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IN REPLY REFER TO:

Attorney Docket No. 84454  
Date: 14 November 2003

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Serial Number      10/644,549  
Filing Date        8/19/03  
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OPTICAL FIBER COUPLER

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT (1) LYNN T. ANTONELLI, and (2) PATRICK J. MONAHAN, citizens of the United States of America, employees of the United States Government, and residents of (1) Cranston, County of Providence, State of Rhode Island, and (2) Gales Ferry, County of New London, State of Connecticut, have invented certain new and useful improvements entitled as set forth above, of which the following is a specification.

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20031119 133

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Michael F. Oglo  
APPLICANT'S ATTORNEY

19 August 2003  
DATE OF SIGNATURE

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OPTICAL FIBER COUPLER

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STATEMENT OF GOVERNMENT INTEREST

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BACKGROUND OF THE INVENTION

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(1) Field of the Invention

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(2) Description of the Prior Art

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The present invention is a continuation-in-part of U.S. Application 10/231,693, filed 17 September 2002, in the names of Lynn T. Antonelli and Patrick J. Monahan.

The invention described herein may be manufactured and used by or for the Government of the United States of America for Governmental purposes without the payment of any royalties thereon or therefor.

The invention relates to fiber optic elements and is directed more particularly to an optical fiber coupler wherein fiber optic elements are coupled so as to provide a physical and optical connection therebetween.

Fiber optic strands typically include a central region in which light propagates, a cladding region to contain the light within the central region, and customarily a protective jacket. It is generally known to consolidate light carried in a group of fiber optic strands into a single strand, and, conversely, to

1 channel light broadcast through a single strand into a plurality  
2 of strands in a bundled fiber optic element. Either way, it is  
3 necessary that light be released from one or more fiber optic  
4 strands and captured by another one or more fiber optic strands.

5 To couple fiber optic strands such that light is transferred  
6 from one to the other, it is common to remove protective jackets  
7 and cladding from the strands, fuse the strands together, and  
8 then re-jacket the coupled strands for structural integrity.  
9 Alternatively, welding together of the fiber optic strands has  
10 been utilized, which affects the cladding only at the welding  
11 site. In other instances, the fiber optic strands have simply  
12 been terminated and lenses are used to feed the light into the  
13 receiving strand or strands. In still other instances, glass-  
14 based waveguides have been attached to optical fibers for  
15 transmitting light therebetween.

16 There is a need for a coupler for interconnecting fiber  
17 optic strands wherein the strands are connected both optically  
18 and physically without the need for lenses, waveguides, and the  
19 like.

20

## 21 SUMMARY OF THE INVENTION

22 An object of the invention is, therefore, to provide an  
23 optical fiber coupler wherein first and second fiber optic  
24 elements are connecting together optically and physically, such  
25 that the elements need not be altered prior to being connected,

1 do not require any intermediary lenses, or the like, and such  
2 that the connection, once effected, serves to provide structural  
3 integrity.

4 With the above and other objects in view, a feature of the  
5 present invention is the provision of an optical fiber coupler  
6 for connecting a first fiber optic element to a second fiber  
7 optic element. The coupler comprises a first fiber optic element  
8 extending in a first direction whereby to position a free end of  
9 the first fiber element in a selected zone, and a second fiber  
10 optic element extending into the selected zone from a direction  
11 generally opposite to the first direction, such that a free end  
12 of the second fiber optic element is disposed in the selected  
13 zone in confronting relationship with the first fiber optic  
14 element free end. A cured optical grade epoxy resin body defines  
15 the selected zone and envelopes the free ends of the elements to  
16 provide physical and optical connection between the first and  
17 second fiber optic elements. Once, cured, the housing material  
18 is removed, leaving the completed coupler device. The free ends  
19 of the fiber optic elements are in close proximity to one  
20 another, or in the case of coupling from one strand to a  
21 plurality of strands, in enough of a spaced relationship to cause  
22 needed light diffusion in the resin medium.

23 The above and other features of the invention, including  
24 various novel details of construction and combinations of  
25 elements, will now be more particularly described with reference

1 to the accompanying drawings and pointed out in the claims. It  
2 will be understood that the particular device embodying the  
3 invention is shown by way of illustration only and not as a  
4 limitation of the invention. The principles and features of this  
5 invention may be employed in various and numerous embodiments  
6 without departing from the scope of the invention.

#### 8 BRIEF DESCRIPTION OF THE DRAWINGS

9 Reference is made to the accompanying drawings in which is  
10 shown an illustrative embodiment of the invention, from which its  
11 novel features and advantages will be apparent, wherein  
12 corresponding reference characters indicate corresponding parts  
13 throughout the several views of the drawings and wherein:

14 FIG. 1 is an end elevational view of one form of a rigid  
15 body member for forming an embodiment of the invention;

16 FIG. 2 is a sectional view taken along line II-II of FIG. 1;

17 FIG. 3 is an end elevational view of the rigid body member  
18 of FIG. 1 with a wax coating thereon;

19 FIG. 4 is a sectional view taken along line IV-IV of FIG. 3;

20 FIG. 5 is an end elevational view similar to FIG. 3, but  
21 with the rigid body member removed from the wax to provide a  
22 hollow wax housing;

23 FIG. 6 is a sectional view taken along line VI-VI of FIG. 5;

24 FIG. 7 is an end elevational view similar to FIG. 5, but  
25 showing a first fiber optic element disposed in the wax housing;

1        FIG. 8 is a sectional view taken along line VIII-VIII of  
2        FIG. 7;

3        FIG. 9 is an end elevational view of the wax housing of  
4        FIGS. 7 and 8, and showing a second fiber optic element including  
5        a plurality of strands disposed in the wax housing and potted in  
6        an epoxy resin;

7        FIG. 10 is a sectional view taken along line X-X of FIG. 9,  
8        simplified and with certain components in side elevation for  
9        clarity;

10       FIG. 11 is an end elevational view similar to FIG. 9, but  
11       showing the coupler with the wax housing removed; and

12       FIG. 12 is similar to FIG. 10, but with the wax housing  
13       removed.

14

#### 15        DESCRIPTION OF THE PREFERRED EMBODIMENTS

16        Referring to FIGS. 1 and 2, it will be seen that in  
17        manufacture of the optical fiber coupler there is firstly  
18        provided a rigid body 20 of a selected configuration, such as  
19        conical. The body 20 forms a mold core and preferably is of a  
20        metal, such as brass or aluminum. In a conical configuration the  
21        body 20 is provided with a pointed end 22 and a circular base end  
22        24. The body 20, in one embodiment, is about one inch long with  
23        a diameter of about 0.375 in. and a pointed end taper of about  
24        30° from the internal central axis of the body.

1       As shown in FIGS. 3 and 4, the body 20 is coated with a  
2   layer of mold making wax 26 extending over all outer surfaces of  
3   the body 20 except the base end 24, as by building up the layer  
4   through repeated dipping of the body into molten wax. The wax 26  
5   is hardened, as by freezing or curing. Upon removal of the body  
6   20 from the wax 26, there is provided a hollow wax housing 28  
7   (FIGS. 5 and 6) having a pointed end 30 and an open-base end 32.  
8   A portion 38 of the housing 28, shown in phantom in FIG. 6, is  
9   removed to provide a hole 34 in the pointed end 30.

10       A first fiber optic element 40, which may comprise a single  
11   fiber optic strand 42, is inserted into the housing 28 through  
12   the hole 34 made in the housing pointed end 30, to position a  
13   free end 44 of the first fiber optic element 40 in the housing  
14   28. The form which free end 44 takes is a butt-ended termination  
15   of strand 42. A sealant 36 is used to seal the hole 34 around  
16   the strand 42, as shown in FIG. 8. The diameter of the hole 34  
17   is complementary to the diameter of the strand 42.

18       Prior to insertion of the first element strand 42, about 1/4  
19   inch of a jacket 46 covering a central region 48 of the strand 42  
20   may be removed to expose 1/4 inch, or so, of the central region  
21   48, as shown in FIG. 8. However, removal of the jacket end is  
22   not necessary for the function of the connection, but may improve  
23   entrapment within resin 60 in the housing 28, described further  
24   hereinbelow.

1       After the first fiber optic element 40 is in place, a second  
2 fiber optic element 50 is inserted into the open-base end 32 of  
3 housing 28 to position a free end 52 of the second fiber optic  
4 element 50 in the housing 28 and in confronting relation to the  
5 first fiber optic element free end 44, as shown in FIG. 10. The  
6 second fiber optic element 50 may comprise a plurality of second  
7 fiber optic strands 54. Again, the form which the free ends 52  
8 of strands 54 take are butt-ended terminations of each strand,  
9 with a linear marginal edge portion of the jacket 46 of each  
10 strand 42, 54 optionally removed. In one embodiment, shown in  
11 FIG. 9, the plurality of strands 54 is inserted into the open-  
12 base end 32 of wax housing 28 in a ring-like arrangement about  
13 the central axis of the housing.

14       The housing 28 is then filled with the optical grade epoxy  
15 resin 60, which is allowed to cure, thereby potting all the fiber  
16 optic strands 42, 54 in place in the housing 28. The wax housing  
17 28 is then removed, completing formation of the optical fiber  
18 coupler, FIGS. 11 and 12.

19       In the cases of either or both of fiber optic elements 40  
20 and 50 comprising a plurality of butt-end terminations of fiber  
21 optic strands, free ends 44 and 52 are spaced apart by a distance  
22 allowing a sufficient extent of spatial diffusion of light  
23 issuing from the butt-ended fibers and propagating in the optical  
24 grade epoxy resin therebetween to couple light between each  
25 strand of the first element with each strand of the second

1 element. However, in the case of fiber optic elements 40 and 50  
2 each consisting of a single fiber optic element, the free ends  
3 44, 52 may be spaced as close as is practical.

4 Light exiting either the first or second fiber optic  
5 elements 40, 50 is propagated out of the appropriate strand end  
6 or ends 44, 52. Light exiting the selected element is  
7 transported through the cured optically transparent resin 60  
8 towards the receiving fiber optic element.

9 The coupler described hereinabove provides a connection  
10 which allows light to be coupled from a group of optical fiber  
11 strands into a single strand or several other strands, or from a  
12 single strand into another single strand or into a plurality of  
13 strands. Further, it is to be understood that an n-by-n coupler  
14 may be provided. The first and second fiber optic elements 40  
15 and 50 in an n-by-n coupler each comprise a plurality of strands.  
16 Such n-by-n couplers find utility in linear arrays of pulse  
17 responsive, 2-mode, in-line within a fiber, Fabry-Perot  
18 interference cavity sensors, which are disclosed in U.S. Patent  
19 Application Serial Number 06/795,843, filed 5 September 1985, by  
20 Eugene Green et al, entitled "Pulse Sample Optical Fiber  
21 Hydrophone Array". In the type of hydrophone array systems which  
22 employ pulse-responsive, 2-mode, interference cavity fiber  
23 sensors as their individual hydrophone elements, one of the  
24 strands of first fiber optic element 40 propagates pulses to a  
25 plurality of strings of fiber sensors connected to respective

1 strands of the plurality of strands of the second fiber optic  
2 element 50. The distal positioning of individual sensors on a  
3 string, and an arrangement of different delay lengths of fibers  
4 at the front end of respective strings of sensors cause the  
5 reflected signals from the sensors to return to the respective  
6 strands of second fiber optic elements 50 in time division  
7 sampled relationship. These time division sampled signals  
8 propagate to a second strand of first fiber optic element 40  
9 which couples them to a receiver processor.

10 In addition to serving as an optical connection between the  
11 first and second fiber optic elements 40, 50, the coupler  
12 simultaneously provides a physical connection of structural  
13 integrity. The resin 60 provides a protective shield for the  
14 fibers. Inasmuch as there is no need to remove whatever cladding  
15 and jacketing may be present on the fiber optic strands, such  
16 protective layers remain in the finished coupler, providing  
17 additional security. As noted above, a small end portion of the  
18 jacket 46 may be removed (FIG. 8) for improved bonding, depending  
19 on the material of the strand 42 and the epoxy resin used.

20 It will be apparent that the housing 28 may be of any  
21 selected configuration and while the illustrated cone shape is  
22 appropriate for a first fiber optic element including only one or  
23 a few strands and a second fiber optic element including a  
24 comparatively large number of strands, other housing shapes are  
25 suitable for other variations of elements. The respective

1 elements preferably are insertable from generally opposite  
2 directions so that the free ends thereof are positioned opposite  
3 to each other and in close proximity to each other.  
4 Alternatively, if diffusion of light is necessary because one or  
5 both of the fiber optic elements comprises a plurality of  
6 strands, then sufficient space is provided therebetween to allow  
7 such diffusion.

8       There is thus provided a coupler for connecting together  
9 first and second fiber optic elements optically and physically,  
10 such that the coupler serves to transport light from one element  
11 to the other and serves further as supporting and protective  
12 structure.

13       It will be understood that many additional changes in the  
14 details, materials, steps and arrangement of parts, which have  
15 been herein described and illustrated in order to explain the  
16 nature of the invention, may be made by those skilled in the art  
17 within the principles and scope of the invention as expressed in  
18 the appended claims.

3 OPTICAL FIBER COUPLER

5 ABSTRACT OF THE DISCLOSURE

6 Optical fiber coupler for coupling fiber optic elements  
7 includes a first fiber optic element extending in a first  
8 direction to position a free end thereof in a selected zone, and  
9 a second fiber optic element extending into the selected zone  
10 from an opposite direction to position a free end of the second  
11 fiber optic element in the zone confronting the first fiber optic  
12 element free end. A cured optical grade epoxy resin body defines  
13 the zone and envelopes the free ends of the fiber optic elements,  
14 to effect physical and optical connection between the first and  
15 second fiber optic elements. Once cured, the housing material is  
16 removed leaving the completed coupler device. The free ends of  
17 the fiber optic elements are in close proximity, or in the case  
18 of coupling from one strand to a plurality of strands, in enough  
19 of a spaced relation, to permit required light diffusion.

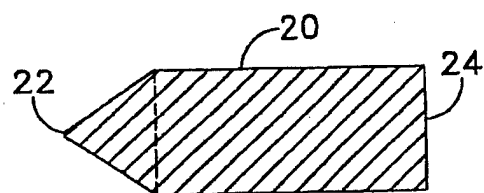


FIG. 2

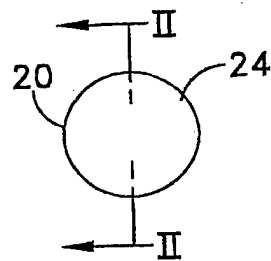


FIG. 1

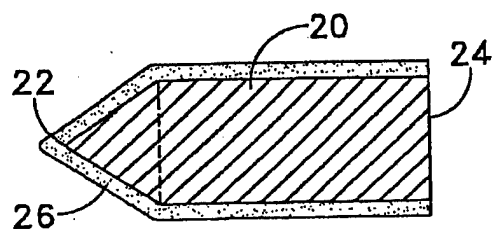


FIG. 4

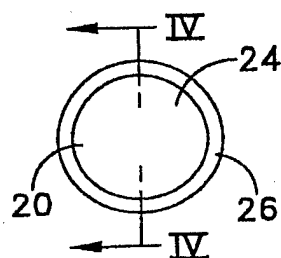


FIG. 3

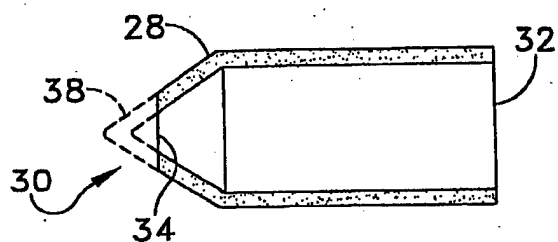


FIG. 6

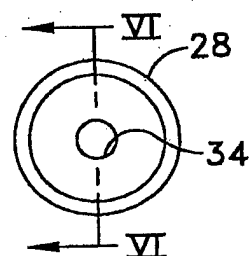


FIG. 5

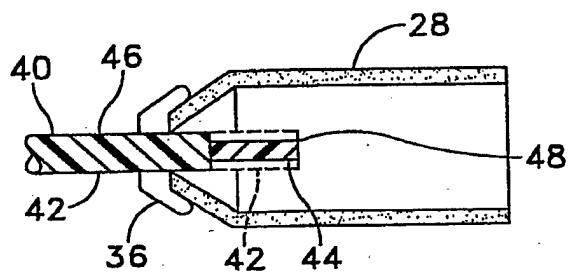


FIG. 8

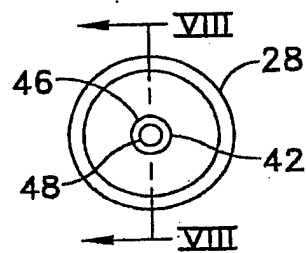


FIG. 7

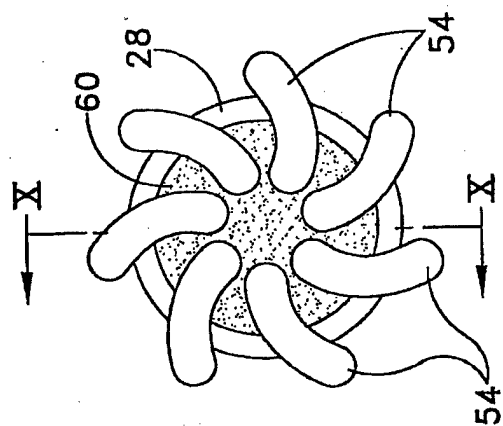


FIG. 9

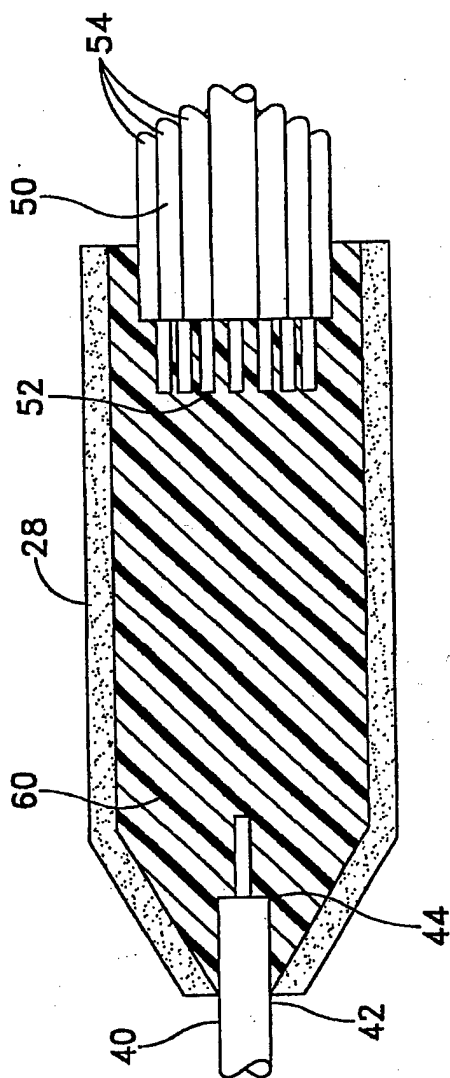


FIG. 10

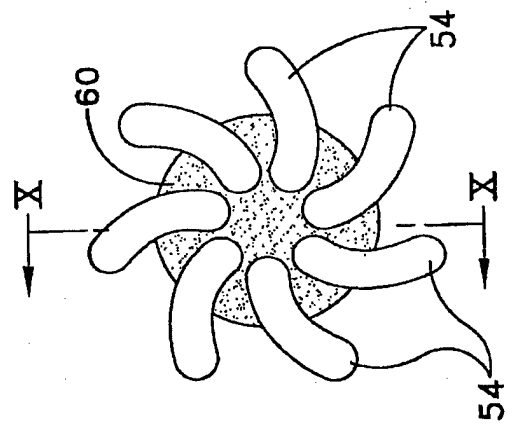


FIG. 11

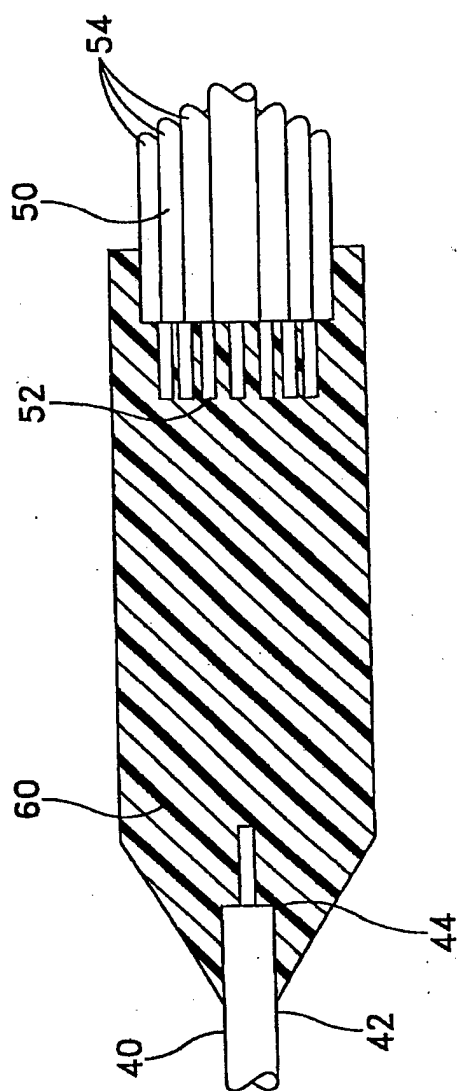


FIG. 12