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(58) Field of Search:
INT CL^7 **G02B**
Other: **Online: WPI, EPODOC, JAPIO**

(54) Abstract Title: **Expanded beam optical fibre connector with ball lens**

(57) An optical connector, for use in a fibre optic communications system comprises a housing (106), an aperture (127) in the housing, an optical fibre (16) mounted within the housing (106) and directed towards the aperture (127), a lens (8) mounted in the aperture (127) and optically coupled with the optical fibre (16) so that optical radiation projected from the fibre (16) is collimated (37) by the lens (8) into an expanded beam (36) which is projected from the housing aperture (127) and/or so that an expanded beam (36) of optical radiation directed at the housing aperture (127) is focussed (37) by the lens (8) into the optical fibre (16), the connector comprising additionally a connector portion for connecting the optical fibre connector to another expanded beam optical fibre connector so that said expanded beam (36) traverses between said connector portions, wherein the lens is a ball lens (8) which abuts an end of the optical fibre (16) and both the ball lens (8) and the optical fibre (16) are permanently bonded (26,128) in place eg. using UV curable optical adhesive. The connector may be hermaphroditic. Each connector may have a retained plastic moulded dust cap. Mated connectors may have a water tight seal.

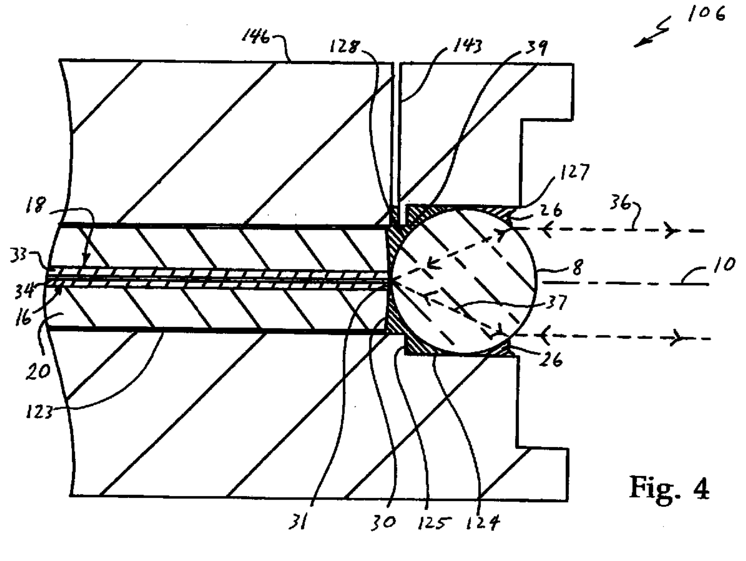

Fig. 4

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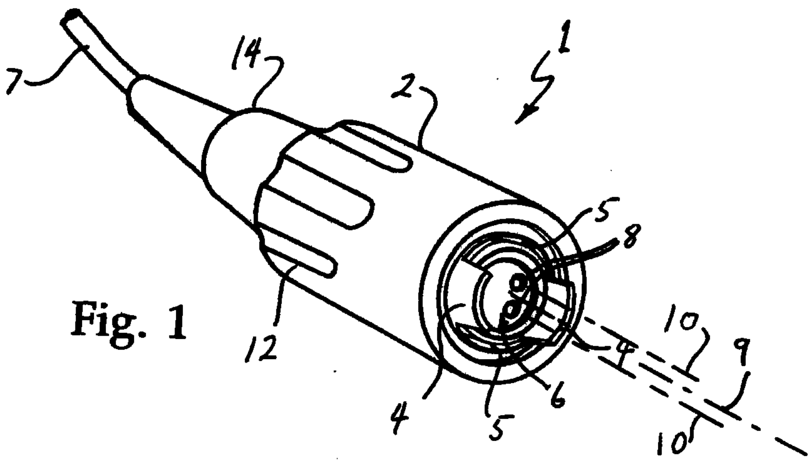

Fig. 1

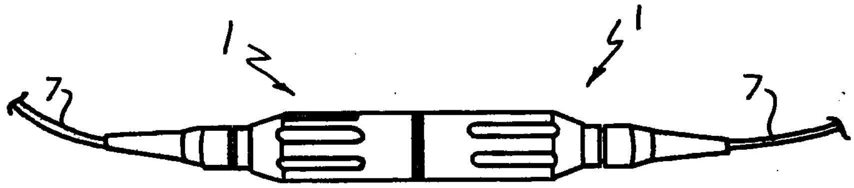

Fig. 2

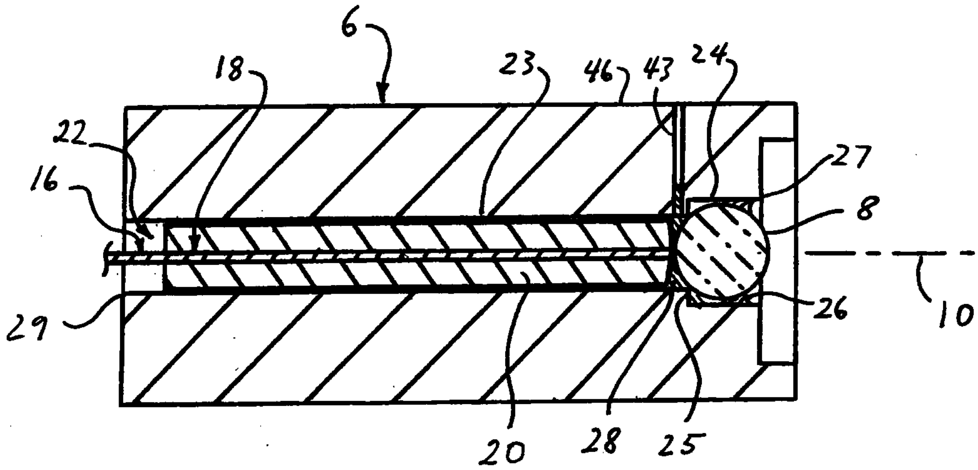

Fig. 3

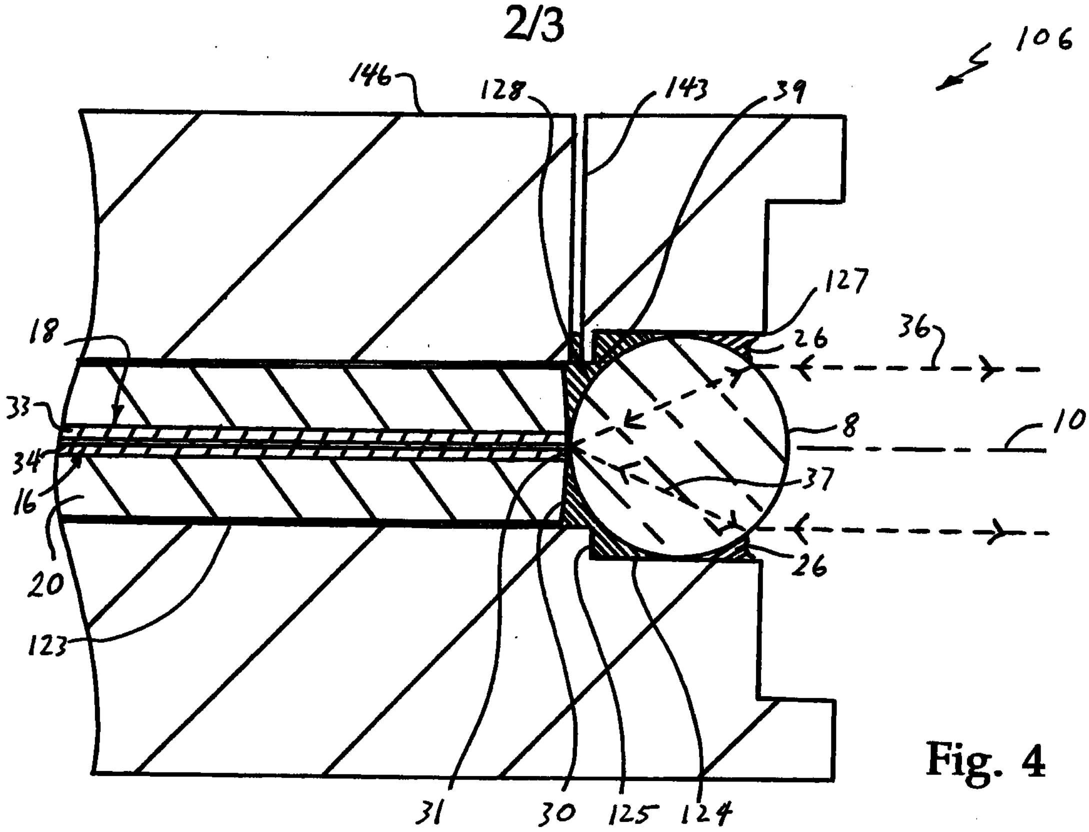

Fig. 4

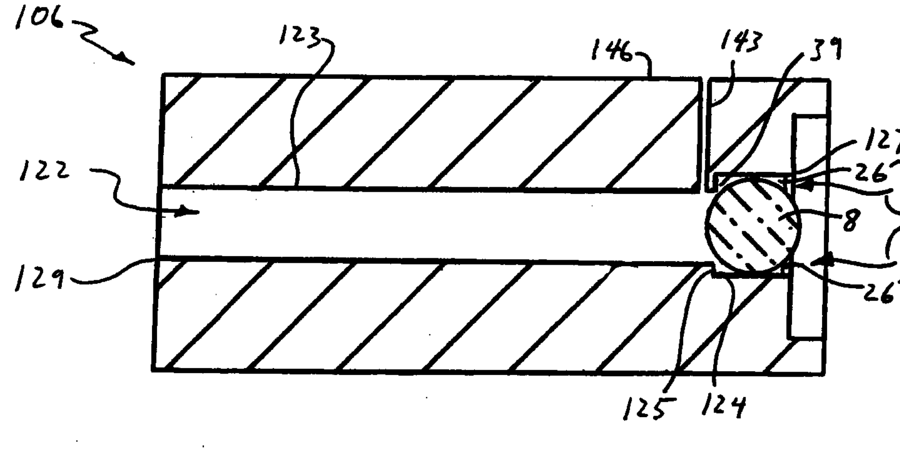

Fig. 5

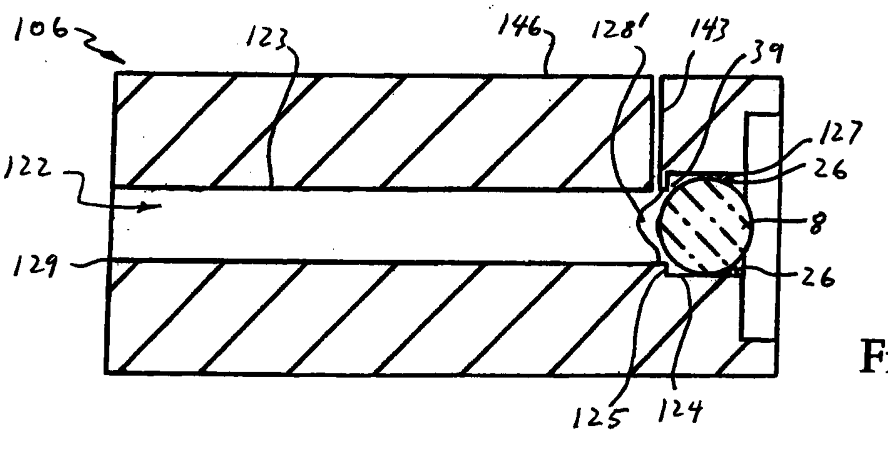

Fig. 6

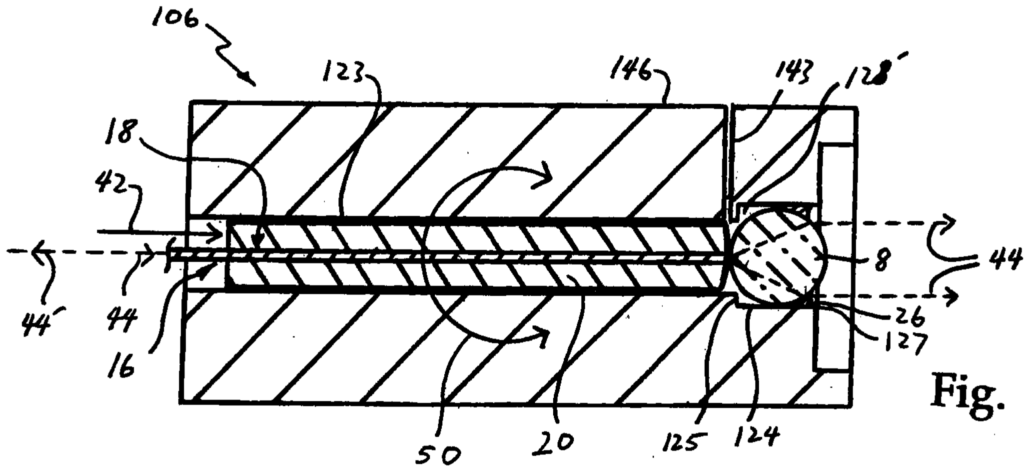
106
123
146
143
128'
18
42
44'
44
16
8
44"
26
127
50
20
125
124

Fig. 7

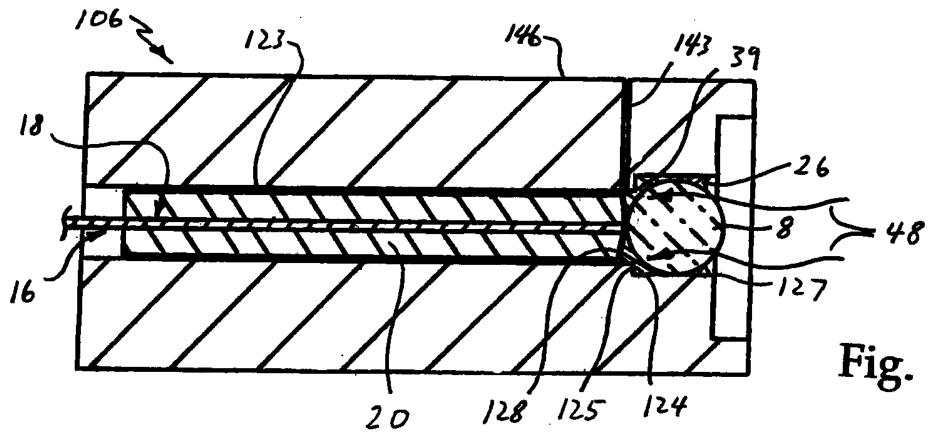
106
123
146
143
39
18
26
8
48
16
127
20
128
125
124

Fig. 8

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Optical Connector

The present invention relates to an optical connector for use in a fibre optic communications system, and particularly an expanded beam optical connector.

An optical fibre communications system may need to be used in a harsh environment where the connector may be subject to impacts, dirt or extremes of temperature and moisture. One application where optical connectors are used in a harsh environment is in the broadcast industry, where cameras or sound equipment are joined to other electronic equipment by means of fibre optic cables extending across open spaces. The cables may be joined together with optical connectors that may have to lie on the open ground where dirt or mud may find their way into the connector.

One known way to increase the reliability of an optical connector is to make use of an expanded optical beam which is projected between mating connector portions. Then, if dirt or moisture comes between the connector portions, this may only obscure or degrade a portion of the expanded beam between the mated connector portions.

One known type of expanded beam optical connector uses a double cone arrangement to position both an optical fibre and a collimating spherical lens with respect to each other. The cones open outwards in opposite directions along a common optical axis defined by the lens and optical fibre. The lens is seated in one cone and the optical fibre is held within a ferrule that has a conical taper matching the taper of the other cone so that the ferrule may be seated in the other cone. A gap separates the lens and cone. The ferrule is held in position by a threaded retainer at an end of a bore leading to the cone for the ferrule. An arrangement such as this is relatively difficult and expensive to manufacture and may require special CNC machinery. This design may in certain circumstances also be susceptible to failure due to vibration, for example the ferrule retainer working loose, or owing to condensation forming within the air gap between the fibre and the lens.

Another known type of expanded beam optical connector uses a fibre ferrule that is sprung loaded and in physical contact with a spherical lens. This design is also subject to condensation in the fibre / lens cavity, and may suffer from the effects of vibration due to the sprung ferrule, causing errors in transmission. This design is also mechanically complicated, and relatively expensive to manufacture.

One reason for the complexity of such prior art connectors is that many of these were originally developed for military applications and have therefore been specified to be field terminable and field repairable. This does not make the product simple to handle and can make the connectors less reliable.

It is an object of the present invention to provide a more convenient expanded beam optical connector.

According to the invention, there is provided an expanded beam optical fibre connector for joining optical fibres, comprising a housing, an aperture in the housing, an optical fibre mounted within the housing and directed towards the aperture, a lens mounted in the aperture and optically coupled with the optical fibre so that optical radiation projected from the fibre is collimated by the lens into an expanded beam which is projected from the housing aperture and/or so that an expanded beam of optical radiation directed at the housing aperture is focussed by the lens into the optical fibre, the connector comprising additionally a connector portion for connecting the optical fibre connector to another expanded beam optical fibre connector so that said expanded beam traverses between said connector portions, wherein the lens is a ball lens which abuts an end of the optical fibre and both the ball lens and the optical fibre are permanently bonded in place.

The abutting and bonded contact of the optical fibre and ball lens provides an economical and simple yet effective means of ensuring a repeatable alignment between these components in a manufacturing process.

It is particularly advantageous if the lens has a focal point for said optical radiation which is on said end of said optical fibre. This helps to optimize the optical coupling between the optical fibre and the ball lens.

The optical fibre will normally have a core and cladding, and in particular may be a gain-guided optical fibre. The lens is then preferably focussed substantially on the optical fibre core in order to transfer more efficiently optical radiation from the optical fibre to the lens or *vice versa*.

In a preferred embodiment of the invention, the aperture leads to a bore that extends through the housing, with both the optical fibre and the ball lens being secured within the bore.

The bore may be a stepped bore with the ball lens being seated on a constricting feature in the stepped bore. During assembly of the optical connector, the ball lens may then be inserted into the aperture until the ball lens comes to rest on the securing feature. This provides a convenient way of aligning the ball lens in an axial direction within the bore.

Another way of aligning the ball lens with respect to the fibre is if the lens makes an interference fit within the bore. This has the advantage of ensuring axial alignment of the ball lens and optical fibre.

The ball lens may be bonded in abutting engagement with the optical fibre by means of an adhesive which is substantially transparent to said optical radiation.

A vent may extend from a location in the bore between the optical fibre and the ball lens to an outer surface of the housing, said vent serving in use to vent air and/or adhesive from between the optical fibre and the ball lens when these are brought into abutting actual contact or effective contact.

In a preferred embodiment of the invention, the optical fibre is held within a cylindrical ferrule which makes a slide-fit within a matching cylindrical bore of the housing. The ferrule is then also bonded to the ball lens by the adhesive.

The adhesive may be a uv-curable adhesive, the lens being capable of transmitting ultra-violet optical radiation directed at the housing aperture towards the uv-curable adhesive in order to cure the adhesive.

The adhesive is preferably an index matching adhesive that reduces loss (for example insertion loss) and reflections of optical radiation transmitted between the ball lens and the optical fibre.

The ball lens may be bonded to the housing at least partly by an adhesive between the lens and an externally accessible surface of the housing aperture. This adhesive is preferably applied separately and independently from the adhesive used to affix the optical fibre to the ball lens.

The invention further provides a fibre optic communications system, comprising a pair of mated expanded beam optical fibre connectors and a length of optical fibre cable leading to at least one of said connectors, wherein at least one of said mated connectors is an expanded beam optical fibre connector according to the invention.

Also according to the invention there is also provided a method of fabricating an expanded beam optical fibre connector for joining optical fibres, said connector being according to the invention, the method comprising the steps of:

i) inserting the ball lens into the aperture;

ii) either before, during or after step i), inserting the optical fibre into the bore;

iii) placing said adhesive between the ball lens and the optical fibre;

iv) maintaining the ball lens and optical fibre in abutting contact until the adhesive bonds the ball lens to the optical fibre.

The adhesive may be placed between the ball lens and the optical fibre most conveniently before both the ball lens and the optical fibre have been inserted into the housing. Therefore, it is not necessary to provide any other means of access for placing the adhesive into the housing other than the bore itself.

In a preferred embodiment of the invention, step i) is performed first. Then, prior to step iv), the ball lens is first bonded to the housing by an adhesive applied to an externally accessible surface of the ball lens and/or of the housing aperture. For example, the adhesive may be a ring of adhesive that surrounds an externally accessible periphery of the ball lens and which contacts an annular surface of the bore which is externally accessible. This adhesive used to bond the lens in place may therefore also be applied externally.

As described above, there may be a vent that extends from a location in the bore between the optical fibre and the ball lens to an outer surface of the housing, in order to vent air from between the optical fibre and the ball lens when these are brought into abutting contact. Prior to the bonding of the ball lens and optical fibre, as these are brought together along an axis of the bore, there will be a void which is at least partially filled, and preferably fully filled, by adhesive. The vent then serves to allow air and/or excess adhesive to escape from the void as the ball lens and optical fibre are brought into abutting contact so that said adhesive fills the void at least partially, and preferably fully, when the ball lens and optical fibre are bonded together. The advantage of fully filling the gap between the optical fibre and the ball lens is that environmental performance will be improved, particularly protection from condensation and improved mechanical stability in the presence of vibration or temperature changes.

Before the ball lens and optical fibre are bonded by the adhesive, the optical fibre may be aligned with respect to the ball lens by moving the optical fibre in the bore. In this way it is possible to optimise the optical coupling between the ball lens and the optical fibre.

In a preferred embodiment of the invention, this alignment is accomplished by rotating the ferrule and optical fibre in the matching cylindrical bore while the optical fibre is in effective abutting contact with the ball lens.

The invention will now be further described by way of example only, and with reference to the accompanying drawings in which:

Figure 1 is perspective view of an expanded beam connector according to a preferred embodiment of the invention showing a generally cylindrical connector portion or shell with a hermaphroditic connection mechanism that surrounds a first embodiment of a central fibre optic housing that holds two spherical lenses for projecting or receiving an expanded beam;

Figure 2 is a view of two of the expanded beam connectors of Figure 1 when joined together;

Figure 3 is a cross-section view of the central housing of Figure 1, showing a ferrule that holds an optical fibre in abutting contact with a spherical lens;

Figure 4 is an enlarged cross-section of a portion of a second embodiment of a central housing similar to that of Figure 3, showing in detail the optical arrangement of the spherical lens and optical fibre; and

Figures 5 to 8 illustrate the main steps taken in the assembly of the second embodiment of the fibre optic housing.

Figure 1 shows a perspective view of an expanded beam connector 1 having a generally cylindrical connector portion or shell 2 with a hermaphroditic connection mechanism 4,5 that surrounds a first embodiment of a central fibre optic housing 6. The housing 6 holds two ball lenses 8, which here are spherical lenses, for corresponding optical communication channels. The connector shell 2 defines a connector axis 9 which is in-line with a fibre optic cable 7 that is terminated by the connector 1.

It should be noted however, that the number of lenses and hence the number of communication channels is not critical to the invention, and that the connector may have any convenient number of lenses, for example between one and eight lenses.

Figure 2 shows how two such connectors may be joined together. As will be explained in detail below, a spherical lens 8 in each connector is optically coupled to an optical channel through the housing 6 provided by an optical fibre, and projects and/or receives an expanded optical beam from an opposed lens 8 in the other connector 1.

The two connectors 1 have a hermaphroditic coupling mechanism, comprising in each connector two similar part cylindrical protrusions 4 from the connector shell 2 which seat and lock within two corresponding part cylindrical recesses 5 within the other connector shell 2 when the two connectors are brought together along an axial direction and then counter-rotated about the connector axis 9.

Although not illustrated, each connector 1 may be provided with a retained plastic moulded dust cap to cover and protect the fibre optic housing 6 within the connector shell 2 when the connector is not joined to another similar connector.

In general, as shown in Figure 1, the connector assembly 1 may utilize more than one expanded beam and so there may be more than one spherical lens 8 and more than one corresponding optical channel through the housing 6. The spherical lenses 8 and optical channels will not, in general, have optical axes 10 which are coincident with the connector axis 9 of the cylindrical housing 6, but will be positioned off-axis and usually parallel with the connector axis 9 so that the expanded beams come into alignment as the two mated connectors 1 are rotated as these are locked together.

An advantage of this type of hermaphroditic design is that there can be no confusion in the field with male or female types and there is no requirement for adaptors. The connector assembly 1 may, however be used also with panel-mount bulkhead connector shells. The shell material is a hard aluminium alloy with a hard black anodised finish. A rubber grip ring sleeve 12 and strain relief boot 14 are also provided.

A water tight seal is made between the mated connector shells 2 by use of internal O-rings (not shown).

For clarity in the drawings, just one of the spherical lenses 8 is illustrated together with the components that make up the optical channel leading to the lens 8, namely an optical fibre 16, which is seated within a cylindrical bore 18 of a cylindrical ceramic ferrule 20.

The housing has a stepped bore 22, having inner and outer cylindrical portions 23,24 which are concentric with one another about the optical axis 10 defined by the spherical lens 8 and optical fibre 16. The spherical lens 8 is aligned within the outer cylindrical portion 24 that terminates at a circular front aperture 27 in the housing 6. The lens 8 is bonded to externally accessible surfaces of the outer bore 24 by means of a uv-curable optical adhesive 26.

The ferrule makes a sliding fit within the inner cylindrical portion 23, which terminates at a circular rear aperture 29 in the housing 6. Although the lens 8 may be aligned by contact with the cylindrical surface of the outer cylindrical portion 24, in the first embodiment of the housing 6 it is preferred if there is a small clearance gap between these walls and the spherical lens to aid insertion of the lens 8 into the bore 22. The lens 8 is then aligned when this is seated on a constricting feature in the bore 22, here an annular step 25 that extends perpendicularly to the longitudinal axis 10 of the concentric cylindrical portions 23,24 of the bore 22.

Both the lens 8 and ferrule 20 are therefore aligned radially with respect to the common axis 10 of the inner and outer cylindrical portions 23,24.

After alignment of the lens 8 and optical fibre 16, the lens and optical fibre 16 are bonded together and to the housing 6 by a uv-curable adhesive 28 that fills the space between the lens and the assembly of ferrule 20 and optical fibre 16. As will be explained below, to aid this process, a radially extending vent 43 is provided that extends from the inner bore 23 to an outer surface 46 of the housing 6.

Reference is now made to Figure 4, which shows a second embodiment of a housing 106 for the expanded beam optical connector 1, in which features the same as those of Figure 3 are indicated by the same reference numerals, and features similar to those of Figure 3 are indicated by reference numerals incremented by 100.

The second embodiment of the housing 106 differs from the first embodiment 6 essentially in that the lens 8 makes an interference fit with the outer portion 124 of the bore 122, so that the outer portion of the bore aligns the lens 8 axially with respect to the optical fibre 16. The lens 8 is therefore not seated on the annular step 125 within the bore, which is displaced relatively towards the optical fibre 16 so that cured adhesive 128 extends fully around the surface of the lens 8 within the housing 106. This provides the advantage of making an even more secure join and seal between the lens 8 and the housing 106. Furthermore, machining tolerances on the annular step 125 may be relaxed.

As shown in Figure 4, the lens 8 is bonded to externally accessible surfaces of the outer bore 124 by means of an optical adhesive 126. The adhesive 126 extends in a full annulus around the lens 8, thereby making a seal between the lens 8 and the housing 106.

A separate adhesive 128 lies in both the inner bore 123 and the outer bore 124 between the assembly of the ferrule 20 and the optical fibre 16 on the one hand, and the spherical lens 8 on the other hand. An end 30 of the ferrule is spherically polished together with an end 31 of the optical fibre 16. The adhesive 128 completely fills a void that would otherwise exist between the opposed spherical surfaces of the lens 8 and the assembly of ferrule 20 and optical fibre 16.

The optical fibre 16 is a gain-guided fibre with an outer cladding 33 and an inner core 34. At least a portion of the fibre 16 abuts the spherical lens 8. The lens has a diameter and an index of refraction such that an external expanded optical beam 36 along the optical axis 10 is focussed 37 through the lens 8 into the fibre core 34. This optical system may be designed to operate in this manner at any of the usual operating wavelengths of fibre optic communications systems, for example 850 nm, 1300 nm or 1550 nm.

To aid the coupling of the optical radiation 36 into or out of the optical fibre 16, the spherical lens 8 is bonded in abutting engagement with the optical fibre 16 by means of an adhesive which is substantially transparent to this optical radiation 36.

Reference is now made to Figures 5 to 8, which show a method according to the invention for assembling the second embodiment of the housing 106.

As shown in Figure 5, the spherical lens 8 is first inserted into the front aperture 27 until this makes an interference fit with the outer bore 124, while leaving a gap 39 between the lens 8 and the annular step 125. In the case of the first embodiment 6, the lens would be inserted until this is seated on the annular step 25. Then, uncured lens adhesive 26′ is applied around the externally accessible outer periphery of the lens 8 where this meets the outer cylindrical portion 124 of the bore 122. Ultra-violet optical radiation 40 is then applied to the adhesive 26 to cure this and bond the spherical lens 8 in place.

A quantity of uncured ferrule adhesive 128′ is then introduced through the rear aperture 129 and inner bore 123 onto the surface of the lens 8 within the bore 122, as shown in Figure 6. The uncured adhesive 128′ flows fully over the surface of the lens 8 within the bore 122, including between the gap 39 between the lens 8 and the annular step 125.

Then, as illustrated in Figure 7, the assembly of the ferrule 20 and the optical fibre 16 is inserted into the rear aperture 129 of bore 122 and made to slide 42 all the way into the inner bore 123 until the end 31 of the optical fibre 16 abuts the spherical lens 8.

As this takes place, air inside the inner bore 123 is vented through a radially extending vent 143 that extends from the inner bore 123 to an outer surface 146 of the housing. As the ferrule 20 and optical fibre 18 assembly come into contact with the spherical lens 8, excess uncured adhesive 128′ is also forced into the vent 143. The vent 143 therefore helps the adhesive 128′ to fill completely a void between the optical fibre 16 and the spherical lens 8. If any such uncured adhesive 128′ escapes from the vent 143, then this may be cleaned away.

As shown in Figure 8, ultra-violet optical radiation 48 is then shone through the lens 8 and into the uncured adhesive 128′ to cure this adhesive 128 and make a secure bond of the ferrule, and hence optical fibre 16, to the housing 6, and also to fix the orientation of the ferrule 20 and optical fibre 16 assembly with respect to the spherical lens 8.

Optionally, prior to bonding of the ferrule adhesive 128, as shown in Figure 7 an insertion loss test is made to reduce the insertion loss from optical interfaces between the end 31 of the optical fibre 16 and the spherical lens 8. This optical alignment step adjusts the point of contact between the assembly of optical fibre 16 and ferrule 20 and the spherical lens 8. In practice, the fibre core 34 is unlikely to be precisely on the optical axis 10. In practice it is also not necessary for the core 34 itself to be in actual physical contact with the lens 8 as long as some portion of the ferrule/fibre assembly 16,20 is in actual contact with the lens 8 so that the optical fibre 16 is in effective contact with the lens 8.

If the fibre core 34 is on the optical axis 10, then no further alignment will be necessary, but if there is some slight misalignment, then this may be minimized by rotating 50 the ferrule 20 and hence optical fibre 16 while optical radiation 44 is passed along the optical fibre core 34 towards the lens. Small changes in alignment as the optical fibre 16 is rotated 50 may result in small changes in the amount of optical radiation 44′. This may be monitored either by detecting directly the insertion loss 44′ or by monitoring the intensity of the expanded beam 44″.

After assembly of the components within the housing 6,106, the connector shell 2, grip 12 and strain relief boot 14 are assembled around the housing 6,106 and optical fibre cable 7.

The optical fibre connector 1 described above is intended to be permanently fixed to the fibre optic cable 7, and therefore does not suffer from design constraints associated with field terminable products. The optical fibre housing of the invention may be designed to be manufactured on commercial high precision machining centres, rather than requiring bespoke CNC machines as in the case of existing products.

In optical fibre connectors such as the connector 1 according to the invention, the fibre optic housing 6,106 is an important component, as this houses the optical arrangement. If the expanded beam connector 1 is to be backwards compatible with prior art expanded beam connectors, then certain aspects of the optical design will be determined by the optical and physical characteristics of the prior art connectors, such as the optical beam diameter and all positional dimensions regarding the optical channels and the arrangement of the connection mechanism 4,5.

The method described above of permanently bonding the optical fibre 16 within the housing 6,106 will provide a higher level of environmental performance. In particular, this method will provide greater resistance to damp, heat and vibration than other optical arrangements which have experienced failure under extreme conditions.

The diameter of the spherical lens, refractive index and any anti-reflection coatings (not shown) are chosen to provide the correct expanded beam diameter, focal point on the optical fibre and a sufficiently low Fresnel Reflections.

It is a particular advantage that the optical adhesive fills the void inside the housing, and in addition at least a lower end of the vent, as this helps to maximise the environmental performance of the connector against extremes of temperature and humidity. The arrangement also has good resistance against damage due to vibration.

The expanded beam optical fibre connector according to the invention also provides significant advantages when used underwater. For example, in the oil exploration industry it is sometimes necessary to use a fibre optic communications system to transmit information from undersea sensors or to control remotely an undersea vehicle. The connector described above is resistant to high pressures and so may be used in such applications.

The invention described above makes use of the ease of alignment and the mechanical stability of an optical fibre bonded directly to a spherical lens within the housing using an optical adhesive. By selecting a spherical lens with a focal point equal to its radius, and by selecting a UV curing optical adhesive with a refractive index close to that of the fibre and the sphere, an efficient optical path between the components is created.

Claims:

1. An expanded beam optical fibre connector for joining optical fibres, comprising a housing, an aperture in the housing, an optical fibre mounted within the housing and directed towards the aperture, a lens mounted in the aperture and optically coupled with the optical fibre so that optical radiation projected from the fibre is collimated by the lens into an expanded beam which is projected from the housing aperture and/or so that an expanded beam of optical radiation directed at the housing aperture is focussed by the lens into the optical fibre, the connector comprising additionally a connector portion for connecting the optical fibre connector to another expanded beam optical fibre connector so that said expanded beam traverses between said connector portions, wherein the lens is a ball lens which abuts an end of the optical fibre and both the ball lens and the optical fibre are permanently bonded in place.

2. An optical fibre connector as claimed in Claim 1, in which the lens has a focal point for said optical radiation which is on said end of said optical fibre.

3. An optical fibre connector as claimed in Claim 1 or Claim 2, in which the aperture leads to a bore that extends through the housing, both the optical fibre and the ball lens being secured within said bore.

4. An optical fibre connector as claimed in Claim 3, in which the lens makes an interference fit within the bore.

5. An optical fibre connector as claimed in Claim 3, in

which the bore is a stepped bore with the ball lens being seated on a constricting feature in said stepped bore.

6. An optical fibre connector as claimed in Claim 4 or Claim 5, in which said stepped bore has inner and outer cylindrical portions, said cylindrical portions being concentric with one another and the ball lens being aligned within the outer cylindrical portion.

7. An optical fibre connector as claimed in Claim 5, in which the constricting feature is an annular step that extends perpendicularly to a longitudinal axis of the concentric cylindrical portions of the bore.

8. An optical fibre connector as claimed in any preceding claim, in which the ball lens is bonded in abutting engagement with the optical fibre by means of an adhesive which is substantially transparent to said optical radiation.

9. An optical fibre connector as claimed in Claim 8, in which the adhesive fills completely a void between the optical fibre and the ball lens.

10. An optical fibre connector as claimed in Claim 8 or Claim 9, in which a vent extends from a location in the bore between the optical fibre and the ball lens to an outer surface of the housing, said vent serving in use to vent air and/or adhesive from between the optical fibre and the ball lens when these are brought into abutting contact.

11. An optical fibre connector as claimed in Claim 10, in which the optical fibre is held within a cylindrical ferrule

which makes a slide-fit within a matching cylindrical bore of the housing, the ferrule also being bonded to the ball lens by said adhesive.

12. An optical fibre connector as claimed in any of Claims 8 to 11, in which the adhesive is a uv-curable adhesive, the lens being capable of transmitting ultra-violet optical radiation directed at the housing aperture towards the uv-curable adhesive in order to cure said adhesive.

13. An optical fibre connector as claimed in any of Claims 8 to 12, in which the adhesive is an index matching adhesive that reduces loss of optical radiation transmitted between the ball lens and the optical fibre.

14. An optical fibre connector as claimed in any preceding claim, in which the ball lens is bonded to the housing at least partly by an adhesive between said lens and an externally accessible surface of said housing aperture.

15. A fibre optic communications system, comprising a pair of mated expanded beam optical fibre connectors and a length of optical fibre cable leading to at least one of said connectors, wherein at least one of said mated connectors is an expanded beam optical fibre connector as claimed in any preceding claim.

16. A method of fabricating an expanded beam optical fibre connector for joining optical fibres, said connector being as claimed in any preceding claim, the method comprising the steps of:

i) inserting the ball lens into the aperture;

ii) either before, during or after step i), inserting the optical fibre into the bore;

iii) placing said adhesive between the ball lens and the optical fibre;

iv) maintaining the ball lens and optical fibre in abutting contact until the adhesive bonds the ball lens to the optical fibre.

17. A method as claimed in Claim 16, in which step iii) is performed before both steps i) and ii) have been completed.

18. A method as claimed in Claim 16 or Claim 17, in which step i) is performed first, followed prior to step iv) by the step of bonding the ball lens to the housing by an adhesive applied to an externally accessible surface of the ball lens and/or of the housing aperture.

19. A method as claimed in any of Claims 16 to 18, when appendant from Claim 10, in which a void extends between the ball lens and optical fibre prior to bonding of the ball lens and optical fibre, in which in step iii) said adhesive at least partially fills said void prior to the ball lens and optical fibre being brought into abutting contact, said vent serving to allow air and/or excess adhesive to escape from said void as the ball lens and optical fibre are brought into abutting contact so that said adhesive at least partially fills said void when the ball lens and optical fibre are bonded together.

20. A method as claimed any of Claims 16 to 19, comprising additionally the step of moving the optical fibre in the bore prior to step iv) in order to optimise the optical coupling between the ball lens and the optical fibre.

21. A method as claimed in Claim 20, when appendant from Claim 11, comprising prior to step iv) the step of rotating said ferrule and optical fibre in said matching cylindrical bore while the optical fibre is in abutting contact with the ball lens in order to optimise the optical coupling between the ball lens and the optical fibre.

22. An expanded beam optical fibre connector for joining optical fibres, substantially as herein described, with reference to or as shown in the accompanying drawings.

23. A fibre optic communications system, comprising a pair of mated expanded beam optical fibre connectors, wherein at least one of said expanded beam optical fibre connectors is substantially as herein described, with reference to or as shown in the accompanying drawings.

24. A method of fabricating an expanded beam optical fibre connector for joining optical fibres, substantially as herein described, with reference to or as shown in the accompanying drawings.

Application No: GB 0326979.2
Claims searched: 1-24
Examiner: Chris Ross
Date of search: 6 May 2004

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X	1, 15, 16 at least	EP 0226881 A2	(POLAROID) the Figs
"	"	US 4327963 A	(USPC) Figs 4, 8-10
"	"	JP 560006209 A	(NT&T) abstract, the Figs
"	1, 16 at least	EP 0473429 A2	(NGKI) the Figs
"	"	JP 040331904 A	(NE) abstract, Figs 1
"	"	JP 590198412 A	(FUJITSU) abstract, the Figs
"	1 at least	JP 640048007 A	(") abstract, Figs 2, 4
"	"	JP 610185706 A	(MEI) abstract, the Figs
"	"	JP 590224807 A	(FUJITSU) abstract, the Figs
"	"	GB 2145534 A	(DCEC) the Figs
"	"	US 4265511 A	(USPC) Figs 1, 2
"	"	JP 560033617 A	(FUJITSU) abstract, Fig 1

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[W]:

Worldwide search of patent documents classified in the following areas of the IPC[7]:

G02B

The following online and other databases have been used in the preparation of this search report:

The Patent Office

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Application No:	GB 0326979.2	**Examiner:**	Chris Ross
Claims searched:	1-24	**Date of search:**	6 May 2004

WPI, EPODOC, JAPIO