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TITLE OF THE INVENTION:

Miniature Bend Splice in Optical Fibers
and Method of Forming Same

5 CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C.
§ 119(e) of U.S. Provisional Application Nos. 60/148,375,
filed on August 11, 1999, the disclosure of which is
incorporated by reference herein.

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STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR
DEVELOPMENT

N/A



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15 BACKGROUND OF THE INVENTION

A common way of permanently joining optical
telecommunications fibers is with a fusion splice,
thereby forming a continuous glass strand. The splice is
formed by carefully removing the protective polymer
20 buffer that surrounds the fibers near the ends to be
spliced. The bare fiber ends are cleaved and cleaned. The
end faces of the fibers are placed in contact, and the
fibers are fused together with heat from a torch or
electric arc. This type of splice provides robust low
25 loss transmission between the spliced segments. In the
splice region, the fiber may be recoated to protect the
bare glass or it may be packaged in a surrounding
protective housing.

This type of splice has, however, several
30 disadvantages. The protective splice housing is typically
long. Some splice packages are as long as 2.375 inches in
length. In addition, the fiber emerges from both ends of

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the splice package. Because the recommended bend radius of the fiber is approximately one inch, it may be necessary to leave as much as an additional inch at each end of the splice package to allow the fibers to bend into another direction.

This combination of long splice package, large bend radius of the fiber, and emergence of the fiber from both ends of the housing may cause difficulty in packaging splices compactly. For example, if it is desired to splice together the pigtails from two fiber optic splitters, each of which may reside in a package more than two inches in length, the splice may add an additional three or four inches to the overall length to allow for bends and pigtails from the components. The end to end length of two spliced splitters can easily be ten inches or more. See Fig. 5. To accommodate this inconveniently long length, the fibers are often coiled in a box, as shown in Fig. 6. This configuration results in a lesser overall length, but a greater overall area.

As noted above, a turn or bend in an optical fiber typically requires a bend radius of 2 cm or more to avoid light loss and maintain a useful longevity in an unprocessed bent fiber. It is also known that this radius may be substantially reduced to as little as 50 μ using a miniature bend. To form a miniature bend, the diameter along a length of bare fiber is reduced to as little as 1 μ , by, for example, drawing, etching, or a combination thereof. In the reduced diameter region, the fiber conducts light by internal reflection at least partially due to the difference in index of refraction at the interface between the fiber and the surrounding environment, generally air. Thus, in this region, the

fiber may be bent with no substantial light loss from the bend. See US Patent Nos. 5,138,676 and 5,452,393, the disclosures of which are incorporated by reference herein.

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SUMMARY OF THE INVENTION

The present invention provides a fiber optic device having a miniature bend splice for changing direction along a fiber optic path in a compact space.

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More particularly, the device comprises a first optical fiber having a first end portion and a second optical fiber having a second end portion. The first end portion and the second end portion are joined at a fusion splice in a fusion splice region. A miniature bend is formed in at least a portion of the fusion splice region that has a diameter reduced to less than a diameter of the first optical fiber and the second optical fiber and is capable of transmitting light with substantially less light loss due to bending than an unreduced fiber portion. The splice and bend are preferably housed in a suitable support structure or packaging. In this manner, the bend provides a change of direction between the first optical fiber and the second optical fiber in a compact space.

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The fusion splice and miniature bend fiber optic device is particularly useful in the routing of optical fibers in the field. Often, the technician laying new optical fiber or repairing existing fibers must determine or accommodate an appropriate and efficient routing in the field and must bend the fibers as necessary to achieve this routing. The present invention allows the technician to splice two fibers and then bend the splice

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region to a desired angle in the field so that the fiber heads in the desired direction. The device is also particularly useful in combination with two fiber optic splitters that must be spliced together. The combination
5 of two splitters and a miniature bend splice may be housed in a highly compact package.

DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood from the
10 following detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a cross-sectional view of a 180° miniature bend and splice according to the present invention;

Fig. 2 is a plan view of a 90° miniature bend and
15 splice;

Fig. 3 is a plan view of a 45° miniature bend and splice;

Fig. 4 is partial cross-sectional view of a 180° miniature bend and splice in combination with two
20 splitters;

Fig. 5 is a prior art combination of two 2x2 splitters and a splice; and

Fig. 6 is a prior art combination of two 1x2 splitters and a splice packaged in a coiled
25 configuration.

DETAILED DESCRIPTION OF THE INVENTION

A fiber optic device 10 having a fusion splice and a miniature bend according to the present invention is illustrated in Fig. 1. The device 10 is formed with two optical fibers 12, 14, having ends 16, 18 from which the polymer buffers or jackets 20, 22, have been removed. The fibers are joined by a fusion splice in a splice region 24. The miniature bend 26 is formed in at least a portion of the splice region having a reduced diameter.

The splice between the two fibers 12, 14 may be formed using conventional fusion splice technology with known fusion splice equipment. Thus, the fiber ends are cleaved and cleaned. The fiber ends are aligned and placed with their end faces in contact. The fibers are then joined by heating the fusion region, for example, using a torch or electric arc.

Next, the diameter within the fusion splice region 24 is reduced to an appropriate diameter to achieve a miniature bend with minimum light loss. The diameter is preferably reduced by heating the splice region and drawing the fiber down to the desired diameter. The draw may be performed by the fusion splice equipment. The draw parameters, such as arc current and duration, are adjusted as necessary to achieve the desired draw, which can be readily determined by those of ordinary skill in the art. The draw typically includes a ramp up to a desired current, a steady state while the draw occurs, and a ramp down as the diameter decreases to prevent melting of the fiber. Typically, the draw reduces the diameter of the fiber from, for example, 125 μ to a diameter sufficient to minimize loss of the optical energy in the bend, preferably approximately 15 μ . The

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draw may occur immediately after the fusion splice while the fiber is still heated, or the fiber may be allowed to cool down before performing the draw. The diameter may also be reduced by etching or a combination of drawing and etching if desired. Preferably, straight tapered transition regions 28, 30 are left on each side between the fusion splice region.

The bend 26 is formed in the reduced diameter region in any suitable manner known in the art. Alternatively, the fusion splice equipment may include a suitable movable support to bend one fiber over to the appropriate angle. After bending, the bend is annealed at a low temperature to relieve stresses in the bend region, as is known in the art. For example, the fusion splice equipment may be operated at low current while the bend is still retained therein.

The particular bend angle may be chosen as necessary for the particular application. In Fig. 1, the direction of the fused fibers is reversed, so that one of the fibers is folded back over the other fiber in a substantially 180° bend. Thus, the two fibers are parallel or substantially parallel and extend adjacent or close to each other along parallel or substantially parallel axes. Other bend angles may be provided, however. For example, Fig. 2 illustrates a bend angle of 90°, and Fig. 3 illustrates a bend angle of 45°.

The splice and bend are preferably supported by a suitable support structure or housing 32, such as in a channel 34 formed in a substrate 36. The two fibers may be retained within the channel by a suitable adhesive 38, as known in the art. The bend is preferably supported so

that it does not touch the sides of the substrate, which would degrade the optical performance therein.

The bent splice 10 may be formed with the pigtails 40, 42, from two splitters 44, 46, as shown in Fig. 4. 5 The two splitters may be retained within a single housing 48. The combination of the two splitters and the bent splice may be further housed within a rigid protective shield (not shown) if desired. As is apparent, the entire package of two splitters and the bent splice occupies 10 less area and is substantially shorter than the known prior art splitter/splice/splitter combinations shown in Figs. 5 and 6.

The fusion splice and miniature bend combination is also particularly useful in the routing of optical fibers 15 in the field. Often, the technician laying new optical fiber or repairing existing fibers must determine or accommodate an appropriate and efficient routing in the field and must bend the fibers as necessary to achieve this routing. The present invention allows the technician 20 to splice two fibers and then bend the splice region to a desired angle in the field so that the fiber heads in the desired direction.

The invention is not to be limited by what has been particularly shown and described, except as indicated by 25 the appended claims.

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CLAIMS

We claim:

- 5 1. A fiber optic device for changing direction along a
fiber optic path, comprising:
 a first optical fiber having a first end portion,
and a second optical fiber having a second end portion,
the first end portion and the second end portion joined
10 at a fusion splice in a fusion splice region; and
 a bend formed in the fusion splice region, the
fusion splice region including a portion having a
diameter reduced to less than a diameter of the first
optical fiber and the second optical fiber and capable of
15 transmitting light with substantially less light loss due
to bending than an unreduced fiber portion, the bend
providing a change of direction between the first optical
fiber and the second optical fiber.
- 20 2. The fiber optic device of claim 1, wherein the
change of direction an angle up to 180°.
3. The fiber optic device of claim 1, wherein the bend
provides a reversal of direction between the first
25 optical fiber and the second optical fiber.
4. The fiber optic device of claim 1, wherein the bend
has a radius of curvature selected to minimize loss of
optical energy in the bend.

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5. The fiber optic device of claim 1, further comprising a buffer covering the first optical fiber and the second optical fiber spaced from the bend.

5 6. The fiber optic device of claim 1, wherein the diameter of the portion of the fusion splice region is reduced by etching, drawing, or a combination of etching and drawing.

10 7. The fiber optic device of claim 1, wherein the diameter of the portion of the fusion splice region is sufficiently reduced to minimize loss of optical energy in the bend.

15 8. The fiber optic device of claim 1, further comprising a support structure, the bend housed within the support structure.

20 9. The fiber optic device of claim 1, further comprising two fiber optic splitters, wherein the first optical fiber comprises a pigtail from one of the two fiber optic splitters and the second optical fiber comprises a pigtail from another of the two fiber optic splitters.

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10. The fiber optic device of claim 9, wherein the change of direction is an angle up to 180°.

30 11. A method of forming a fiber optic device having a change of direction along a fiber optic path, comprising:
providing a first optical fiber having a first end
and a second optical fiber having a second end;

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fusing the first end and the second end to form a fusion splice in a fusion splice region;

5 reducing the diameter of at least a portion of the fusion splice region to a diameter less than a diameter of the first optical fiber and the second optical fiber and capable of transmitting light with substantially less light loss due to bending than an unreduced optical fiber; and

10 bending the portion of the fusion splice region to form a bend.

12. The method of claim 11, wherein the reducing step further comprises drawing, etching, or a combination of drawing and etching the fusion splice region.

15 13. The method of claim 11, further comprising supporting the fusion splice region and the bend on a substrate.

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