of the bore of the ferrule and a high concentricity between the fiber and the outer cylinder of the ferrule. Hereafter, it will compare the single-mode single bore ferrule and the multi-mode single bore ferrule on following precision requirements.

1) Dimensional tolerance on the outer cylinder of the ferrule.

For the single-mode ferrule, the dimensional tolerance of the outer cylinder of the ferrule is generally required to reach about a range of -0.0005mm ~ 0.0005mm.

For the multi-mode ferrule, the dimensional tolerance of the outer cylinder of the ferrule is generally required to reach about a range of -0.001mm ~ 0.001mm.

2) Dimensional tolerance on the diameter of the bore of the ferrule.

For the single-mode ferrule, the dimensional tolerance of the diameter of the bore of the ferrule is generally required to reach about a range of 0.000 ~ 0.001mm, or even required to reach about a range of 0.0000 ~ 0.0005mm for a low insertion loss single-mode ferrule.

For the multi-mode ferrule, the dimensional tolerance of the diameter of the bore of the ferrule is generally required to reach about a range of 0.000 ~ 0.004mm.

3) Concentricity between the fiber and the outer cylinder of the ferrule.

For the single-mode ferrule, the concentricity between the fiber and the outer cylinder of the ferrule is generally required to reach about 0.001mm, or even required to reach about 0.0005mm for a low insertion loss single-mode ferrule.

For the multi-mode ferrule, the concentricity between the fiber and the outer cylinder of the ferrule is generally required to reach about 0.004mm.

(ii) The single-mode multi-bore and multi-mode multi-bore ferrules

The precision requirements on the single-mode multi-bore ferrule mainly comprise a high size precision on the diameter of the bore of the ferrule, a high size precision on a diameter of a guide hole/rod of the ferrule and a high position accuracy of the bore with respect to the guide hole/rod of ferrule. Hereafter, it will compare the single-mode multi-bore ferrule and the multi-mode multi-bore ferrule on following precision requirements.

1) Dimensional tolerance on the guide hole/rod of the ferrule.

For the single-mode ferrule, the dimensional tolerance of the guide rod of the ferrule is generally required to reach about a range of -0.0005mm ~ 0.0005mm, the dimensional tolerance of the guide hole of the ferrule is generally required to reach about a range of -0.001mm ~ 0.001mm; for a low insertion loss single-mode ferrule, the dimensional tolerance of the guide rod of the ferrule is even required to reach about a range of -0.0001mm ~ 0.0001mm, the dimensional tolerance of the guide hole of the ferrule is even required to reach about a range of -0.0003mm ~ 0.0003mm.

For the multi-mode ferrule, the dimensional tolerance of the guide rod/hole of the ferrule is generally required to reach about a range of -0.001mm ~ 0.001mm.

2) Dimensional tolerance on the diameter of the bore of the ferrule.

For the single-mode ferrule, the dimensional tolerance of the diameter of the bore of the ferrule is generally required to reach about a range of -0.00075mm ~ 0.00075mm, or even required to reach about a range of -0.0003mm ~ 0.0003mm for a low insertion loss single-mode ferrule.

For the multi-mode ferrule, the dimensional tolerance of the diameter of the bore of the ferrule is generally required to reach about a range of -0.001mm ~ 0.001mm.

3) The position accuracy of the bore of the ferrule with respect to the guide hole of the ferrule.

For the single-mode ferrule, the position accuracy of the bore of the ferrule with respect to the guide hole of the ferrule is generally required to reach about 0.003mm, or even required to reach about 0.0018mm for a low insertion loss single-mode ferrule.

For the multi-mode ferrule, the position accuracy of the bore of the ferrule with respect to the guide hole of the ferrule is generally required to reach about 0.006mm.

Accordingly, in order to ensure the single-mode fiber optic connector to satisfy with the above precision requirements, it is necessary to use the high precision single-mode

ferrule to manufacture the high precision single-mode fiber optic connector, and it is impossible to use the low precision multi-mode ferrule to manufacture the high precision single-mode fiber optic connector. That is, during manufacturing the high precision single-mode fiber optic connector, it is necessary to differentiate the high precision single-mode ferrule and the low precision multi-mode ferrule. Although the single-mode single bore ferrule (plurality of bores) and the multi-mode single bore ferrule (plurality of bores) both have the same outer appearance and almost the same in structure, the single-mode ferrule has a much higher precision requirement than that of the multi-mode ferrule. For example, for the single-mode single bore ferrule, the requirement on centricity between the bore of ferrule and the outer cylinder of the ferrule is very strict, generally required to reach within $1.5\mu\text{m}$, or even required to less than $1\mu\text{m}$ for the single-mode fiber optic connector with an ultralow insertion loss; and for the single-mode multi-bore ferrule, the requirement on the precision of the diameter of the bore of the ferrule and the position accuracy of the bore with respect to the guide hole of ferrule is very strict, generally required to reach within $3.0\mu\text{m}$, or even required to less than $1\mu\text{m}$ for the single-mode fiber optic connector with an ultralow insertion loss.

As those skilled in this art all known, the cost of the high precision single-mode ferrule is much higher than that of the low precision multi-mode ferrule, therefore, using the high precision single-mode ferrule to manufacture the high precision single-mode fiber optic connector has a disadvantage of increasing the cost of the single-mode fiber optic connector, and the cost of the single-mode fiber optic connector with the ultralow insertion loss may be times than that of the multi-mode fiber optic connector manufactured by the multi-mode ferrule.

As described above, in the prior art, the high precision single-mode fiber optic connector only can be manufactured by using the high precision single-mode ferrule, and it is impossible to use the low precision multi-mode ferrule to manufacture the high precision single-mode fiber optic connector, therefore, the cost of the high precision single-mode fiber optic connector manufactured in the prior art is very high. Furthermore, in order to avoid the deviation distance between the bore of the ferrule and the fiber inserted the bore of the ferrule, the diameter of the bore of the high precision single-mode ferrule is formed very small and almost equal to that of the fiber, therefore, it is difficult to insert the fiber into the bore, and the fiber is easily broken during inserting the fiber, decreasing the insertion efficiency of the fiber.

SUMMARY OF THE INVENTION

The present invention has been made to overcome or alleviate at least one aspect of the above mentioned disadvantages.

Accordingly, an object of the present invention is to provide an indexing tool for

calibrating a position of an optical fiber in a bore of a low precision ferrule (for example, a low precision multi-mode ferrule) to increase the position accuracy of the fiber in the bore of the low precision ferrule, so that the position accuracy of the fiber in the bore of the low precision ferrule at least reaches that of the fiber in a bore of a high precision ferrule (for example, a high precision single-mode ferrule).

Accordingly, another object of the present invention is to provide a method for calibrating a position of an optical fiber in a bore of a low precision ferrule (for example, a low precision multi-mode ferrule) to increase the position accuracy of the fiber in the bore of the low precision ferrule, so that the position accuracy of the fiber in the bore of the low precision ferrule at least reaches that of the fiber in a bore of a high precision ferrule (for example, a high precision single-mode ferrule).

According to an embodiment of an aspect of the present invention, there is provided an indexing tool for calibrating a position of an optical fiber in a bore of a ferrule, the fiber extending outward from an end surface of the ferrule, the ferrule having a first indexing feature, and the bore being positioned with respect to the first indexing feature. The indexing tool comprises: a second indexing feature shaped to be complementary with the first indexing feature and capable of being mated with the first indexing feature to align them with each other; and an indexing element having an alignment bore for receiving the fiber extending outward from the ferrule, wherein the alignment bore is positioned with respect to the second indexing feature, such that when the first and second indexing features are mated and aligned with each other and the fiber is received in the alignment bore, the position accuracy of the fiber in the bore of the ferrule with respect to the first indexing feature is calibrated to reach that of the fiber in the alignment bore with respect to the second indexing feature.

According to an embodiment of another aspect of the present invention, there is provided a method for calibrating a position of an optical fiber in a bore of a ferrule, the fiber extending outward from an end surface of the ferrule, the ferrule having a first indexing feature, and the bore of the ferrule being positioned with respect to the first indexing feature, the method comprising steps of:

providing an indexing tool according to the above embodiment; and calibrating the position of the fiber in the bore of the ferrule by means of the indexing tool.

According to an embodiment of a further aspect of the present invention, there is provided a ferrule assembly comprising a ferrule and a fiber in a bore of the ferrule, wherein the position of the fiber in the bore of the ferrule is calibrated by the above indexing tool or by the above method.

According to an embodiment of a still aspect of the present invention, there is provided a fiber optic connector comprising a ferrule assembly according to the above embodiment.

In the present invention, since the position accuracy of the fiber in the bore of the low

precision multi-mode ferrule can be calibrated to reach the position accuracy of the fiber in the bore of the high precision single-mode ferrule, a high precision single-mode fiber optic connector can be manufactured by using the low precision multi-mode ferrule, instead of using the expensive single-mode ferrule with high precision. Thereby, the present invention decreases the cost of the high precision single-mode fiber optic connector.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the accompanying drawings, in which:

Fig. 1 is an illustrative axial section view of an indexing tool for calibrating a position of an optical fiber in a bore of a single-fiber ferrule according to a first exemplary embodiment of the present invention;

Fig. 2 is an illustrative axial section view of using a holding seat to fix the indexing tool of Fig. 1, in which a spacer and an extractor are shown;

Fig. 3 is an illustrative lateral cross section view of the indexing tool of Fig. 1;

Fig. 4 is an illustrative lateral cross section view of an indexing tool according to another example of the present invention;

Fig. 5 is an illustrative lateral cross section view of an indexing tool according to another example of the present invention;

Fig. 6 is an illustrative axial section view of an indexing tool according to another example of the present invention;

Fig. 7 is an illustrative lateral cross section view of the indexing tool of Fig. 6;

Fig. 8 is an illustrative lateral cross section view of an indexing tool according to a fifth exemplary embodiment of the present invention;

Fig. 9 is an illustrative lateral cross section view of a ferrule assembly manufactured by a method of the present invention;

Fig. 10 is an illustrative lateral cross section view of a fiber according to another example of the present invention;

Fig. 11 is an illustrative perspective view of a plurality of loose fibers;

Fig. 12 is an illustrative end view of the plurality of loose fibers of Fig. 11;

Fig. 13 is an illustrative perspective view of a fiber bundle formed by calibrating the plurality of loose fibers of Figs. 11-12 in an alignment bore;

Fig. 14 is an illustrative end view of the fiber bundle of Fig. 13;

Fig. 15 is an illustrative view of an indexing tool for calibrating positions of optical fibers in bores of a multi-fiber ferrule according to a second exemplary embodiment of the present invention;

Fig. 16 is an illustrative view of using a clamp to fix the indexing tool of Fig. 15, in which a spacer is shown;

Fig. 16A is an illustrative view of a clamp according to another example of the present invention;

Fig. 17 is an illustrative perspective view of the indexing tool of Figs. 15, 16 and 16A;

Fig. 18 is an illustrative perspective view of an indexing tool according to another
5 example of the present invention;

Fig. 19 is an illustrative end view of the indexing tool of Fig. 18;

Fig. 20 is illustrative perspective view of an indexing tool according to another example of the present invention;

Fig. 21 is an illustrative end view of the indexing tool of Fig. 20; and

10 Fig. 22 is an illustrative local end view of the multi-fiber ferrule of Fig. 15.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Exemplary embodiments of the present disclosure will be described hereinafter in detail
15 with reference to the attached drawings, wherein the like reference numerals refer to the like elements. The present disclosure may, however, be embodied in many different forms and should not be construed as being limited to the embodiment set forth herein; rather, these embodiments are provided so that the present disclosure will be thorough and complete, and will fully convey the concept of the disclosure to those skilled in the art.

20 According to a general concept of the present invention, there is provided an indexing tool for calibrating a position of an optical fiber in a bore of a ferrule, the fiber extends outward from an end surface of the ferrule, the ferrule has a first indexing feature, and the bore is positioned with respect to the first indexing feature. The indexing tool comprising: a second indexing feature being complementary with the first indexing feature and capable of
25 being mated with the first indexing feature to align them with each other; and an indexing element having an alignment bore for receiving the fiber extending outward from the ferrule, wherein the alignment bore is accurately positioned with respect to the second indexing feature, such that when the first and second indexing features are mated and aligned with each other and the fiber is received in the alignment bore, the position accuracy of the fiber
30 in the bore of the ferrule with respect to the first indexing feature is calibrated to reach that of the fiber in the alignment bore with respect to the second indexing feature.

In the following detailed description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the disclosed embodiments. It will be apparent, however, that one or more embodiments may be practiced
35 without these specific details. In other instances, well-known structures and devices are schematically shown in order to simplify the drawing.

It should be appreciated for those skilled in this art that the fiber of the present invention comprises a standard single-core fiber, a multi-core fiber or a fiber bundle. Accordingly, the fiber mentioned herein covers the above variations of the fiber.

First Embodiment

Fig. 1 is an illustrative axial section view of an indexing tool for calibrating a position of an optical fiber in a bore of a single-fiber ferrule (also referred as a single-bore ferrule) according to a first exemplary embodiment of the present invention; Fig. 2 is an illustrative axial section view of using a holding seat 500 to fix the indexing tool of Fig. 1, in which a spacer 610 and an extractor 600 are shown.

As shown in Figs. 1-2, the indexing tool is used to calibrate the position of the fiber 400 in the bore of the single-fiber ferrule 300. The fiber 400 extends outward from an end surface of the ferrule 300, the ferrule 300 has an outer cylinder (a first indexing feature), and the bore of the ferrule 300 is positioned with respect to the outer cylinder.

As shown in Figs. 1-2, the indexing tool mainly comprises a second indexing feature 100 and an indexing element 200. In the illustrated embodiment, the second indexing feature is configured to be an alignment sleeve 100. The alignment sleeve 100 is shaped to be complementary with the outer cylinder and capable of being mated with the outer cylinder of the ferrule 300 to align them with each other. The indexing element 200 has an alignment bore 201 for receiving an end of the fiber 400 extending outward from the ferrule 300. The alignment bore 201 is accurately positioned at an ideal position with respect to the alignment sleeve 100, such that when the outer cylinder of the ferrule 300 and the alignment sleeve 100 are mated and aligned with each other and the fiber 400 is received in the alignment bore 201, the position accuracy of the fiber 400 in the bore of the ferrule 300 with respect to the outer cylinder of the ferrule 300 is calibrated to reach that of the fiber 400 in the alignment bore 201 with respect to the alignment sleeve 100.

In the illustrated embodiment, the precision of the indexing element 200 may be equal to or higher than that of a current standard single-mode ferrule, and the precision of the ferrule 300 may be equal to or lower than that of a current standard multi-mode ferrule. The fiber 400 may be a standard single-mode fiber or a fiber having a diameter less or larger than that of the standard single-mode fiber. In an example of the present invention, the ferrule 300 may be a low precision multi-mode ferrule, and the fiber 400 may be a single-mode fiber. Please be noted that the diameter of the bore of the low precision multi-mode ferrule is much larger than the diameter of the single-mode fiber. Thereby, when the small diameter fiber 400 is fitted in the large diameter bore of the ferrule 300, a random deviation may be easily occurred between them. Thereby, it is difficult to position the fiber 400 in the bore of the ferrule 300 at an ideal position determined with reference to the outer cylinder the ferrule 300.

As shown in Figs. 1-2, the alignment sleeve 100 has a first end and a second end opposite to the first end. The indexing element 200 is inserted into the alignment sleeve 100 from the first end (left end) of the alignment sleeve 100, and the ferrule 300 is inserted into the alignment sleeve 100 from the second end (right end) of the alignment sleeve 100, such

that the center axis of the outer cylinder of the ferrule 300 is aligned with a center axis of a cylindrical body of the indexing element 200. As a result, a centricity between a center axis of the fiber 400 in the bore of the ferrule 300 and the center axis of the outer cylinder of the ferrule 300 is calibrated, such that the center axis of the fiber 400 in the bore of the ferrule 300 is aligned with a center axis of the alignment bore 201 of the indexing element 200. In an example, the centricity between the center axis of the fiber 400 in the bore of the ferrule 300 and the center axis of the alignment bore 201 of the indexing element 200 is equal to an order of submicron, so that the centricity between the center axis of the fiber 400 in the bore of the ferrule 300 and the center axis of the outer cylinder of the ferrule 300 can be calibrated to reach the order of submicron, or the centricity between an actual center axis of the fiber 400 in the bore of the ferrule 300 and an ideal center axis of the fiber 400 in the bore of the ferrule 300 determined with reference to the outer cylinder of the ferrule 300 can be calibrated to reach the order of submicron.

As shown in Figs.1-2, the small diameter fiber 400 is firstly inserted through the large diameter bore of the low precision multi-mode ferrule 300, and then introduced into the small diameter alignment bore 201 of the indexing element 200 under the guidance of a guide structure at the front end of the indexing element 200. The alignment bore 201 calibrates the position accuracy of the center axis of the fiber 400 in the large diameter bore of the low precision ferrule 300 with respect to the ideal center axis of the fiber 400 determined with reference to the outer cylinder of the ferrule 300, eliminating the deviation distance between the actual center axis and the ideal center axis of the fiber 400 occurred during fitting the small diameter fiber 400 in the large diameter bore of the ferrule 300. As a result, when the outer cylinder of the ferrule 300 is mated and aligned with the alignment sleeve 100, the position accuracy of the small diameter fiber 400 in the large diameter bore of the ferrule 300 with respect to the outer cylinder of the ferrule 300 can be calibrated to reach the position accuracy of the small diameter fiber 400 in the small diameter alignment bore 201 with respect to the alignment sleeve 100, that is, the center axis of the fiber 400 in the bore of the ferrule 300 is calibrated to accurately align with the center axis of the outer cylinder of the ferrule 300.

As shown in Fig.1, a gel or a curable agent 302 may be prefilled in the bore of the ferrule 300 before the fiber 400 is inserted through the bore, or filled in a gap between the fiber 400 and an inner wall of the bore of the ferrule 300 from a rear end of the bore after the fiber 400 is calibrated and aligned.

Since the gel may overflow from the end surface of the ferrule 300, the end surface of the ferrule 300 cannot be in contact with an end surface of the indexing element 200. As shown in Figs.1-2, the end surface of the indexing element 200 inserted into the alignment sleeve 100 is separated from the end surface of the ferrule 300 inserted into the alignment sleeve 100 by a predetermined distance $d1$. Also, as shown in Figs.1-2, a portion of the fiber 400 received in the alignment bore 201 of the indexing element 200 has a predetermined

length d2.

Since the distance d1 between the end surfaces of the indexing element 200 and the ferrule 300 and the length d2 of the portion of the fiber 400 received in the alignment bore 201 both affect the calibration accuracy and render the difficulty of calibration operation, it is necessary to properly control the distance d1 and the length d2. It should be appreciated for those skilled in this art that the distance d1 or the length d2 may be adjusted according the practical requirement without being limited to a fixed value.

As shown in Fig.2, the indexing tool may further comprise a holding seat 500 for fixing the alignment sleeve 100 and the indexing element 200. In the illustrated embodiment, the alignment sleeve 100 and the indexing element 200 are fixed in a chamber of the holding seat 500 by screws 510. In this way, the alignment sleeve 100 and the indexing element 200 can be dismantled from the holding seat 500 by loosening the screws 510.

In the illustrated embodiment of Figs.1-2, the indexing tool is formed by assembling the alignment sleeve 100 and the indexing element 200. That is, the alignment sleeve 100 and the indexing element 200 are configured to be two separate members. But the present invention is not limited to this, in another example, the alignment sleeve 100 and the indexing element 200 may be configured to be a single piece.

After the fiber 400 is calibrated in the bore of the ferrule 300, the fiber 400 is fixed in the bore of the ferrule 300 by curing the gel. After the fiber 400 is fixed in the bore of the ferrule 300, the ferrule 300 can be taken out from the indexing tool, and then cutting the fiber, grinding and polishing the ferrule and the fiber to form a low cost ferrule assembly in which the fiber 400 is accurately positioned.

Fig.2 shows an extractor 600 for taking the ferrule 300 out of the indexing tool. As shown in Fig.2, the extractor 600 is fitted on the rear seat 310 of the ferrule 300, for taking out the ferrule 300 from the indexing tool after the fiber 400 has been calibrated and fixed in the bore of the ferrule 300.

As shown in Fig.2, the indexing tool further comprises a spacer 610 disposed between the holding seat 500 and a rear seat 310 of the ferrule 300, for controlling the distance d1 between the end surface of the indexing element 200 inserted into the alignment sleeve 100 and the end surface of the ferrule 300 inserted into the alignment sleeve 100. In practice use, the distance d1 may be adjusted by changing the thickness of the spacer 610.

But the present invention is not limited to the illustrated embodiment, for example, the spacer 610 may be disposed inside the alignment sleeve 100.

As shown in Fig.2, the spacer 610 and the extractor 600 are configured to be a single piece. But the present invention is not limited to this, the spacer 610 and the extractor 600 may be configured to be two separate members.

In the embodiment of the present invention, since the position accuracy of the fiber 400 in the bore of the low precision multi-mode single-fiber ferrule 300 can be calibrated by the indexing tool to reach the position accuracy of the fiber 400 in the bore of the high precision

single-mode single-fiber ferrule, a high precision single-mode single-fiber optic connector can be manufactured by using the low precision multi-mode single-fiber ferrule, instead of using the expensive single-mode single-fiber ferrule with high precision. Thereby, the embodiment of the present invention decreases the cost of the high precision single-mode single-fiber fiber optic connector.

Fig.3 is an illustrative lateral cross section view of the indexing tool of Fig.1.

As shown in Figs.1-3, the indexing element 200 is configured to be a single piece, and the alignment bore 201 is configured to be a circular hole or a special shape hole mated with an outer profile of the fiber 400.

Fig.4 is an illustrative lateral cross section view of an indexing tool according to another example of the present invention. The indexing tool of Fig.4 is different from the indexing tool of Figs.1-3 only in that the indexing element 200' has a different structure.

As shown in Fig.4, the indexing element 200' comprises a base 2001 and a press block 2002 separate from the base 2001. The base 2001 has a recess with an alignment bore 201' formed in a bottom wall of the recess. The press block 2002 is fitted in the recess so as to hold the fiber in the alignment bore 201'. In an exemplary embodiment, when the press block 2002 is fitted in the recess of the base 2001, the base 2001 and the press block 2002 together form a whole cylindrical body adapted to be inserted into the alignment sleeve 100. In the illustrate embodiment of Fig.4, the alignment bore 201' is configured to be a substantial U-type hole.

Fig.5 is an illustrative lateral cross section view of an indexing tool according to another example of the present invention. The indexing tool of Fig.5 is different from the indexing tool of Figs.1-3 only in that the indexing element 200'' has a different structure.

As shown in Fig.5, the indexing element 200'' comprises a base 2011 and a press block 2012 separate from the base 2011. The base 2011 has a recess with a alignment bore 201'' formed in a bottom wall of the recess. The press block 2012 is fitted in the recess so as to hold the fiber in the alignment bore 201''. In an exemplary embodiment, when the press block 2012 is fitted in the recess of the base 2011, the base 2011 and the press block 2012 together form a whole cylindrical body adapted to be inserted into the alignment sleeve 100. In the illustrate embodiment of Fig.5, the alignment bore 201'' is configured to be a substantial V-type hole. Please be noted that the present invention is not limited to the illustrated embodiments, the alignment bore may be configured to be a substantial semi-circular hole or any other suitable hole.

Although the indexing element shown in Figs.4-5 is configured to be a single piece, the present invention is not limited to this, for example, the indexing element may be formed by three or more separate members.

As shown in Fig.1, the alignment sleeve 100 is configured to be formed by only a single piece. But the present invention is not limited to this, for example, the alignment sleeve may be configured to be formed by at least two separate members, as shown in Fig.6.

Fig.6 is an illustrative axial section view of an indexing tool according to another example of the present invention; Fig.7 is an illustrative lateral cross section view of the indexing tool of Fig.6.

The main difference of the indexing tool shown in Figs.6-7 from the indexing tool shown in Fig.1 is that the second indexing feature has a different structure.

As shown in Figs.6-7, the second indexing feature 100' consists of two separate members. The second indexing feature 100' comprises a base 1001 and a top block 1002 separate from the base 1001. The base 1001 has a recess 1003 with a positioning groove 1004 formed in a bottom wall of the recess. The top block 1002 is fitted in the recess 1003 of the base 1001 so as to hold the indexing element 200 in the positioning groove 1004.

As shown in Figs.6-7, the whole second indexing feature 100' may have a cuboid shape. In an example, when the top block 1002 is fitted in the recess 1003 of the base 1001, the top surface of the top block 1002 is substantially flush with the top surface of the base 1001.

As shown in Figs.6-7, the positioning groove 1004 is configured to be a V-type positioning groove.

Fig.8 is an illustrative lateral cross section view of an indexing tool according to another example of the present invention.

As shown in Fig.8, the second indexing feature consists of two separate members. More specifically, the second indexing feature comprises a base 1011 and a top block 1012 separate from the base 1011. The base 1011 has a recess 1013 with a positioning groove 1014 formed in a bottom wall of the recess. The top block 1012 is fitted in the recess 1013 of the base 1011 so as to hold the indexing element 200 in the positioning groove 1014.

The main difference of the indexing tool shown in Fig.8 from the indexing tool shown in Figs.6-7 is that the positioning groove has a different shape. As shown in Fig.8, the positioning groove 1014 is configured to be a U-type positioning groove. But the present invention is not limited to the illustrated embodiments, the positioning groove may be formed to have any other suitable shape.

According to another general concept, there is provided a method for calibrating a position of an optical fiber in a bore of a ferrule, the fiber extends outward from an end surface of the ferrule, the ferrule has a first indexing feature, and the bore of the ferrule is positioned with respect to the first indexing feature, the method comprising steps of:

providing an indexing tool according to the above embodiments; and
calibrating the position of the fiber in the bore of the ferrule by means of the indexing tool.

In an example of the present invention, said step of calibrating the position of the fiber in the bore of the ferrule by means of the indexing tool comprises steps of:

mating the first and second indexing features together to accurately align them with each other; and

inserting an end of the fiber extending outward from the ferrule into the alignment bore, so that the position accuracy of the fiber in the bore of the ferrule with respect to the first indexing feature is calibrated to reach that of the fiber in the alignment bore with respect to the second indexing feature.

- 5 In another example of the present invention, said step of calibrating the position of the fiber in the bore of the ferrule by means of the indexing tool further comprises a step of:
curing a gel to fix the fiber in the bore of the ferrule after the fiber is calibrated by the indexing tool.

10 The gel may be filled in the bore of the ferrule before or after the fiber is inserted into the bore of the ferrule.

In an exemplary embodiment, after being calibrated by the indexing tool, a deviation distance between the center axis of the fiber 400 in the bore of the ferrule 300 and the center axis of the outer cylinder of the ferrule 300 may be decreased to an order of submicron.

15 Fig.9 is an illustrative lateral cross section view of a ferrule assembly manufactured by the above method.

As shown in Fig.9, after the calibrated fiber 400 is fixed in the bore of the ferrule 300 with the gel 302, a maximum distance (that is, a maximum thickness of the ring of gel 302) between an inner peripheral surface of the bore of the ferrule 300 and an outer peripheral surface of fiber 400 is larger than or equal to the deviation distance between the center axis C400 of the fiber 400 and the center axis C300 of the outer cylinder of the ferrule 300. In the present invention, the indexing tool is used to calibrate the position of the fiber 400 in the bore of the ferrule 300, so that the deviation distance between the center axis C400 of the fiber 400 and the center axis C300 of the outer cylinder of the ferrule 300 is equal to zero or within an allowable range, for example, within the order of submicron.

25 In an example of the present invention, the diameter dimensional tolerance of the outer cylinder of the ferrule 300 is in a range of $-0.001\text{mm} \sim 0.001\text{mm}$.

In an example of the present invention, the diameter dimensional tolerance of the bore of the ferrule 300 is in a range of $0.000 \sim 0.030\text{mm}$.

30 It should be appreciated for those skilled in this art that the present invention not only covers the above indexing tool and the above method, but also a ferrule assembly manufactured by the above indexing tool and the above method and a fiber optic connector comprising the ferrule assembly.

35 In another general concept of the present invention, there is provided a ferrule assembly comprising a ferrule and a fiber in a bore of the ferrule, wherein the position of the fiber in the bore of the ferrule is calibrated by the indexing tool according to the above embodiments or by the method according to the above embodiments.

In another general concept of the present invention, there is provided a fiber optic connector comprising the above ferrule assembly.

As shown in Fig.1, the fiber 400 is a standard single-core fiber. But the present

invention is not limited to the embodiments shown in Fig. 1, the fiber may be any other suitable type of fiber, for example, Figs. 10-14 show two different types of fibers.

Fig. 10 is an illustrative lateral cross section view of a fiber according to another example of the present invention.

5 As shown in Fig. 10, the fiber is a multi-core fiber 410 comprising a plurality of cores 411. The multi-core fiber 410 comprises nineteen cores 411. But the present invention is not limited to this, the multi-core fiber 410 may comprise two or more cores 411. As shown in Fig. 10, the plurality of cores 411 is encapsulated and positioned in place by a coating layer 412. The coating layer 412 is shaped as a cylinder.

10 Fig. 11 is an illustrative perspective view of a plurality of loose fibers; Fig. 12 is an illustrative end view of the plurality of loose fibers of Fig. 11; Fig. 13 is an illustrative perspective view of a fiber bundle formed by calibrating the plurality of loose fibers of Figs. 11-12 in an alignment bore; and Fig. 14 is an illustrative end view of the fiber bundle of Fig. 13.

15 As shown in Figs. 11-12, a plurality of fibers 421 are loosely and irregularly arranged together, and the fibers 421 are positioned random relative to each other. Once the loose fibers 421 are inserted into the alignment bore 201 of the indexing element 200, the loose fibers 421 are held together and positioned in place relative to each other, such that the fibers 421 together constitute a fiber bundle 420, as shown in Figs. 13-14.

20 As shown in Figs. 13-14, two adjacent fibers 421 of the fiber bundle 420 are tangent with each other. In the illustrated embodiment, one fiber is positioned at the center of the fiber bundle 420, and other fibers are positioned around the center fiber.

Although the fiber bundle 420 comprises seven fibers 421 in the embodiment shown in Figs. 11-14, the fiber bundle 420 may comprise two or more fibers 421.

25 In an example, the fibers 421 of the fiber bundle 420 each may be the standard single-core fiber shown in Fig. 1 or the multi-core fiber shown in Fig. 10.

In order to receive the plurality of fibers 421, the alignment bore 201 of the indexing element 200 may be formed as a circular hole, a plum blossom shaped hole, a polygon hole or any other suitable shape hole, so as to hold and position the plurality of fibers 421 to a
30 fiber bundle in which adjacent fibers 421 are tangent with each other.

Second Embodiment

Fig. 15 is an illustrative view of an indexing tool for calibrating positions of optical fibers in bores of a multi-fiber ferrule (also referred as a multi-bore ferrule) according to a
35 second exemplary embodiment of the present invention. Fig. 16 is an illustrative view of using a clamp to fix the indexing tool of Fig. 15, in which a spacer is shown. Fig. 17 is an illustrative perspective view of the indexing tool of Figs. 15-16.

As shown in Figs. 15-17, the ferrule 300 is a multi-fiber ferrule for a multi-fiber optic connector, and the indexing element 200 is an indexing element having a plurality of

alignment bores 201 for the multi-fiber optic connector.

As shown in Figs.15-17, the indexing tool is used to calibrate the position of the respective fiber 400 in the respective bore of the multi-fiber ferrule 300. The fiber 400 extends outward from an end surface of the ferrule 300, and the ferrule 300 has a pair of
5 guide holes (a first indexing feature), and the bores of the ferrule 300 each is positioned with respect to the guide holes.

As shown in Figs.15-17, the indexing tool mainly comprises a second indexing feature 100 and an indexing element 200. In the illustrated embodiment, the second indexing feature is configured to be a pair of alignment rods 100. The alignment rods 100 are formed on an
10 end surface of the indexing element 200 and extend horizontally forward from the end surface of the indexing element 200. The alignment rod 100 is shaped to complement with the guide hole formed in the end surface of the ferrule 300 and capable of being mated with the guide hole of the ferrule 300 to align them with each other. When the alignment rod 100 of the indexing element 200 is inserted into the guide hole of the ferrule 300, a center axis of
15 the alignment rod is aligned with a center axis of the guide hole. The indexing element 200 has a plurality of alignment bores 201 for receiving ends of the respective fibers 400 extending outward from the ferrule 300. The alignment bores 201 each is accurately positioned at an ideal position with reference to the alignment rod 100, such that when the guide hole of the ferrule 300 and the alignment rod 100 are mated and aligned with each
20 other and the fibers 400 each is received in the respective alignment bore 201, the position accuracy of the fiber 400 in the bore of the ferrule 300 with respect to the guide hole of the ferrule 300 is calibrated to reach that of the fiber 400 in the alignment bore 201 with respect to the alignment rod 100.

In the illustrated embodiment, the precision of the indexing element 200 may be equal
25 to or higher than that of a current standard single-mode ferrule, and the precision of the ferrule 300 may be equal to or lower than that of a current standard multi-mode ferrule. The fiber 400 may be a standard single-mode fiber or a fiber having a diameter less or larger than that of the standard single-mode fiber. In an example of the present invention, the ferrule 300 may be a low precision multi-mode ferrule, and the fiber 400 may be a
30 single-mode fiber. Please be noted that the diameter of the bore of the low precision multi-mode ferrule is much larger than the diameter of the single-mode fiber. Thereby, when the small diameter fiber 400 is fitted in the large diameter bore of the ferrule 300, a random deviation may be easily occurred between them. Thereby, it is difficult to position the fiber 400 in the bore of the ferrule 300 at an ideal position determined with reference to the guide
35 hole of the ferrule 300.

Since gel may overflow from the end surface of the ferrule 300, the end surface of the ferrule 300 cannot be in contact with the end surface of the indexing element 200. As shown in Fig.16, when the alignment rods 100 of the indexing element 200 are mated in the guide holes of the ferrule 300, the end surface of the indexing element 200 is separated from the

end surface of the ferrule 300 by a predetermined distance. Also, although it is not shown, a portion of each of the fibers 400 received in the alignment bore 201 of the indexing element 200 has a predetermined length.

As shown in Figs.15-16, the indexing tool further comprises a spacer 610 disposed
5 between the end surfaces of the ferrule 300 and the indexing element 200 for controlling the distance between the end surfaces of the ferrule 300 and the indexing element 200 during calibrating the fibers 400. As shown in Fig. 15, the alignment rods 100 pass through the spacer 610.

Since the distance between the end surfaces of the indexing element 200 and the ferrule
10 300 and the length of the portion of the fiber 400 received in the alignment bore 201 both affect the calibration accuracy and result in the difficulty of calibration operation, it is necessary to properly control the distance and the length. It should be appreciated for those skilled in this art that the distance or the length may be adjusted according the practical requirement without being limited to a fixed value.

As shown in Figs.15-16, when the alignment rods 100 of the indexing element 200 are
15 inserted into the guide holes of the ferrule 300, the indexing element 200 and the ferrule are assembled together. In order to reliably hold the indexing element 200 and the ferrule in the assembled state, as shown in Fig.16, a clamp is provided to hold them in the assembled state.

In the illustrated embodiment of Fig.16, the clamp comprises a sheet-like clamping
20 spring 700. The sheet-like clamping spring 700 grips the indexing element 200 and the ferrule 300 together.

Please be noted that the present invention is not limited to the embodiment of Fig.16, the clamp may comprise a screw clamp, as shown in Fig.16A.

Fig.16A is an illustrative view of a clamp according to another example of the present
25 invention.

As shown in Fig.16A, the clamp according to an exemplary embodiment is provided as a screw clamp mainly comprising a housing 10, a screw rod 20 and a push block 30. More specifically, the housing 10 has a chamber 14 defined between a first end 11 and a second
30 end 12 of the housing 10, the multi-fiber ferrule 300 and the indexing element 200 are received in the chamber, and the multi-fiber ferrule 300 is abutted against an inner wall of the chamber at the first end. The push block 30 is received in the chamber and located between the indexing element 200 and the second end of the housing 10. The screw rod 20 is screwed into a screw hole formed in an end wall of the housing 10 at the second end and
35 enters into the chamber through the screw hole. In this way, the multi-fiber ferrule 300 and the indexing element 200 can be held together by screwing the screw rod 20 to push the push block 30.

As shown in Fig.17, the plurality of alignment bores 201 in the indexing element 200 are arranged in one or more row or in an array of rows and columns. The pair of alignment

rods 100 of the indexing tool are symmetrically located at both sides of the one or more row of alignment bores 201.

As shown in Fig.17, the indexing element 200 is configured to be a single piece; and the alignment bore 201 is configured to be a circular hole or a special shape hole mated with an outer profile of the fiber.

Hereafter, it will describe in detail a process of calibrating the fibers 400 in the bores of the ferrule 300.

Firstly, assembling the ferrule 300 and the indexing element 200 by inserting the alignment rods 100 into the guide holes of the ferrule 300, and controlling the distance between the ferrule 300 and the indexing element 200, and holding the ferrule 300 and the indexing element 200 together by the clamp 700, so that the guide holes of the ferrule 300 are aligned with the alignment rods 100, and the bores of the ferrule 300 are aligned with the alignment bores 201 of the indexing element 200.

Secondly, receiving the fibers 400 in the respective alignment bores 201 of the indexing element 200, so that the position accuracy of the fiber 400 in the respective bore of the ferrule 300 with respect to the guide hole of the ferrule 300 is calibrated to reach that of the fiber 400 in the respective alignment bore 201 with respect to the alignment rod 100.

Finally, filling gel in the bores of the ferrule 300, fixing the gel, and grinding and polishing the fibers and the ferrule 300 to form a low cost ferrule assembly in which the fibers 400 each is accurately positioned.

As shown in Figs.15-17, the indexing element 200 is configured to be formed by only a single piece. But the present invention is not limited to this, the indexing element 200 may be configured to be formed by at least two separate members, as shown in Figs.18-19.

Fig.18 is an illustrative perspective view of an indexing tool according to another example of the present invention; Fig.19 is an illustrative end view of the indexing tool of Fig.18.

As shown in Figs.18-19, the indexing element 200 comprises a base 200' and a press block 800 separated from the base 200'. The base 200' has a recess 202 with one row of alignment bores 201' formed in a bottom wall of the recess 202. The press block 800 is fitted in the recess 202 so as to hold the fibers 400 (not shown) in the respective alignment bores 201'.

As shown in Figs.18-19, the alignment bore 201' is configured to be a U-type hole.

Fig.20 is illustrative perspective view of an indexing tool according to another example of the present invention; Fig.21 is an illustrative end view of the indexing tool of Fig.20.

The main difference of the indexing tool shown in Figs.20-21 from the indexing tool shown in Figs.18-19 is only that the alignment bore is configured to be V-type hole 201''.

According to another general concept, there is provided a method for calibrating positions of optical fibers in bores of a multi-fiber ferrule, the fibers extend outward from an end surface of the ferrule, the ferrule has a first indexing feature, and the bores of the ferrule

each is positioned with reference to the first indexing feature, the method comprising steps of:

providing an indexing tool according to the above embodiments; and
calibrating the position of the respective fiber in the respective bore of the ferrule by
5 means of the indexing tool.

In an example of the present invention, said step of calibrating the position of the respective fiber in the respective bore of the ferrule by means of the indexing tool comprises steps of:

10 mating the alignment rods and the guide holes to assemble the indexing element and the ferrule together, and holding the indexing element and the ferrule together by the clamp; and

inserting the fibers 400 through the respective bores of the ferrule 300, and inserting the ends of the fibers 400 extending outward from the end surface of the ferrule 300 into the respective alignment bores 201 of the indexing element 200, so that the position accuracy of
15 the fiber in the respective bore of the ferrule 300 with respect to the first indexing feature (the guide hole) is calibrated to reach that of the fiber 400 in the alignment bore 201 with respect to the second indexing feature (the alignment rod 100).

In another example of the present invention, said step of calibrating the position of the respective fiber in the respective bore of the ferrule by means of the indexing tool further
20 comprises a step of:

curing a gel to fix the fiber in the respective bore of the ferrule after the fiber is calibrated by the indexing tool.

The gel may be filled in the bores of the ferrule before or after the fibers are inserted into the bores of the ferrule.

25 It should be appreciated for those skilled in this art that the present invention not only covers the above indexing tool and the above method, but also a ferrule assembly manufactured by the above indexing tool and the above method and a fiber optic connector comprising the ferrule assembly.

30 In another general concept of the present invention, there is provided a ferrule assembly comprising a multi-fiber ferrule and fibers in bores of the ferrule, wherein the position of the fiber in the respective bore of the ferrule is calibrated by the indexing tool according to the above embodiments or by the method according to the above embodiments.

In another general concept of the present invention, there is provided a multi-fiber optic connector comprising the above multi-fiber ferrule assembly.

35 In the embodiments of the present invention, since the position accuracy of the fiber 400 in the respective bore of the low precision multi-mode multi-fiber ferrule 300 can be calibrated by the indexing tool to reach the position accuracy of the fiber 400 in the respective bore of the high precision single-mode multi-fiber ferrule, a high precision single-mode multi-fiber optic connector can be manufactured by using the low precision

multi-mode multi-fiber ferrule, instead of using the expensive single-mode multi-fiber ferrule with high precision. Thereby, the present invention decreases the cost of the high precision single-mode multi-fiber optic connector.

Fig.22 is an illustrative local end view of the multi-fiber ferrule of Fig.15.

5 In Fig.22, only one bore 301 of the ferrule 300 and only one guide hole 320 are shown. As shown in Fig.22, after the calibrated fiber 400 is fixed in the bore 301 of the ferrule 300 with the gel 302, a maximum distance (that is, a maximum thickness of the ring of gel 302) between an inner peripheral surface of the bore 301 of the ferrule 300 and an outer peripheral surface of fiber 400 is larger than or equal to the deviation distance between the center axis C400 of the fiber 400 and the ideal center axis C400' of the fiber 400 determined with reference to the center axis C320 of the guide hole of the ferrule 300 and/or the alignment rods 100. In the present invention, the indexing tool is used to calibrate the position of the fiber in the bore of the ferrule, so that the deviation distance between the center axis C400 of the fiber 400 and the ideal center axis C400' of the fiber 400 is equal to zero or within an allowable range, for example, within the order of submicron.

15 In an example of the present invention, the deviation distance between the center axis C400 of the fiber 400 and the ideal center axis C400' of the fiber 400 is in a range of 0 ~ 0.002mm.

20 In an example of the present invention, the diameter dimensional tolerance of the guide hole of the multi-fiber ferrule 300 is in a range of -0.001mm ~ 0.001mm.

In an example of the present invention, the diameter dimensional tolerance of the bore of the multi-fiber ferrule 300 is in a range of 0.000 ~ 0.030mm.

25 As shown in Fig.15, the fiber 400 is a standard single-core fiber. But the present invention is not limited to the embodiments shown in Fig.15, the fiber may be any other suitable type of fiber, for example, a multi-core fiber as shown in Fig.10, or a fiber bundle as shown in Fig.14.

30 In the present invention, since the position accuracy of the small diameter single-mode fiber in the large diameter bore of the low precision multi-mode ferrule can be calibrated by the indexing tool to reach the position accuracy of the fiber in the bore of the high precision single-mode ferrule, a high precision single-mode optic connector can be manufactured by using the low precision multi-mode ferrule, instead of using the expensive single-mode ferrule with high precision. Thereby, the present invention decreases the cost of the high precision single-mode multi-fiber optic connector.

35 Furthermore, as described above, since the diameter of the bore of the low precision multi-mode ferrule is much larger than the diameter of the single-mode fiber, the small diameter single-mode fiber can be easily and smoothly inserted into the large diameter bore of the low precision multi-mode ferrule, improving the insertion efficiency of the fiber.

It should be appreciated for those skilled in this art that the above embodiments are intended to be illustrated, and not restrictive. For example, many modifications may be

made to the above embodiments by those skilled in this art, and various features described in different embodiments may be freely combined with each other without conflicting in configuration or principle.

5 Although several exemplary embodiments have been shown and described, it would be appreciated by those skilled in the art that various changes or modifications may be made in these embodiments without departing from the principles and spirit of the disclosure, the scope of which is defined in the claims and their equivalents.

10 As used herein, an element recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural of said elements or steps, unless such exclusion is explicitly stated. Furthermore, references to "one embodiment" of the present invention are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Moreover, unless explicitly stated to the contrary, embodiments "comprising" or "having" an element or a plurality of elements having a particular property may include additional such elements not having that property.

15

What is claimed is,

1. An indexing tool for calibrating a position of an optical fiber (400) in a bore of a ferrule (300), the fiber (400) extending outward from an end surface of the ferrule (300), the ferrule (300) having a first indexing feature, and the bore being positioned with respect to the first indexing feature,

the indexing tool comprising:

a second indexing feature shaped to be complementary with the first indexing feature and capable of being mated with the first indexing feature to align them with each other; and

an indexing element (200) having an alignment bore (201) for receiving the fiber extending outward from the ferrule,

wherein the alignment bore is positioned with respect to the second indexing feature, such that when the first and second indexing features are mated and aligned with each other and the fiber is received in the alignment bore, the position accuracy of the fiber in the bore of the ferrule with respect to the first indexing feature is calibrated to reach that of the fiber in the alignment bore with respect to the second indexing feature.

2. The indexing tool according to claim 1, wherein the ferrule comprises a single-fiber ferrule.

3. The indexing tool according to claim 2, wherein the first indexing feature comprises an outer cylinder of the single-fiber ferrule;

wherein the second indexing feature comprises an alignment sleeve; and wherein the outer cylinder of the single-fiber ferrule is inserted into the alignment sleeve, so that a center axis of the outer cylinder of the single-fiber ferrule is aligned with a center axis of the alignment sleeve.

4. The indexing tool according to claim 1, wherein the ferrule comprises a multi-fiber ferrule.

5. The indexing tool according to claim 4, wherein the first indexing feature comprises a guide hole; wherein the second indexing feature comprises an alignment rod; and wherein the alignment rod is inserted into the guide hole, so that a center axis of the guide hole is aligned with a center axis of the alignment rod.

6. The indexing tool according to claim 3,

wherein the indexing element is configured to have a cylindrical body having an outer diameter equal to an inner diameter of the alignment sleeve.

7. The indexing tool according to claim 6,
5 wherein the indexing element is inserted into the alignment sleeve from one end of the alignment sleeve, and the ferrule (300) is inserted into the alignment sleeve from the other end of the alignment sleeve, such that the center axis of the outer cylinder of the ferrule (300) is aligned with a center axis of the cylindrical body of the indexing element.

10 8. The indexing tool according to claim 3, wherein the alignment sleeve is configured to be formed by only a single piece.

9. The indexing tool according to claim 2, wherein the second indexing feature is configured to be formed by at least two separate members.

15

10. The indexing tool according to claim 9, wherein the second indexing feature comprising:

a base (1001, 1011) having a recess (1003, 1013) with a positioning groove (1004, 1014) formed in a bottom wall of the recess; and

20

a top block (1002, 1012) fitted in the recess (1003, 1013) of the base (1001, 1011) so as to hold the indexing element (200) in the positioning groove (1004, 1014).

11. The indexing tool according to claim 10, wherein the positioning groove (1004, 1014) comprises a V-type positioning groove or a U-type positioning groove.

25

12. The indexing tool according to claim 7,
wherein an end surface of the indexing element (200) inserted into the alignment sleeve (100) is separated from the end surface of the ferrule (300) inserted into the alignment sleeve (100) by a predetermined distance (d1).

30

13. The indexing tool according to claim 12,
wherein a portion of the fiber (400) received in the alignment bore (201) of the indexing element (200) has a predetermined length (d2).

35

14. The indexing tool according to claim 13, further comprising:
a holding seat (500) for fixing the alignment sleeve (100) and the indexing element (200).

15. The indexing tool according to claim 14,

wherein the alignment sleeve (100) and the indexing element (200) are detachably held to the holding seat (500).

16. The indexing tool according to claim 15,
5 wherein the alignment sleeve (100) and the indexing element (200) are configured to be a single piece or two separate members.

17. The indexing tool according to claim 14, further comprising:
a spacer (610) disposed between the holding seat (500) and a rear seat (310) of the
10 ferrule (300) or disposed within the alignment sleeve (100), for controlling the distance (d1) between the end surface of the indexing element (200) inserted into the alignment sleeve (100) and the end surface of the ferrule (300) inserted into the alignment sleeve (100).

18. The indexing tool according to claim 17, further comprising:
15 an extractor (600) fitted on the rear seat (310) of the ferrule (300), for taking out the ferrule from the indexing tool after the fiber (400) has been calibrated and fixed in the bore of the ferrule.

19. The indexing tool according to claim 18, wherein the spacer (610) and the extractor
20 (600) are configured to be a single piece or two separate members.

20. The indexing tool according to claim 3,
wherein the indexing element (200) is configured to be a single piece; and
wherein the alignment bore (201) is configured to be a circular hole or a special shape
25 hole mated with an outer profile of the fiber.

21. The indexing tool according to claim 3, wherein the indexing element (200) is configured to be formed by at least two separate members.

30 22. The indexing tool according to claim 21, wherein the indexing element (200', 200'') comprising:

a base (2001, 2011) having a recess, the alignment bore (201', 201'') being formed in a bottom wall of the recess; and

a press block (2002, 2012) fitted in the recess of the base (2001, 2011) so as to hold the
35 fiber in the alignment bore (201', 201'').

23. The indexing tool according to claim 22, wherein the alignment bore (201', 201'') is configured to be a U-type hole or a V-type hole.

24. The indexing tool according to claim 3, wherein
after being calibrated by the indexing tool, a deviation distance between an axis of the
fiber (400) in the bore of the ferrule (300) and the center axis of the outer cylinder of the
ferrule (300) is decreased to an order of submicron.

5

25. The indexing tool according to claim 24,
wherein the diameter dimensional tolerance of the outer cylinder of the ferrule (300) is
in a range of $-0.001\text{mm} \sim 0.001\text{mm}$.

10

26. The indexing tool according to claim 25,
wherein the diameter dimensional tolerance of the bore of the ferrule (300) is in a range
of $0.000\text{mm} \sim 0.030\text{mm}$.

15

27. The indexing tool according to claim 26, wherein
after the calibrated fiber (400) is fixed in the bore of the ferrule (300) with a gel (302),
a maximum distance between an inner peripheral surface of the bore of the ferrule (300) and
an outer peripheral surface of fiber (400) is larger than or equal to the deviation distance
between the center axis (C400) of the fiber (400) and the center axis (C300) of the outer
cylinder of the ferrule (300).

20

28. The indexing tool according to claim 5, further comprising:
a clamp for holding the multi-fiber ferrule (300) and the indexing element (200)
together.

25

29. The indexing tool according to claim 28, wherein the clamp comprises a sheet-like
clamping spring (700).

30

30. The indexing tool according to claim 28, wherein the clamp comprises a screw
clamp.

35

31. The indexing tool according to claim 30, wherein the screw clamp comprising:
a housing (10) having a chamber (14) defined between a first end (11) and a second end
(12) of the housing (10), the multi-fiber ferrule (300) and the indexing element (200) being
received in the chamber (14), and the multi-fiber ferrule (300) being abutted against an inner
wall of the housing at the first end (11);

a push block (30) received in the chamber (14) and located between the indexing
element (200) and the second end (12) of the housing; and

a screw rod (20) screwed into a screw hole formed in an end wall of the housing at the
second end (12) and entering into the chamber (14) through the screw hole,

wherein the multi-fiber ferrule (300) and the indexing element (200) are held together by screwing the screw rod (20) to push the push block (30).

32. The indexing tool according to claim 5, further comprising:

5 a spacer (610) disposed between the end surface of the multi-fiber ferrule (300) and an end surface of the indexing element (200), for controlling a distance between the end surface of the indexing element (200) and the end surface of the multi-fiber ferrule (300).

33. The indexing tool according to claim 32, wherein

10 during calibrating the fiber, the end surface of the indexing element (200) is separated from the end surface of the multi-fiber ferrule (300) by a predetermined distance.

34. The indexing tool according to claim 33, wherein

15 during calibrating the fiber, a portion of the fiber (400) received in the alignment bore (201) of the indexing element (200) has a predetermined length.

35. The indexing tool according to claim 34, wherein the alignment rod (100) passes through the spacer (610).

20 36. The indexing tool according to claim 5, wherein

after being calibrated by the indexing tool, a deviation distance between a center axis of the fiber (400) in the bore of the ferrule (300) and an ideal center axis of the fiber determined with reference to the center axis of the guide hole and /or the alignment rod is in a range of 0.000mm ~ 0.002mm.

25 37. The indexing tool according to claim 36, wherein the diameter dimensional tolerance of the guide hole of the multi-fiber ferrule (300) is in a range of -0.001mm ~ 0.001mm.

30 38. The indexing tool according to claim 37, wherein the diameter dimensional tolerance of the bore of the multi-fiber ferrule (300) is in a range of 0.000mm ~ 0.030mm.

39. The indexing tool according to claim 38, wherein

35 after the calibrated fiber (400) is fixed in the bore of the ferrule (300) with a gel (302), a maximum distance between an inner peripheral surface of the bore of the ferrule (300) and an outer peripheral surface of fiber (400) is larger than or equal to the deviation distance between the center axis (C400) of the fiber (400) and the ideal center axis (C400') of the fiber (400) determined with reference to the center axis (C320) of the guide hole of the ferrule (300).

40. The indexing tool according to claim 39,
wherein the indexing element (200) has a plurality of alignment bores (201) arranged in
one or more rows; and

5 wherein the indexing tool comprises a pair of alignment rods (100) symmetrically
located at both sides of the one or more rows of alignment bores (201).

41. The indexing tool according to claim 5,
wherein the indexing element (200) is configured to be a single piece; and
10 wherein the alignment bore (201) is configured to be a circular hole or a special shape
hole mated with an outer profile of the fiber.

42. The indexing tool according to claim 5, wherein the indexing element (200) is
configured to be formed by at least two separate members.

15 43. The indexing tool according to claim 42, wherein the indexing element comprising:
a base (200') having a recess (202) with one row of alignment bores formed in a
bottom wall of the recess (202); and
a press block (800) fitted in the recess (202) of the base (200') so as to hold the fiber in
20 the respective alignment bore.

44. The indexing tool according to claim 43, wherein the alignment bore is configured
to be a U-type hole (201') or a V-type hole (201'').

25 45. The indexing tool according to claim 1,
wherein the fiber comprises a standard single-core fiber, a multi-core fiber or a fiber
bundle.

46. The indexing tool according to claim 1,
30 wherein the alignment bore has a diameter smaller than that of the bore of the ferrule;
wherein when the fiber extending outward from the end surface of the ferrule (300) is
received in the alignment bore, the alignment bore functions as a fixture to hold the fiber in
the bore of the ferrule at an ideal center determined with reference to the first indexing
feature; and

35 wherein after a gel filled in the bore of the ferrule is cured, the fiber is fixed in the bore
of the ferrule at the ideal center.

47. A method for calibrating a position of an optical fiber in a bore of a ferrule, the
fiber extending outward from an end surface of the ferrule, the ferrule having a first

indexing feature, and the bore of the ferrule being positioned with respect to the first indexing feature, the method comprising steps of:

providing an indexing tool according to claim 1; and

5 calibrating the position of the fiber in the bore of the ferrule by means of the indexing tool.

48. The method according to claim 47, wherein the step of calibrating the position of the fiber in the bore of the ferrule by means of the indexing tool comprising steps of:

10 mating the first and second indexing features together to accurately align them with each other; and

inserting an end of the fiber extending outward from the ferrule into the alignment bore, so that the position accuracy of the fiber in the bore of the ferrule with respect to the first indexing feature is calibrated to reach that of the fiber in the alignment bore with respect to the second indexing feature.

15

49. The method according to claim 48,

wherein a gel (302) is filled in the bore of the ferrule (300) so as to fix the fiber (400) in the bore of the ferrule after the fiber is calibrated; and

20 wherein the gel is filled in the bore of the ferrule (300) before or after the fiber (400) is inserted into the bore of the ferrule.

50. The method according to claim 49, further comprising a step of:

curing the gel to fix the fiber (400) in the bore of the ferrule (300) after the fiber is calibrated by the indexing tool.

25

51. The method according to claim 48, wherein when the ferrule is a multi-fiber ferrule, calibrating the position of the fiber in the bore of the ferrule by means of the indexing tool further comprising a step of:

holding the multi-fiber ferrule (300) and the indexing tool together by a clamp.

30

52. A ferrule assembly comprising a ferrule and a fiber in a bore of the ferrule, wherein the position of the fiber in the bore of the ferrule is calibrated by the indexing tool according to claim 1 or by the method according to claim 47.

35 53. A fiber optic connector comprising a ferrule assembly according to claim 52.

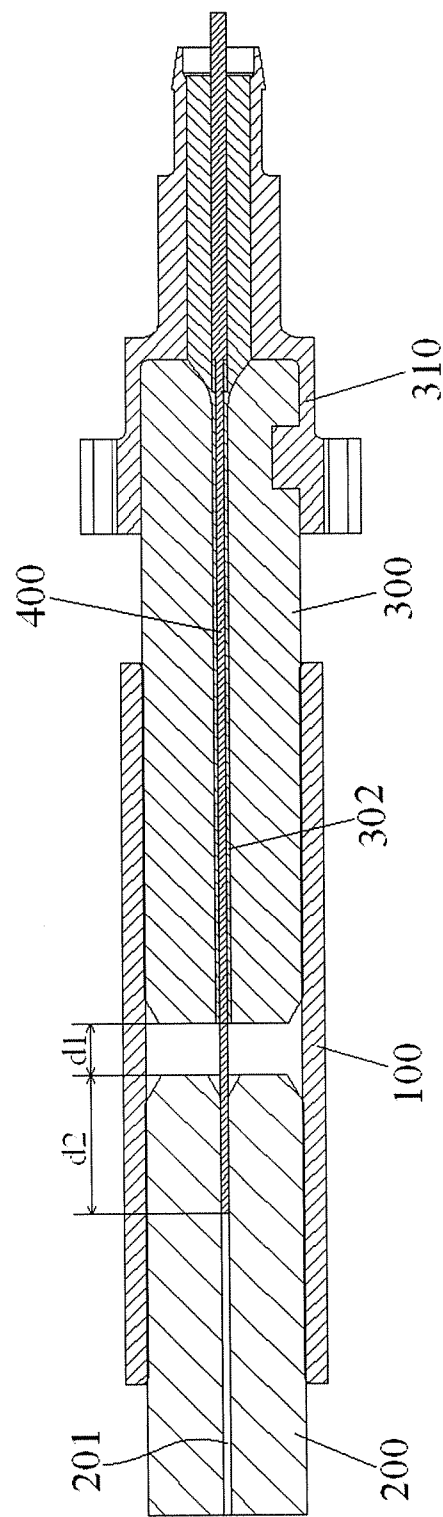


Fig.1

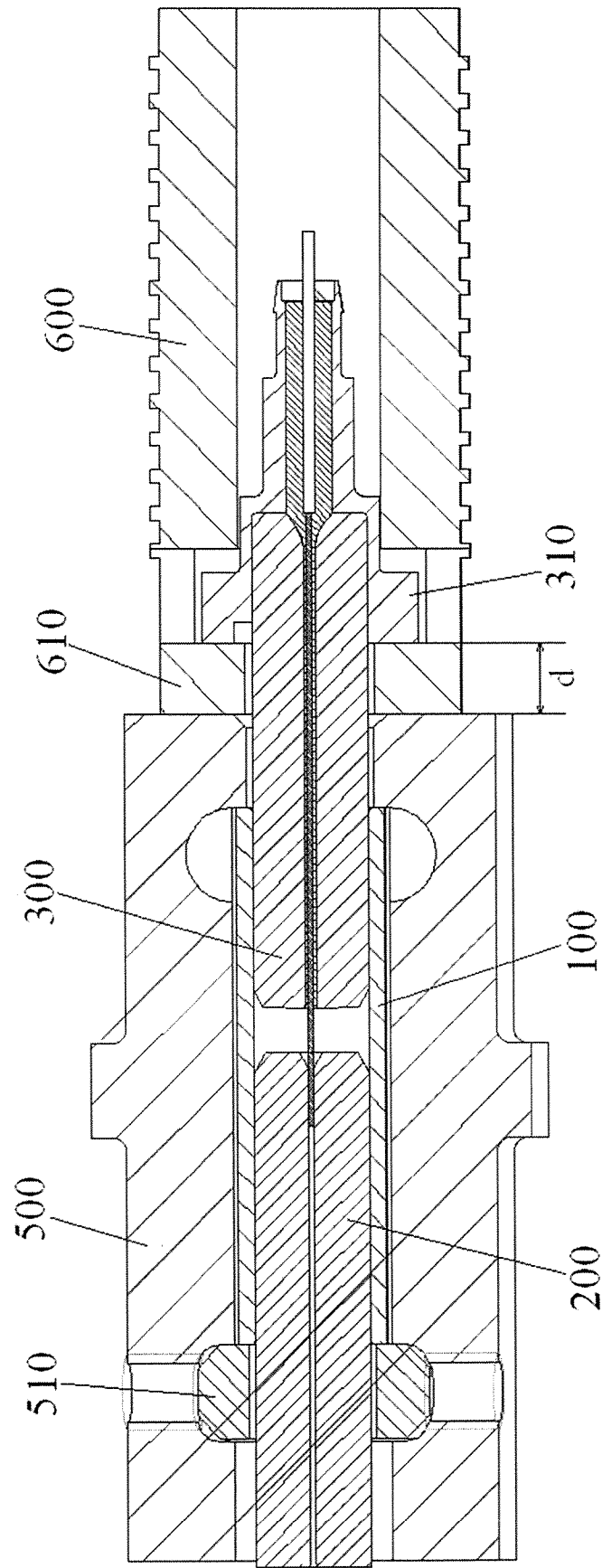


Fig.2

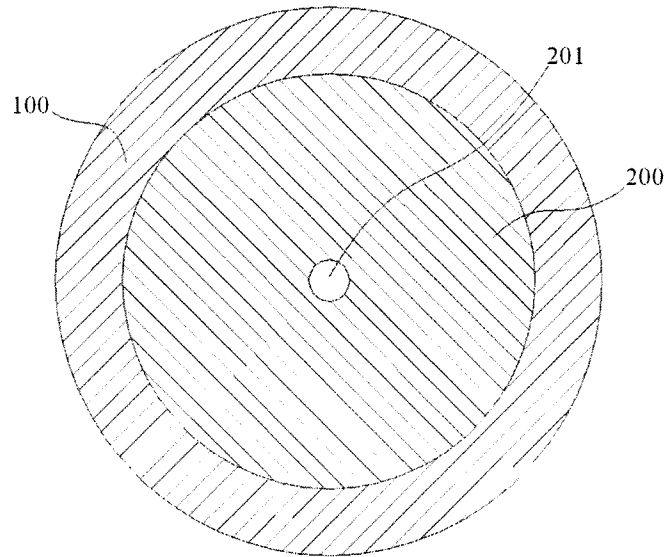


Fig.3

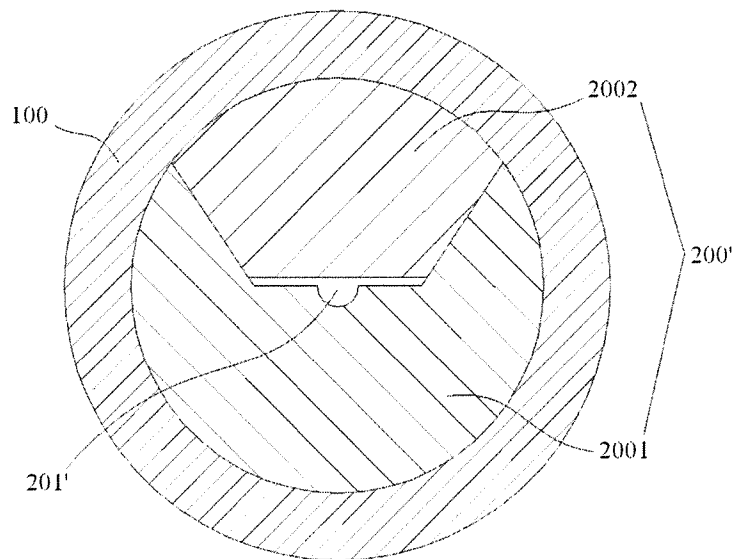


Fig.4

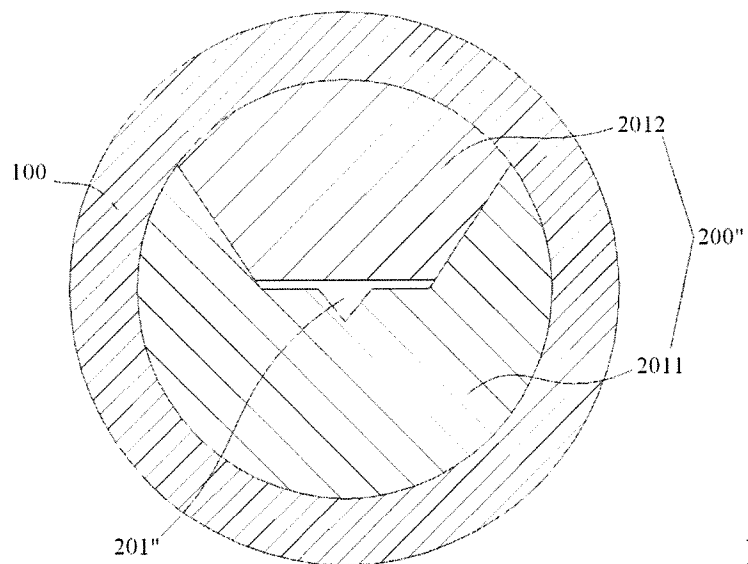


Fig. 5

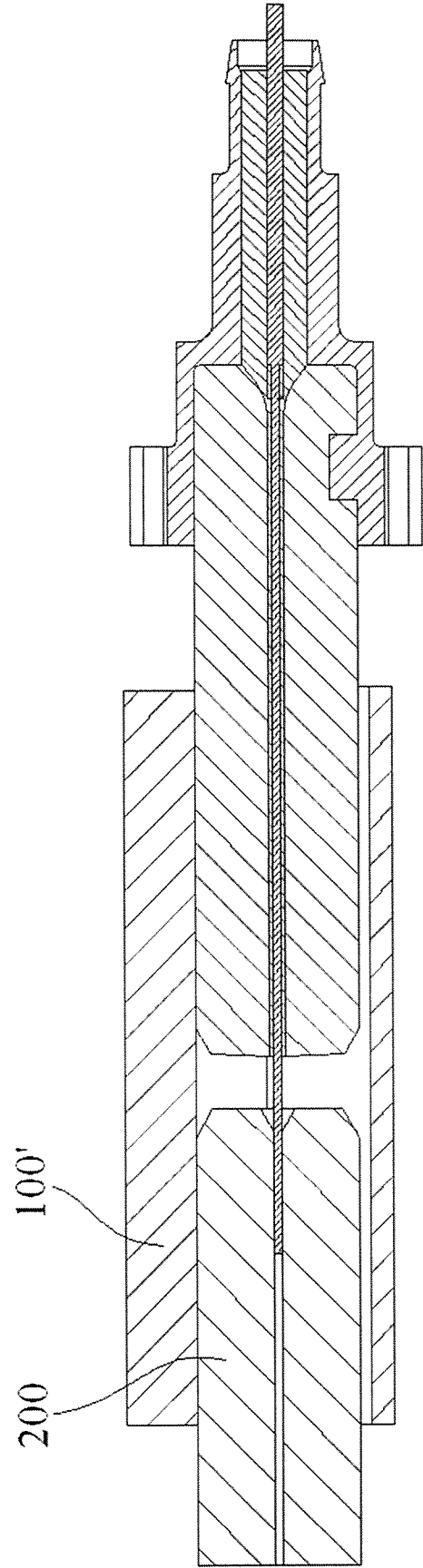


Fig.6

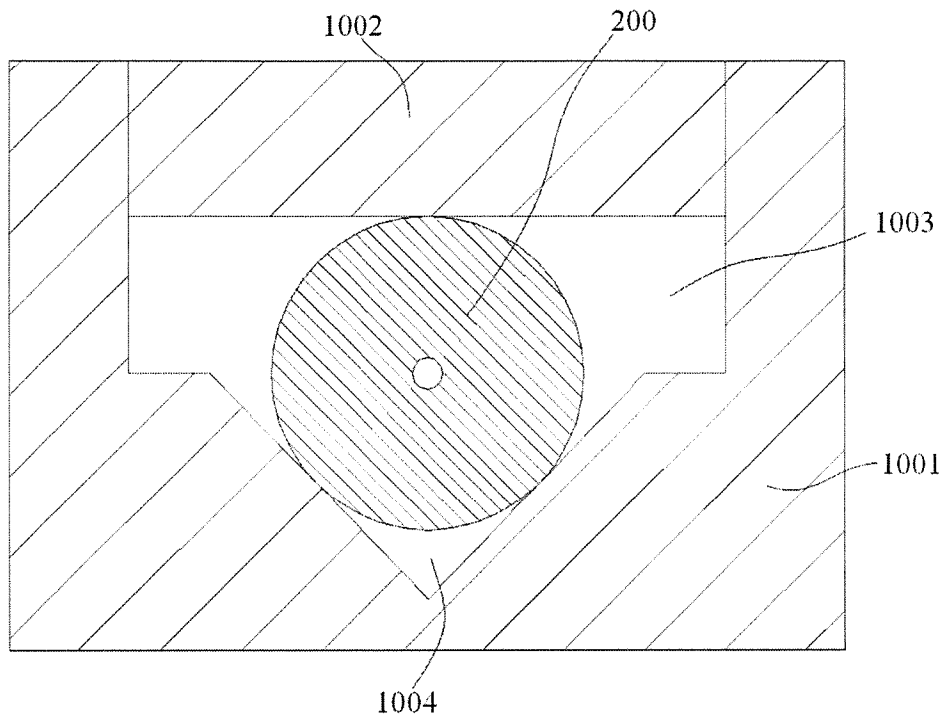


Fig.7

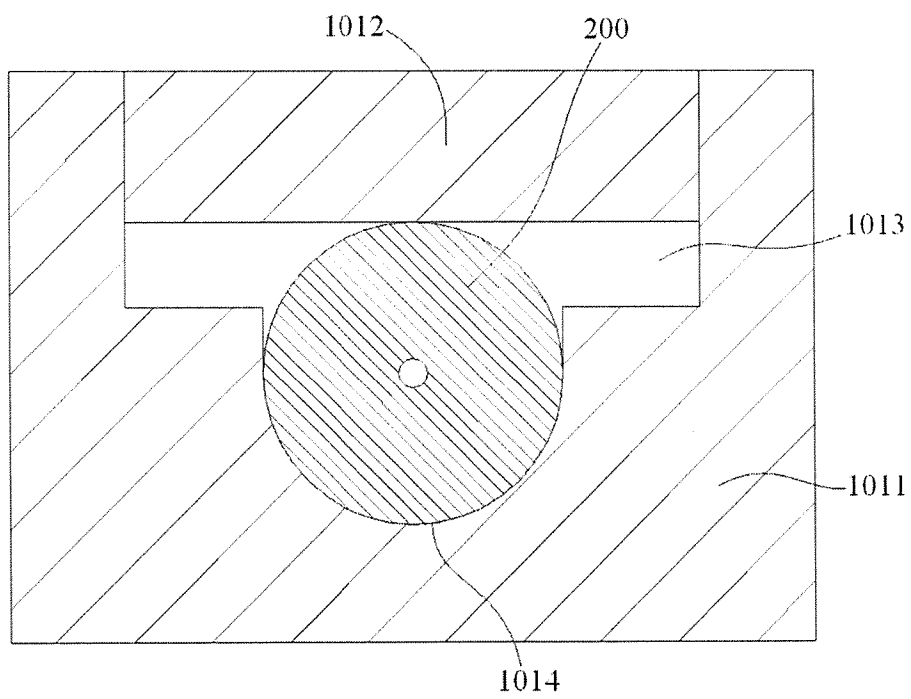


Fig.8

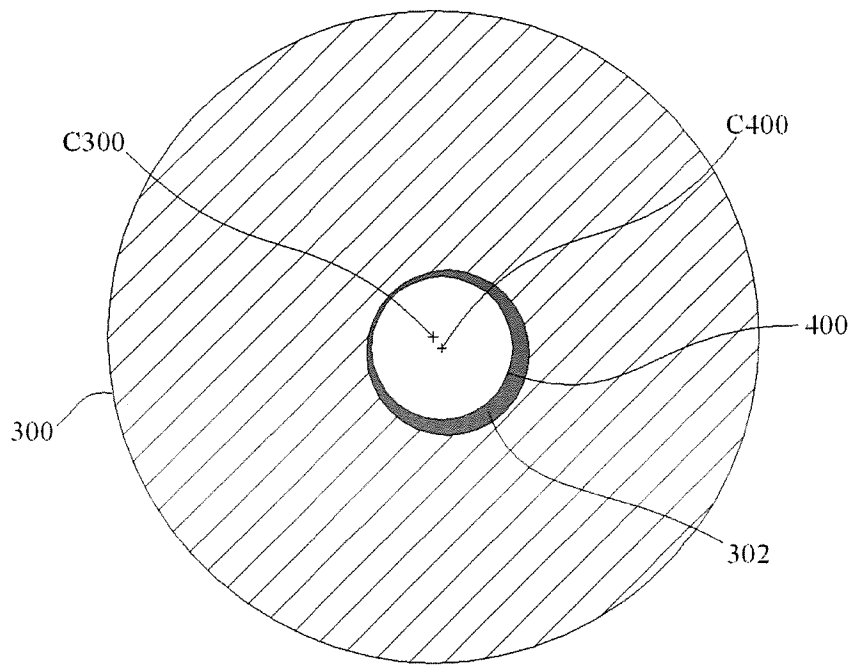


Fig.9

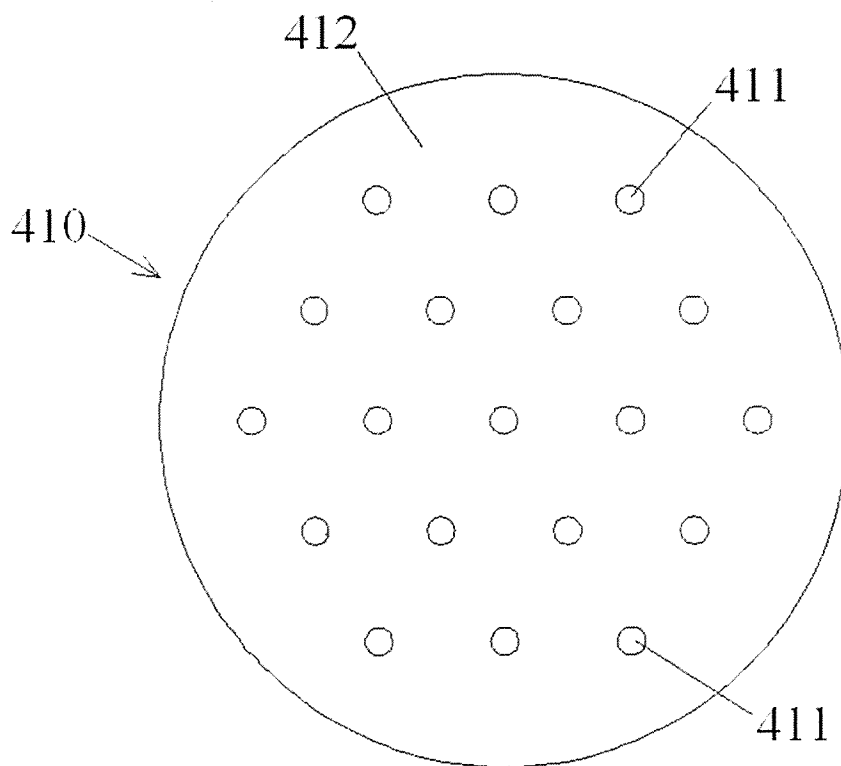


Fig.10

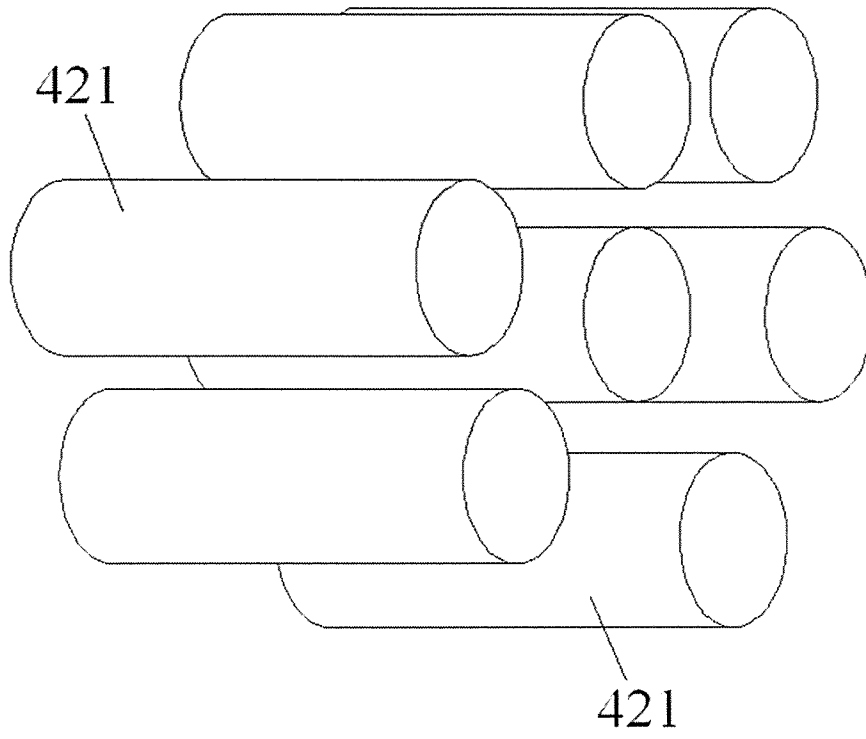


Fig.11

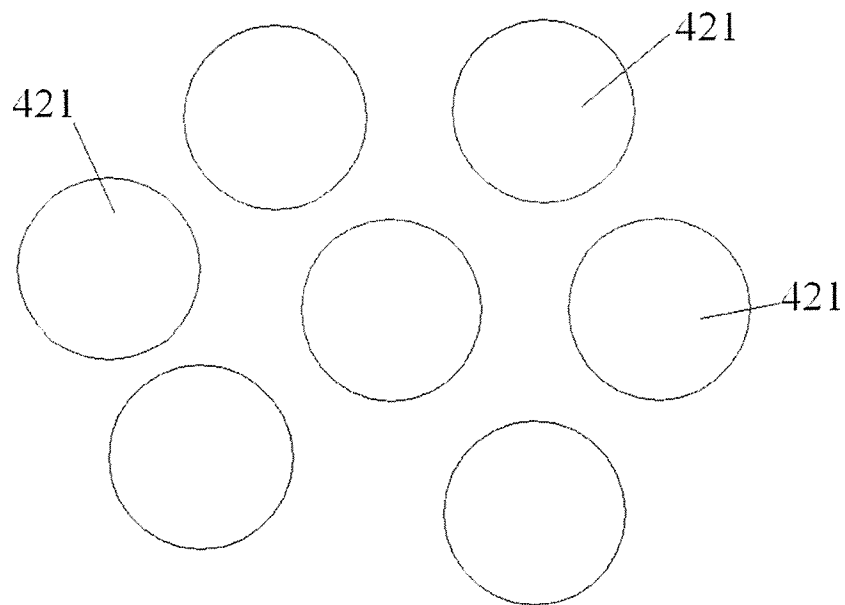


Fig.12

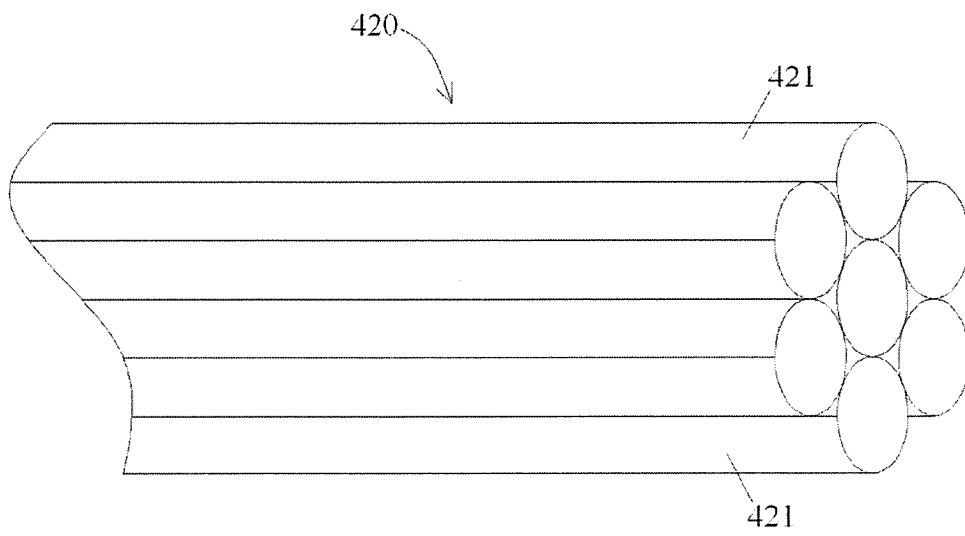


Fig.13

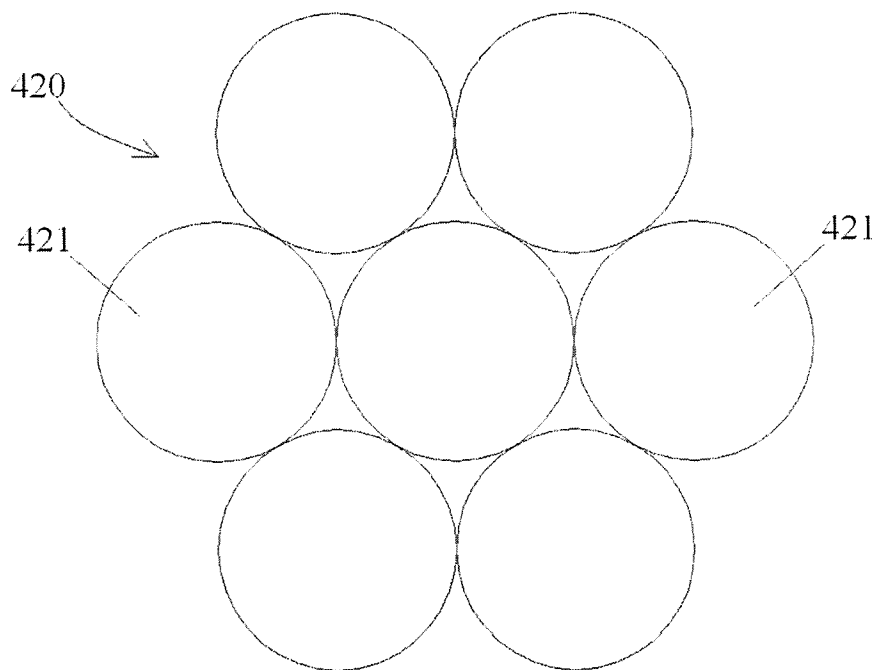


Fig.14

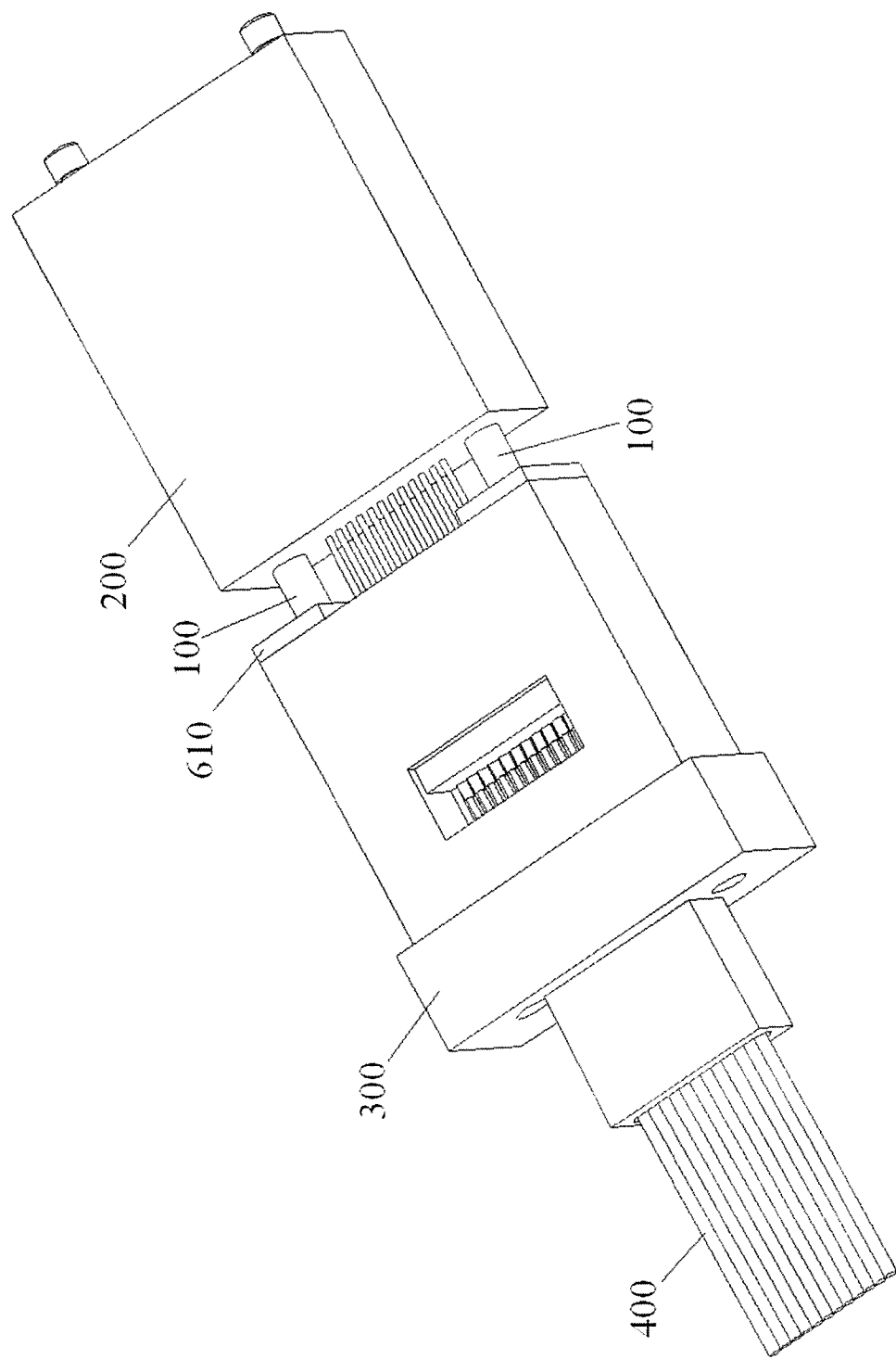


Fig.15

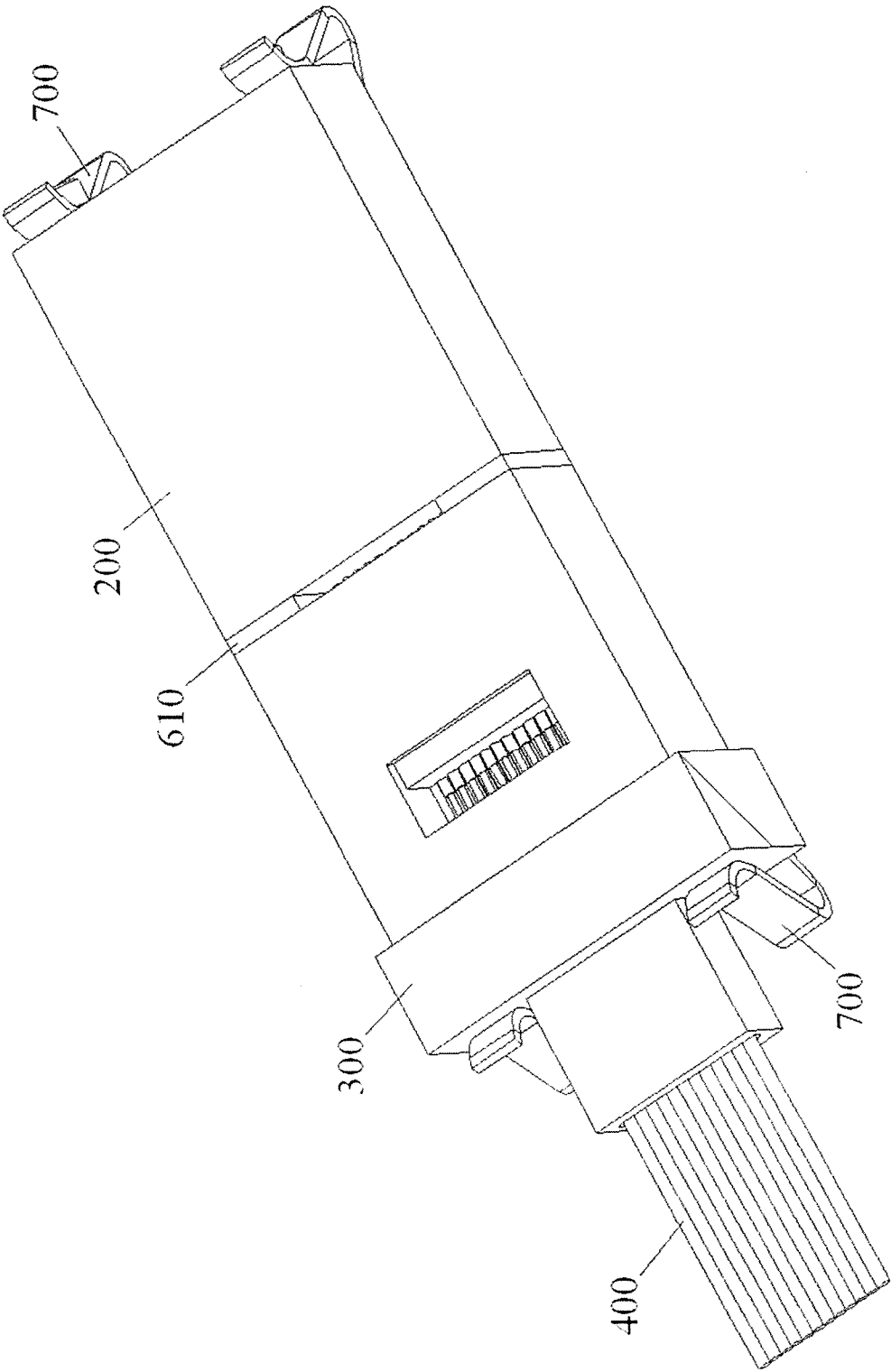


Fig.16

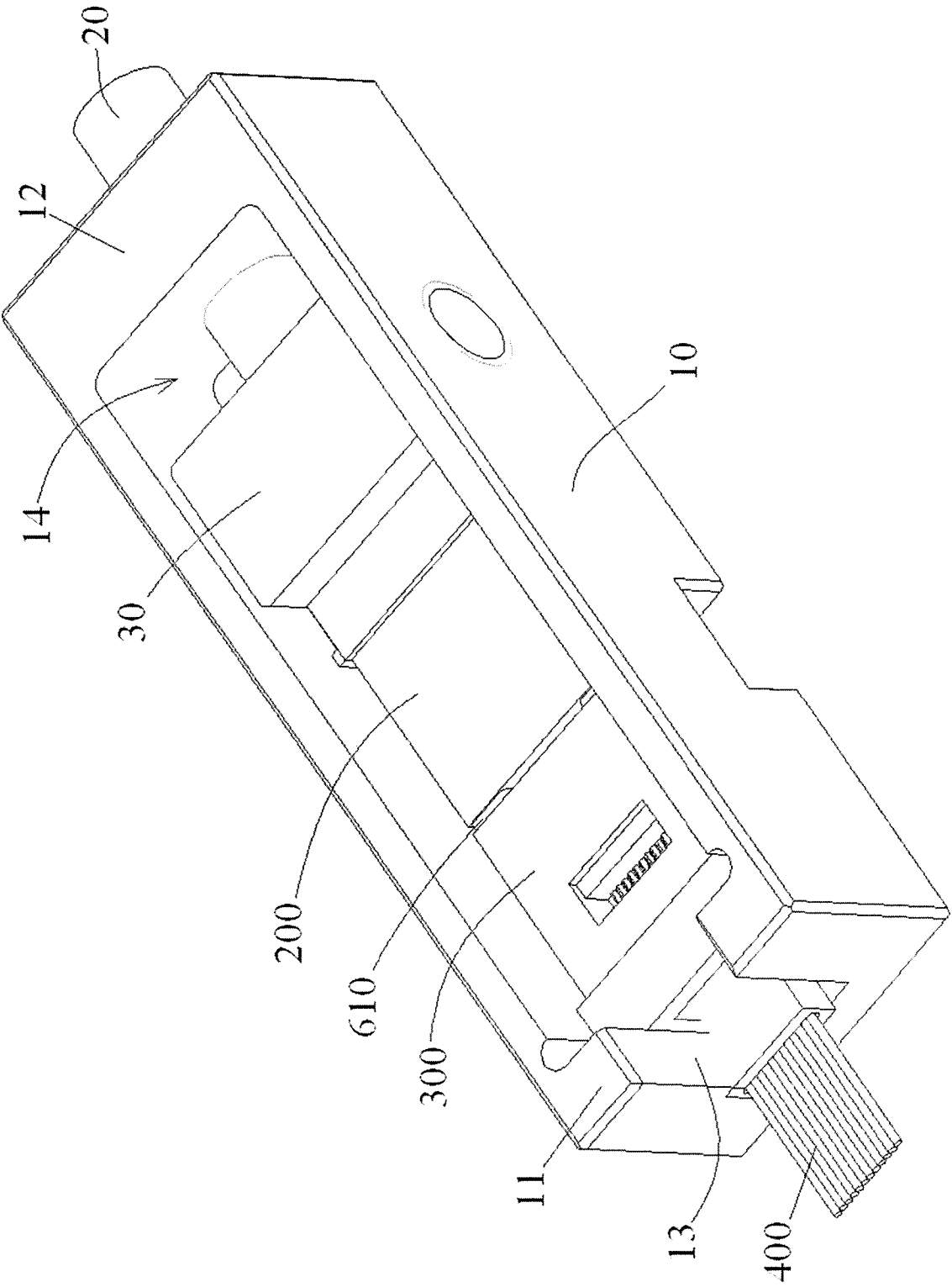


Fig.16A

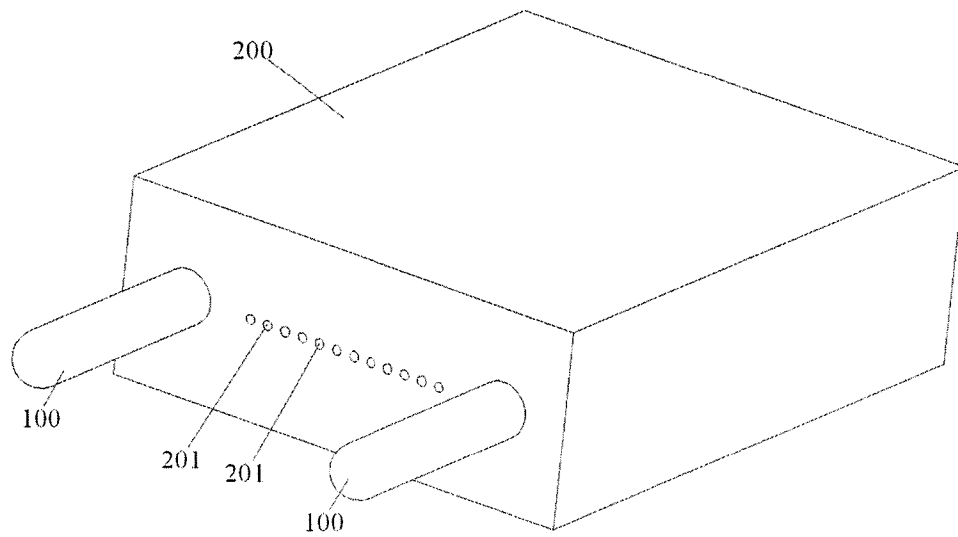


Fig.17

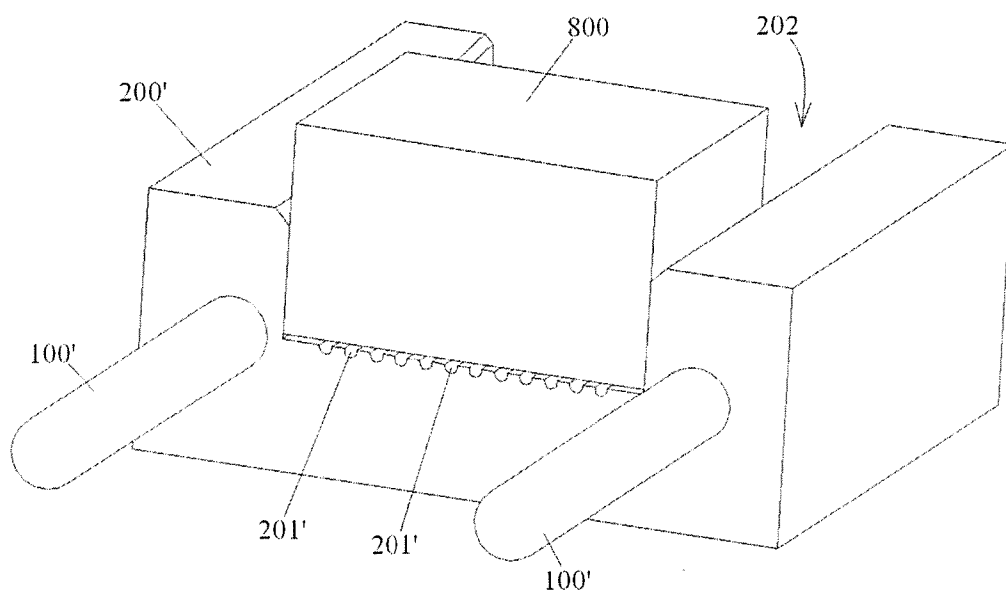


Fig.18

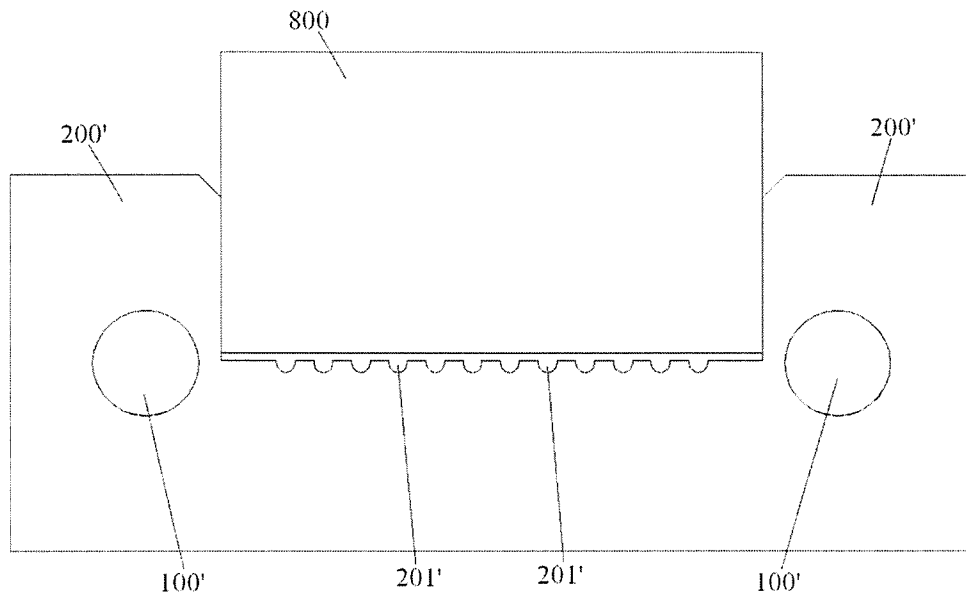


Fig.19

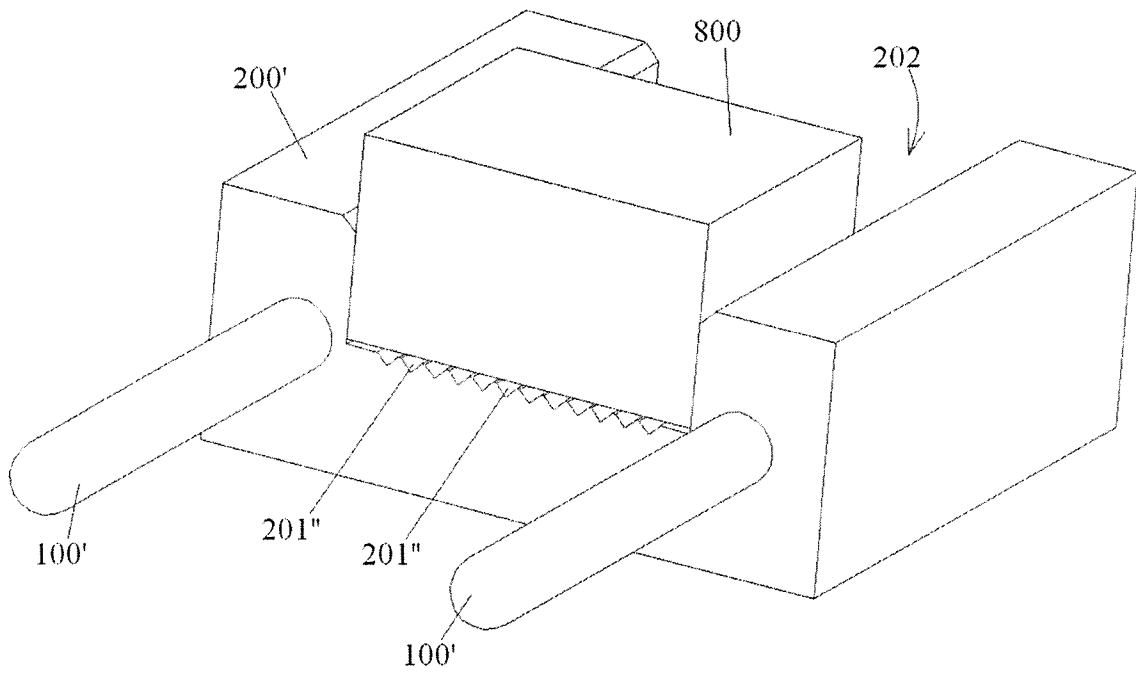


Fig.20

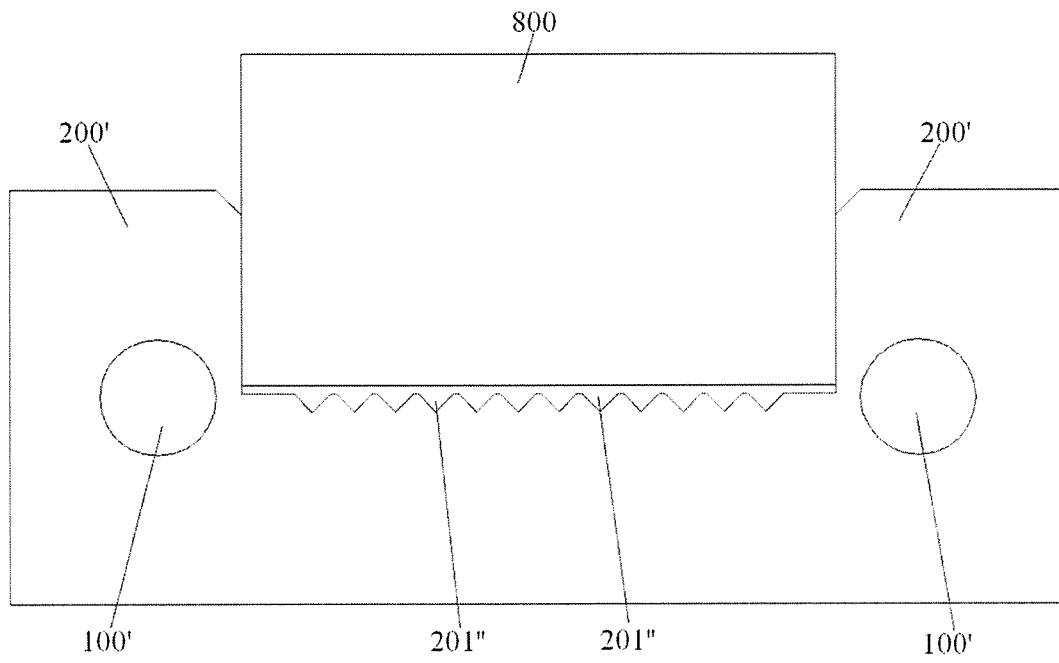


Fig.21

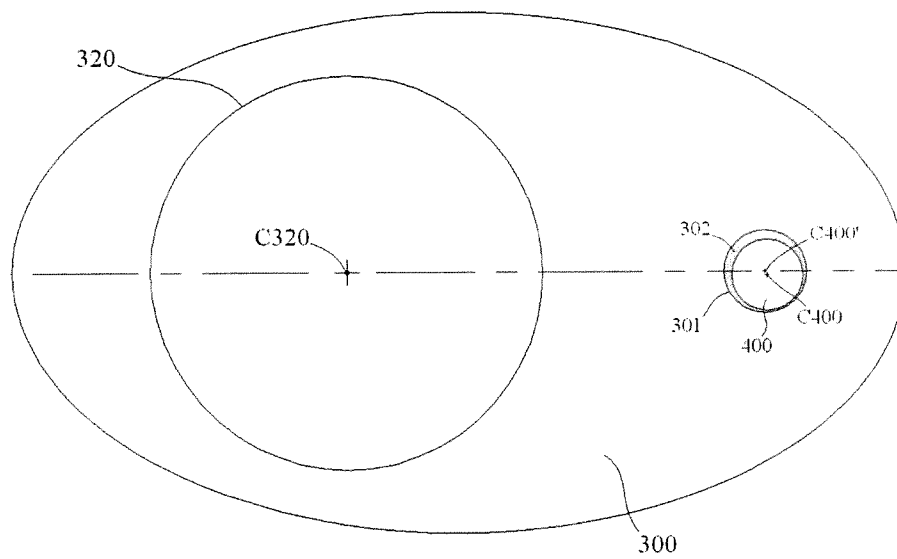


Fig.22

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/061971

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B6/36 G02B6/40
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02B

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

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

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2012 185283 A (FURUKAWA ELECTRIC CO LTD) 27 September 2012 (2012-09-27)	1,4,5, 41, 45-50, 52,53
A	paragraphs [0024] - [0046]; figures 3-10 -----	6-40,51
X	JP 2001 249249 A (FUJIKURA LTD) 14 September 2001 (2001-09-14) paragraphs [0011] - [0015]; figures 5,6 -----	1,4,5, 42-45,47
X	WO 86/06504 A1 (LUXTRON CORP [US]) 6 November 1986 (1986-11-06) page 21, line 18 - page 22, line 26; figures 11a-c -----	1-3,8, 20,47
A	JP H05 119238 A (NEC CORP; NIPPON ELECTRIC ENG) 18 May 1993 (1993-05-18) the whole document -----	1

☐

Further documents are listed in the continuation of Box C.

☒

See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

8 September 2014

Date of mailing of the international search report

17/09/2014

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Andreassen, Jon

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2014/061971

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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