

Description

This invention relates to 1xN fiber optic couplers ($N > 2$) that are capable of coupling substantially equal amounts of power from an input optical fiber to three or more output optical fibers; it also relates to methods of making such couplers.

Methods of making 1xN couplers are disclosed in related U.S. patent application S.N. 380,877. Protective coating is removed from a region of an input optical fiber intermediate the ends thereof, and protective coating is removed from an end of each of a plurality of output optical fibers. The coated portion of the input fiber is threaded through the aperture of a capillary tube until the uncoated region thereof is near the tube end. The uncoated regions of the output fibers are placed around that of the input fiber, and the uncoated regions of all of the fibers are simultaneously fed into the tube aperture until the uncoated regions extend through the midregion of the tube. In order to equally space the output fibers around the input fiber, the uncoated sections of the output fibers are glued to the input fiber prior to inserting the fiber bundle into the tube. The tube midregion is heated to collapse it about the fibers, and the central portion of the midregion is drawn to reduce the diameter thereof over a predetermined length.

U.S. Patent No. 4,902,324 teaches that tubes having bores of predetermined cross-section can be employed to facilitate the alignment of the output fibers around the centrally-disposed input fiber prior to the tube collapse step. The aperture is formed by a plurality of flattened walls, the dimensions and orientations of which are such that the cross-section of the aperture in the central region of the tube is symmetrical with respect to a plane passing through the longitudinal axis of the tube. At any cross-section of the aperture that is adjacent the coated regions of the fibers, each fiber coating contacts two walls of the aperture. The midregion of the tube is heated and collapsed about the fibers, and the central portion of the midregion is drawn to reduce the diameter thereof. For example, four fibers can be positioned in a triangularly shaped bore, three of the fibers being equally spaced about a central fiber. After the tube collapse step, the peripherally disposed fibers are not always equally spaced about the central fiber. A maximum of six fibers can be equally spaced about the central fiber and yet be in contact with the central fiber.

Summary of the Invention

It is an object of the present invention to provide a method of making an overlaid 1xN fiber optic coupler ($N > 2$) wherein a plurality of output fibers remain equally spaced about an input fiber after the overlaid tube has been collapsed onto the fibers. Another object is to provide a reproducible method of making 1xN

overlaid fiber optic couplers. A further object is to provide a fiber optic coupler in which a plurality of output fibers are equally spaced about an input fiber.

According to the present invention there is provided a method of making a fiber optic coupler comprising the steps of assembling a coupler preform having inner and outer concentric glass tubes having a gap therebetween, with a first optical fiber disposed in the axial passageway of the inner tube, and a plurality of optical fibers disposed within said gap and equally spaced about the axis of said inner tube, said first fiber extending through the longitudinal midregion that extends intermediate the first and second ends of the resultant coupler preform, said first fiber extending from the first end of said preform, and said plurality of fibers extending through said midregion and from second end of said tube,

heating and then collapsing said midregion of said coupler preform onto said fibers, and stretching the central portion of said midregion to reduce the diameter thereof.

Various gap configurations are generated, depending upon the shape of the outer surface of the inner tube and the shape of the outer tube aperture. The gap can be azimuthally homogeneous, whereby its thickness at any azimuthal position is sufficient to accept one of the plurality of fibers. In such a gap, each of the output fibers is disposed immediately adjacent two other output fibers. Alternatively, the gap can be azimuthally inhomogeneous, whereby the thickness thereof at equally spaced azimuthal positions is sufficient to accept one of the plurality of fibers, but wherein the thickness of the gap between the spaced azimuthal positions is insufficient to accept one of the plurality of fibers.

The coupler preform can be assembled by inserting a portion of the input fiber into the axially disposed aperture of an inner tube having first and second ends, the remainder of the first fiber extending from the first end of the inner tube. The inner tube is inserted into the aperture of an outer tube, a gap existing between the inner and outer tubes. The ends of a plurality of output optical fibers are inserted into the gap. The input and output fibers extend through the midregion of the resultant coupler preform. The inner tube is preferably formed of a glass having a softening point temperature lower than that of the optical fiber cladding glass and having a refractive index substantially equal to that of the cladding glass. The outer tube is formed of a glass having a refractive index less than that of the optical fiber cladding glass. The softening point temperature of the outer tube is preferably lower than that of the inner tube.

An azimuthally inhomogeneous gap can be formed as follows. The aperture of the outer tube may contain a plurality of equally spaced, inwardly projecting, longitudinally extending protrusions. Alternatively, the outer surface of the inner tube may contain

such protrusions. In either case, one of the output fibers is inserted into the gap between each adjacent pair of protrusions. An alternative method of providing an azimuthally inhomogeneous gap involves the use of an inner tube having a circularly cylindrical outer surface and an outer tube having an aperture which is formed of a plurality of surfaces equal in number to the number of output fibers, the cross-sectional configuration of the outer tube aperture being that of a regular polygon.

The inner tube is preferably slightly longer than the outer tube so that, after it is inserted into the aperture of the outer tube, it extends beyond the outer tube. If the method employs output optical fibers having protective coatings thereon, a portion of the coating is stripped from an end of each fiber. In the resultant coupler preform, the coated portions of the output fibers terminate beyond the protruding second end of the inner tube, and the fibers are glued to the protruding portion of the inner tube.

The resultant fiber optic coupler comprises an elongated glass body having a solid longitudinal mid-region that extends intermediate the first and second ends of said body and first and second opposite end portions which respectively extend from said mid-region to the first and second ends of said body, said body comprising an inner region of a first glass composition having a refractive index n_3 and an outer region of a second glass composition having a refractive index n_4 , wherein n_4 is less than n_3 ,

a first glass optical fiber and a plurality of glass optical fibers, each of said optical fibers having a core surrounded by a cladding having a refractive index lower than that of said core,

said first fiber extending axially through said inner region at the midregion of said body and extending beyond the first end thereof,

said plurality of fibers extending through the midregion of said body and extending beyond the second end thereof, said plurality of fibers being situated between said inner and outer regions of said body and being substantially equally spaced around said first fiber,

the central portion of said midregion having a diameter smaller than the diameter of the remainder of said glass body, the cores of said optical fibers being closer together in the central portion of said mid-region than in the remainder of said glass body.

Each of the output fibers can be in contact with the two adjacent output fibers, or it can be separated from the two adjacent output fibers.

Brief Description of the Drawings

Fig. 1 is a partial cross-sectional view of a coupler preform attached to an evacuation apparatus.

Fig. 2 is a cross-sectional view of the preform of Fig. 1.

Fig. 3 is a cross-sectional view taken along lines 3-3 of Fig. 2.

Fig. 4 is a schematic illustration of an apparatus for collapsing a coupler preform and drawing the mid-region thereof.

Fig. 5 shows a coupler preform after it has been stretched and sealed at its ends.

Figs. 6, 7, 8 and 9 are cross-sectional views illustrating alternative embodiments.

Description of the Preferred Embodiments

The drawings are not intended to indicate scale or relative proportions of the elements shown therein.

By way of example, Figs. 1-3 illustrate a method of assembling a coupler preform 31 that can be formed into a 1x16 fiber optic coupler.

A plurality of lengths of coated optical fiber are severed from a reel of fiber. Each of the coated fibers consists of a glass fiber having a protective coating, and each glass fiber comprises a core of refractive index n_1 and a cladding having a refractive index n_2 ($n_1 > n_2$). The coating is removed from the end of each of the coated fibers, and each of the uncoated ends is optionally provided with an antireflection termination. One method of forming such terminations is disclosed in U.S. patent No. 4,834,493. In accordance with a modification of the method of that patent, an oxygen-acetylene flame is directed at the uncoated fiber a short distance from the end thereof, and the end of the fiber is pulled until it becomes severed from the remainder of the fiber. The fiber now has a tapered end. The fiber end remote from the tapered end is connected to a reflectance monitoring apparatus. The tapered end is provided with a low reflectance termination by heating the tapered end in a flame to lower the viscosity of the material thereof by an amount sufficient to cause the material to recede back along the fiber and form a rounded endface, the final diameter of which is about equal to or slightly smaller than the original uncoated fiber diameter. A current specification for the reflected power is -50 dB. The uncoated sections of fiber are sufficiently long that they extend beyond the tube midregion 27 when the ends of the coating are positioned as described below. When so positioned, the fiber ends preferably do not extend beyond endfaces 23 and 24 of tube 13.

The present method employs concentric tubes 10 and 13 having longitudinal bores or apertures 11 and 14, respectively. The diameter of aperture 14 is sufficiently large as compared to the diameter of inner tube 10 that an annular gap 16 exists therebetween when the tubes are arranged concentrically. Gap 16 is azimuthally homogeneous, whereby its thickness at any azimuthal position is a predetermined thickness that is just large enough to accept one of said plurality of fibers. Thus, sixteen fibers can be disposed therein in side-by-side relationship, each of the

fibers 20 being immediately adjacent two others of the fibers 20. The dimensions of the tubes are determined as follows. For ease of handling, the tube lengths should be at least about 3.8 cm. Inner tube 10 preferably extends beyond the outer overclad tube 13 about 6-7 mm to facilitate the gluing of fibers to the end portion of tube 10. Assuming that a standard fiber diameter of 125 μm is to be employed for fibers 19 and 20, the minimum cross-sectional dimension of each wall of triangular aperture 11 is about 168 μm . About 1-2 μm tolerance should be added to that dimension. If 16 optical fibers are arranged as illustrated in Fig. 3, their centers lie on a circle the diameter of which is about 637 μm . The maximum diameter of tube 10 is therefore about 512 μm , and the minimum diameter of aperture 14 is about 762 μm . Depending on the tolerance with which the fibers can be manufactured, the dimensions of tube 10 and aperture 14 must be modified to ensure that gap 16 is large enough to receive the 16 fibers.

Tubes 10 and 13 can be formed by depositing glass particles on a cylindrical mandrel to form a cylindrical porous preform. The mandrel is removed, and the porous preform is dried and consolidated to form a tubular glass body which is heated and redrawn to reduce its diameter. Apertures of various cross-sectional shapes can be formed in the tube by shrinking the tube onto a carbon graphite member of desired cross-section and then burning out the carbon member and stretching the tube to decrease its diameter. The carbon member surface should be free from impurities that would cause imperfections in the glass surface within the aperture. The details of this process are disclosed in U.S. patent No. 4,750,926, which is incorporated herein by reference. Although aperture 11 could be circular, its cross-sectional shape is preferably triangular, square or the like to facilitate its evacuation. Aperture 14 could also be formed by shrinking a tube onto a carbon member.

Tapered apertures 12 and 15 can be formed by flowing the gas phase etchant NF_3 through the tube while directing a flame toward the end of the tube to create an axial temperature gradient. The tapered apertures form funnel-like entrances to bore 11 and gap 16 to facilitate fiber insertion.

The refractive index n_3 of tube 10 is about the same as n_2 , and that tube is softer than the fiber cladding glass so that it does not excessively deform the fibers during the tube collapse step. If the fiber cladding is SiO_2 , suitable tube compositions are SiO_2 doped with a combination of refractive index increasing and decreasing dopants. For example, the addition of dopants such as GeO_2 to SiO_2 increases the refractive index thereof, whereas the addition of fluorine and/or B_2O_3 to SiO_2 decreases its refractive index. All of these dopants lower the softening point temperature of SiO_2 .

The refractive index n_4 of overclad tube 13 is low-

er than n_2 , and that tube is also softer than the fiber cladding glass and preferably softer than tube 10. Suitable tube compositions are SiO_2 doped with 1 to 25 wt. % B_2O_3 and SiO_2 doped with 0.1 to approximately 2.5 wt. % fluorine. Glasses comprising silica and combinations of these dopants can also be employed.

Following is a typical example of a method that could be employed in the formation of a 1x16 coupler. One of the aforementioned coated fibers is employed as input coated fiber 17, which comprises glass fiber 19 and protective coating 21. Fiber 19 is wiped to eliminate residual material and is inserted through tapered aperture 12 and into aperture 11 until its endface is located beyond the midregion of that tube. Coating 21 may extend into the tapered aperture, but it could be located a few millimeters beyond endface 23. A drop 28 of glue is applied to one side of coated fiber 17 in such a manner that access from endface 23 to aperture 11 is not blocked. Care must be taken not to contaminate the outer surface of tube 10. Tube 10 is then placed in tube 13 such that tapered aperture 15 is at endface 24 opposite tapered aperture 12.

In the described embodiment, sixteen of the aforementioned coated fibers are employed as output coated fibers 18, each of which comprises glass fiber 20 and protective coating 22. Fibers 20 are wiped and are inserted through tapered aperture 15 and into gap 16 until coating 22 is situated just beyond the end of tube 10. A drop 29 of glue is applied to the outer circumference of optical fibers 20 in such a manner that access from endface 24 to gap 16 is not blocked. Glue 29 secures the fibers to tube 10. Additional drops 30 and 36 of glue can be applied to endfaces 23 and 24, respectively, of tube 13 to secure the tubes together.

Apparatus for collapsing and stretching the resultant preform 31 is shown in Fig. 4. Chucks 32 and 33, which secure preform 31 in this apparatus, are mounted on motor controlled stages 45 and 46, respectively, which are preferably controlled by a computer. Heat shield 35 is optionally employed for the purpose of protecting the apparatus located above ring burner 34. Preform 31 is inserted through ring burner 34 and is clamped to the draw chucks. The fibers extending from both ends of tube 13 are threaded through their respective vacuum apparatus, and vacuum attachments 41 and 41' are connected to the ends of preform 31.

Vacuum attachment 41, which is shown in cross-section in Fig. 1, may comprise a tube 40, a collar 39 threaded thereon, and an O-ring 38 disposed between the collar and tube. After vacuum attachment 41 is slid over the end of tube 13, collar 39 is tightened, thereby compressing O-ring 38 against the tube. Vacuum line 42 is connected to tube 40. One end of a length of thin rubber tubing 43 is attached to that end of vacuum attachment 41 that is opposite preform 31; the remaining end of the tubing extends

between clamp jaws 44. The coated portions of fibers 18 extend from tubing 43. Upper vacuum attachment 41' is similarly associated with line 42', tubing 43' and clamp jaws 44'. Vacuum is applied to both ends of coupler preform 31 by clamping jaws 44 and 44' on tubing 43 and 43', respectively.

The flame from ring burner 34 heats preform 31 for a period of time sufficient to increase the temperature of midregion 27 thereof to the softening temperature thereof. With the assistance of the differential pressure on the tubes, tube 10 collapses onto fiber 19, and tube 13 collapses onto fibers 20 and brings each fiber 20 into contact with the two adjacent fibers 20. The matrix glass of the two tubes surrounds the fibers and fills the apertures to form within midregion 27 a solid structure that is free from airlines. The longitudinal length of this collapsed region depends upon such parameters as the temperature and time duration of the flame, the thermal conductivity of the glass tube, and the amount of vacuum applied.

After the preform cools, the flame is reignited, and the center of the collapsed region is reheated to the softening point of the materials thereof. The heating period for the stretch step is usually of shorter duration than the collapse step. Thus, only the central portion of the collapsed midregion is stretched. Stretching only the central portion of the collapsed midregion ensures that the coupling region of the fibers will be embedded in the matrix glass of tubes 10 and 13. During this reheating step, the fibers are also heated since they are completely surrounded by the matrix glass of the capillary tube and are therefore in thermal contact therewith. After the central portion of the collapsed midregion is reheated, the flow of oxygen to burner 34 is turned off and stages 45 and 46 pull in opposite directions until the coupler length has been increased by an amount necessary to reduce the radial distance between the cores of fibers 19 and 20 along a longitudinal distance sufficient to accomplish a predetermined type of coupling. The diameter of the central portion of midregion 27 is reduced as illustrated by region 51 of Fig. 5. Drops 52 of glue can be applied to the ends of the coupler to provide a hermetic seal.

The amount of stretching to which the coupler preform must be subjected to achieve a given type of coupler is initially determined by injecting light energy into input fiber 19 of a coupler preform and monitoring the output power from at least one of the output fibers 20 during the stretch operation. The detection of a predetermined output power from the output fiber can be used as an interrupt to cause stages 45 and 46 to stop pulling the preform. In this case, the predetermined output power would be 1/16 the input power minus 1/16 the total excess device loss, as determined empirically. After having determined the proper stretching distance to achieve predetermined coupling characteristics, the apparatus can be program-

med to move the stages that proper stretching distance during the fabrication of subsequent couplers that are to have said predetermined characteristics.

When the input fiber and the sixteen output fibers are identical, the percent power coupled from the input fiber to the output fiber will be wavelength sensitive. In the above-described example, about 1/16 the input power might couple to each of the output fibers at a predetermined wavelength such as 1310 nm, whereas substantially no power would couple at another wavelength such as 1550 nm. However, if the propagation constants of the output fibers are different from that of the input fiber, the device can be made to function as an achromatic coupler, a wavelength division multiplexer or the like. Various fiber parameters that affect the propagation constant are disclosed in the publication: O. Parriaux et al., "Wavelength Selective Distributed Coupling Between Single Mode Optical Fibers for Multiplexing", Journal of Optical Communications, Vol. 2, No. 3, pp. 105-109.

In the embodiments of Figs. 6-9 the gap is azimuthally inhomogeneous, i.e. the thickness thereof at spaced azimuthal positions is sufficient to accept one of said plurality of output fibers, but the thickness thereof between said spaced azimuthal positions is insufficient to accept one of said plurality of output fibers. An azimuthally inhomogeneous gap is useful for forming 1xN couplers of the type wherein N is relatively small, i.e. wherein N is as small as 3. It is noted that if a 1x8 coupler were being formed in accordance with the example of Figs. 1-3, tube 10 would have an inordinately small thickness and would therefore be difficult to handle. However, a 1x8 coupler, for example, can be made in accordance with the embodiment of Fig. 6 wherein circularly cylindrical inner tube 57 is provided with an axial aperture 56 into which input fiber 55 is disposed. Outer tube 58 has an aperture 59 containing inwardly projecting, equally spaced, longitudinally extending protrusions 60 that are equal in number to the number of output fibers 61 (8 in this embodiment). Aperture 59 can be formed by shrinking tube 58 onto an appropriately shaped carbon member as described above. Fibers 61 are separated by protrusions 60, thereby permitting the use of a tube 57 of greater diameter than that which would have been required if fibers 61 were disposed in a close packed array wherein adjacent fibers were in contact. Projections 60 also eliminate any skew in the orientation of fibers 61, and thereby maintain fibers 61 in parallel relationship with respect to fiber 55.

In the embodiment of Fig. 7, inner tube 65 contains longitudinally extending protrusions 66, whereas outer tube 67 has a circular aperture 68. In a modification of Fig. 7 (not shown), outer tube 67 could also have inwardly extending projections aligned with projections 66. It is more difficult to form the projections on the outer surface of a tube than on the aper-

ture surface. Projections 66 could be formed by machining the glass tube prior to reducing its diameter by drawing.

A spacing member between the input and output fibers could also be employed with as few as two or three output fibers. In Fig. 8, input fiber 72 is disposed in the aperture of circular tube 73. Tube 73 is disposed within outer tube 74 having a square aperture 75 that is just large enough to permit the insertion of inner tube 73. Output fibers 77 fit snugly within the four enlarged regions of the gap 76 that exists between the two tubes.

In the embodiment of Fig. 9, circular tube 80, in which there is disposed an input fiber 81, is positioned within the triangularly shaped aperture 83 of tube 82. Output fibers 84 fit snugly within the three enlarged regions of the gap 85 that exists between the two tubes.

Claims

1. A method of making a fiber optic coupler comprising the steps of

assembling a coupler preform (31) having inner and outer concentric glass tubes (10, 13; 57, 58; 65, 67; 73, 74; 80, 82) having a gap (16, 85) therebetween, with a first optical fiber (19, 55, 72, 81) disposed in the axial passageway (11, 56) of the inner tube (10, 57, 65, 73, 80), and a plurality of optical fibers (20, 61, 69, 77, 84) disposed within said gap and equally spaced about the axis of said inner tube, said first fiber extending through the longitudinal midregion (27) that extends intermediate the first and second ends of the resultant coupler preform, said first fiber extending from the first end of said preform, and said plurality of fibers extending through said midregion (27) and from the second end of said tube,

heating and then collapsing said midregion of said coupler preform onto said fibers, and stretching the central portion of said midregion to reduce the diameter thereof.

2. A method of making a fiber optic coupler comprising the steps of

providing an inner glass tube (10, 57, 65, 73, 80) having first and second ends and an axially disposed passageway (11, 56),

inserting a portion of a first optical fiber (19, 55, 72, 81) into said axially disposed passageway, the remainder of said first fiber extending from said first end of said inner tube,

providing an outer glass tube (13, 58, 67, 74, 82) having an axial passageway (11, 56),

inserting said inner tube into the passageway of said outer tube to provide a gap (16, 85)

between said inner and outer tubes,

inserting the ends of a plurality of optical fibers (20, 61, 69, 77, 84) into said gap, the device so formed constituting a coupler preform, said first fiber and said plurality of fibers extending through the longitudinal midregion (27) that extends intermediate the ends of said coupler preform (31),

heating and then collapsing said preform midregion (27) onto said fibers, and

stretching the central portion of said midregion to reduce the diameter thereof.

3. A method in accordance with claim 2 wherein the step of assembling a coupler preform (31) comprises assembling a preform wherein each of said plurality of fibers (20, 61, 69, 77, 84) is disposed immediately adjacent two other of said plurality of fibers.

4. A method in accordance with claim 1 or 2 wherein the step of assembling a coupler preform (31) comprises assembling a preform wherein said gap (16) has the same radial width around the axis of said coupler, whereby its thickness at any azimuthal position is sufficient to accept one of said plurality of fibers (20), or wherein said gap (85) varies in radial width around the axis of said coupler, whereby the thickness thereof at equally spaced azimuthal positions is sufficient to accept one of said plurality of fibers (61, 69, 77, 84), but wherein the thickness of said gap between said spaced azimuthal positions is insufficient to accept one of said plurality of fibers.

5. A method in accordance with claim 1 or 2 wherein the step of providing an outer tube comprises providing a tube (58), the passageway of which contains a plurality of equally spaced, inwardly projecting, longitudinally extending protrusions (60), and the step of inserting said plurality of fibers (61) comprises inserting one of said plurality of fibers into said gap between each of said protrusions, and/or wherein the step of providing an inner tube comprises providing a tube (65), preferably with a cylindrical outer surface, the outer surface of which contains a plurality of equally spaced, outwardly projecting, longitudinally extending protrusions (66), and the step of inserting said plurality of fibers (69) comprises inserting one of said plurality of fibers into said gap between each of said protrusions.

6. A method in accordance with claim 5 wherein said plurality of fibers (20, 61, 69, 77, 84) each comprises a glass core surrounded by a glass cladding having a refractive index lower than that of said glass core, and wherein the step of providing



ture surface. Projections 66 could be formed by machining the glass tube prior to reducing its diameter by drawing.

A spacing member between the input and output fibers could also be employed with as few as two or three output fibers. In Fig. 8, input fiber 72 is disposed in the aperture of circular tube 73. Tube 73 is disposed within outer tube 74 having a square aperture 75 that is just large enough to permit the insertion of inner tube 73. Output fibers 77 fit snugly within the four enlarged regions of the gap 76 that exists between the two tubes.

In the embodiment of Fig. 9, circular tube 80, in which there is disposed an input fiber 81, is positioned within the triangularly shaped aperture 83 of tube 82. Output fibers 84 fit snugly within the three enlarged regions of the gap 85 that exists between the two tubes.

Claims

1. A method of making a fiber optic coupler comprising the steps of

assembling a coupler preform (31) having inner and outer concentric glass tubes (10, 13; 57, 58; 65, 67; 73, 74; 80, 82) having a gap (16, 85) therebetween, with a first optical fiber (19, 55, 72, 81) disposed in the axial passageway (11, 56) of the inner tube (10, 57, 65, 73, 80), and a plurality of optical fibers (20, 61, 69, 77, 84) disposed within said gap and equally spaced about the axis of said inner tube, said first fiber extending through the longitudinal midregion (27) that extends intermediate the first and second ends of the resultant coupler preform, said first fiber extending from the first end of said preform, and said plurality of fibers extending through said midregion (27) and from the second end of said tube,

heating and then collapsing said midregion of said coupler preform onto said fibers, and stretching the central portion of said midregion to reduce the diameter thereof.

2. A method of making a fiber optic coupler comprising the steps of

providing an inner glass tube (10, 57, 65, 73, 80) having first and second ends and an axially disposed passageway (11, 56),

inserting a portion of a first optical fiber (19, 55, 72, 81) into said axially disposed passageway, the remainder of said first fiber extending from said first end of said inner tube,

providing an outer glass tube (13, 58, 67, 74, 82) having an axial passageway (11, 56),

inserting said inner tube into the passageway of said outer tube to provide a gap (16, 85)

between said inner and outer tubes,

inserting the ends of a plurality of optical fibers (20, 61, 69, 77, 84) into said gap, the device so formed constituting a coupler preform, said first fiber and said plurality of fibers extending through the longitudinal midregion (27) that extends intermediate the ends of said coupler preform (31),

heating and then collapsing said preform midregion (27) onto said fibers, and

stretching the central portion of said midregion to reduce the diameter thereof.

3. A method in accordance with claim 2 wherein the step of assembling a coupler preform (31) comprises assembling a preform wherein each of said plurality of fibers (20, 61, 69, 77, 84) is disposed immediately adjacent two other of said plurality of fibers.

4. A method in accordance with claim 1 or 2 wherein the step of assembling a coupler preform (31) comprises assembling a preform wherein said gap (16) has the same radial width around the axis of said coupler, whereby its thickness at any azimuthal position is sufficient to accept one of said plurality of fibers (20), or wherein said gap (85) varies in radial width around the axis of said coupler, whereby the thickness thereof at equally spaced azimuthal positions is sufficient to accept one of said plurality of fibers (61, 69, 77, 84), but wherein the thickness of said gap between said spaced azimuthal positions is insufficient to accept one of said plurality of fibers.

5. A method in accordance with claim 1 or 2 wherein the step of providing an outer tube comprises providing a tube (58), the passageway of which contains a plurality of equally spaced, inwardly projecting, longitudinally extending protrusions (60), and the step of inserting said plurality of fibers (61) comprises inserting one of said plurality of fibers into said gap between each of said protrusions, and/or wherein the step of providing an inner tube comprises providing a tube (65), preferably with a cylindrical outer surface, the outer surface of which contains a plurality of equally spaced, outwardly projecting, longitudinally extending protrusions (66), and the step of inserting said plurality of fibers (69) comprises inserting one of said plurality of fibers into said gap between each of said protrusions.

6. A method in accordance with claim 5 wherein said plurality of fibers (20, 61, 69, 77, 84) each comprises a glass core surrounded by a glass cladding having a refractive index lower than that of said glass core, and wherein the step of providing



an inner tube (10, 57, 65, 73, 80) comprises providing a tube formed of a glass having a softening point temperature lower than that of said glass cladding and having a refractive index substantially equal to that of said glass cladding, and/or wherein the step of providing an outer tube (13, 58, 67, 74, 82) comprises providing a tube formed of a glass having a refractive index less than that of said glass cladding, and preferably formed of a glass having a softening point temperature lower than that of said inner tube.

7. A method in accordance with claim 5 wherein the step of providing an inner tube comprises providing an inner tube (10) that is longer than said outer tube (13), wherein the step of inserting said inner tube into the passageway of said outer tube results in a coupler preform wherein said second end of said inner tube extends beyond said outer tube, said method further comprising the step of bonding said plurality of fibers (20) to the protruding portion of said inner tube

8. A method in accordance with claim 7 wherein said plurality of glass fibers (20) have coatings (22) thereon, said method further comprising the step of stripping from an end of each of said plurality of fibers a portion the coating thereof, and wherein the step of inserting the ends of a plurality of optical fibers into said gap (16) results in the formation of a coupler preform (31) wherein the coated portions of said plurality of fibers terminate beyond said second end of said inner tube (10).

9. A fiber optic coupler comprising:

an elongated glass body having a solid longitudinal midregion (27) that extends intermediate the first and second ends of said body and first and second opposite end portions which respectively extend from said midregion to the first and second ends of said body, said body comprising an inner region of a first glass composition having a refractive index n_3 and an outer region of a second glass composition having a refractive index n_4 , wherein n_4 is less than n_3 ;

a first glass optical fiber (19) and a plurality of glass optical fibers (20), each of said optical fibers having a core surrounded by a cladding having a refractive index lower than that of said core;

said first fiber extending axially through said inner region at the midregion of said body and extending beyond the first end thereof,

said plurality of fibers extending through the midregion of said body and extending beyond the second end thereof, said plurality of fibers being situated between said inner and outer regions

of said body and being substantially equally spaced around said first fiber,

the central portion (51) of said midregion having a diameter smaller than the diameter of the remainder of said glass body, the cores of said optical fibers being closer together in the central portion of said midregion than in the remainder of said glass body.

10. A coupler in accordance with claim 9 wherein the refractive index of the claddings of said plurality of fibers (20) is about equal to n_3 .

11. A coupler in accordance with claim 9 wherein each of said plurality of fibers (20) is in contact with the two adjacent ones of said plurality of fibers.

12. A coupler in accordance with claim 9, 10 or 11 wherein the glass of said inner region has a softening point temperature lower than that of said cladding glass.

13. A coupler in accordance with claims 9-12 wherein the inner region of said body extends beyond the outer region of said body at said second end of said body.

Patentansprüche

1. Verfahren zur Herstellung eines faseroptischen Kopplers, welches die folgenden Schritte aufweist:

Zusammensetzen einer Kopplervorform (31), die ein inneres und ein äußeres konzentrisches Glasrohr (10, 13; 57, 58; 65, 67; 73, 74; 80, 82) mit einem Spalt (16, 85) dazwischen, wobei eine erste optische Faser (19, 55, 72, 81) innerhalb eines in Axialrichtung verlaufenden Durchgangs (11, 56) des inneren Rohres (10, 57, 65, 73, 80) angeordnet ist, und eine Vielzahl von optischen Fasern (20, 61, 69, 77, 84) aufweist, die innerhalb des Spaltes angeordnet und gleichmäßig um die Achse des inneren Rohres herum beabstandet sind, wobei sich die erste Faser durch einen in Längsrichtung verlaufenden Mittelbereich (27) erstreckt, welcher sich zwischen dem ersten und zweiten Ende der resultierenden Kopplervorform liegend erstreckt, wobei sich die erste Faser von dem ersten Ende der Vorform erstreckt und wobei sich die Vielzahl an Fasern durch den Mittelbereich (27) und von dem zweiten Ende des Rohres erstreckt,

Erhitzen und darauffolgendes Kollabieren des Mittelbereiches der Kopplervorform auf die Fasern, und Ziehen des mittleren Abschnittes des Mittelbereiches zur Verminderung von dessen



Durchmesser.

2. Verfahren zur Herstellung eines faseroptischen Kopplers, welches aus den folgenden Schritten besteht:
 Vorsehen eines inneren Glasrohres (10, 57, 65, 73, 80) mit einem ersten und zweiten Ende sowie einem axial angeordneten Durchgang (11, 56),
 Einführen eines Abschnittes einer ersten optischen Faser (19, 55, 72, 81) in den axial angeordneten Durchgang, wobei der Rest der ersten Faser sich von dem ersten Ende des inneren Rohres erstreckt,
 Vorsehen eines äußeren Glasrohres (13, 58, 67, 74, 82) mit einem axialen Durchgang (11, 56),
 Einführen des inneren Rohres in den Durchgang des äußeren Rohres zur Schaffung eines Spaltes (16, 85) zwischen dem inneren und äußeren Rohr,
 Einführen der Enden von einer Vielzahl an optischen Fasern (20, 61, 69, 77, 84) in den Spalt, wobei die so gebildete Vorrichtung eine Kopplervorform darstellt, und wobei sich die erste Faser und die Vielzahl an Fasern durch den längsverlaufenden Mittelbereich (27) erstrecken, welcher sich zwischen den Enden der Kopplervorform (31) liegend erstreckt,
 Erhitzen und darauffolgendes Kollabieren des Vorformmittelbereiches (27) auf die Fasern, und Ziehen des mittleren Abschnittes des Mittelbereiches zur Verminderung von dessen Durchmesser.
 5
 10
 15
 20
 25
 30
3. Verfahren nach Anspruch 2, bei dem der Schritt des Zusammenbaus einer Kopplervorform (31) das Zusammensetzen einer Vorform enthält, wobei jede Faser aus der Vielzahl an Fasern (20, 61, 69, 77, 84) unmittelbar neben zwei anderen aus der Vielzahl an Fasern angeordnet ist.
 35
 40
4. Verfahren nach Anspruch 1 oder 2, bei dem der Schritt des Zusammenbaus einer Kopplervorform (31) das Zusammensetzen einer Vorform enthält, wobei der Spalt (16) dieselbe radiale Breite um die Achse des Kopplers herum aufweist, wobei dessen Dicke an jeder azimuthalen Position ausreichend für die Aufnahme einer aus der Vielzahl an Fasern (20) ist, oder wobei der Spalt (85) in der radialen Breite rund um die Achse des Kopplers herum variiert, wobei dessen Dicke an gleichmäßig beabstandeten azimuthalen Positionen ausreichend ist zur Aufnahme einer aus der Vielzahl an Fasern (61, 69, 77, 84), jedoch die Dicke des Spaltes zwischen den beabstandeten azimuthalen Positionen nicht ausreichend ist zur Aufnahme einer aus der Vielzahl an Fasern.
 45
 50
 55
5. Verfahren nach Anspruch 1 oder 2, bei dem der Schritt des Vorsehens eines äußeren Rohres das Vorsehen eines Rohres (58) enthält, dessen Durchgang eine Vielzahl an gleichmäßig beabstandeten, nach innen hervorstehenden und sich in Längsrichtung erstreckenden Vorwölbungen (60) aufweist, und der Schritt des Einführens der Vielzahl an Fasern (61) das Einführen einer aus der Vielzahl an Fasern in den Spalt zwischen jeder dieser Vorwölbungen enthält, und/oder wobei der Schritt des Vorsehens eines inneren Rohres das Vorsehen eines Rohres (65) enthält, vorzugsweise mit einer zylindrischen Außenfläche, wobei dessen Außenfläche eine Vielzahl an gleichmäßig beabstandeten, nach außen vorragenden und sich in Längsrichtung erstreckenden Vorwölbungen (66) enthält, und der Schritt des Einführens der Vielzahl an Fasern (69) das Einführen einer aus der Vielzahl an Fasern in den Spalt zwischen jede der Vorwölbungen enthält.
 6. Verfahren nach Anspruch 5, bei dem jede aus der Vielzahl an Glasfasern (20, 61, 69, 77, 84) einen Glaskern enthält, welcher durch einen Glasmantel umgeben ist, der einen Brechungsindex aufweist, der niedriger ist als derjenige des Glaskerns, und wobei der Schritt des Vorsehens eines inneren Rohres (10, 57, 65, 73, 80) das Vorsehen eines Rohres enthält, welches aus einem Glas gebildet ist, das eine Erweichungspunkttemperatur aufweist, die niedriger ist als diejenige des Glasmantels, und einen Brechungsindex aufweist, welcher im wesentlichen gleich dem des Glasmantels ist und/oder wobei des Vorsehens eines äußeren Rohres (13, 58, 67, 74, 82) das Vorsehen eines Rohres enthält, welches aus einem Glas gebildet ist, welches einen Brechungsindex aufweist, der niedriger ist als derjenige des Glasmantels und welches vorzugsweise aus einem Glas gebildet ist, welches eine Erweichungspunkttemperatur aufweist, die niedriger ist als diejenige des inneren Rohres.
 7. Verfahren nach Anspruch 5, bei dem der Schritt des Vorsehens eines inneren Rohres das Vorsehen eines inneren Rohres (10) enthält, welches länger ist als das äußere Rohr (13), bei dem der Schritt des Einführens des inneren Rohres in den Durchgang des äußeren Rohres zu einer Kopplervorform führt, bei der das zweite Ende des inneren Rohres sich über das äußere Rohr erstreckt, wobei das Verfahren ferner den Schritt des Bondens bzw. Kontaktierens der Vielzahl an Fasern an den vorstehenden Abschnitt des inneren Rohres enthält.
 8. Verfahren nach Anspruch 7, bei dem auf der Viel-



- zahl an Glasfasern (20) Beschichtungen (22) vorgesehen sind, wobei das Verfahren ferner den Schritt des Abstreifens eines Abschnittes der Beschichtungen von einem Ende einer jeden aus der Vielzahl an Fasern enthält, und bei dem der Schritt des Einführens der Enden der Vielzahl an optischen Fasern in den Spalt (16) zu der Bildung einer Kopplervorform (31) führt, wobei die beschichteten Abschnitte der Vielzahl an Fasern hinter dem zweiten Ende des inneren Rohres (10) enden.
9. Ein faseroptischer Koppler bestehend aus:
 einem länglichen Glaskörper mit einem längsverlaufenden Mittelbereich (27), welcher sich zwischen dem ersten und zweiten Ende des Körpers liegend erstreckt, und mit ersten und zweiten gegenüberliegenden Endabschnitten, welche sich jeweils von dem Mittelbereich hin zu dem ersten und zweiten Ende des Körpers erstrecken, wobei der Körper einen inneren Bereich aus einer ersten Glaszusammensetzung mit einem Brechungsindex n_3 und einem äußeren Bereich aus einer zweiten Glaszusammensetzung mit einem Brechungsindex n_4 besitzt, wobei n_4 kleiner ist als n_3 ;
 einer ersten optischen Glasfaser (19) und einer Vielzahl an optischen Glasfasern (20), wobei jede der optischen Glasfasern einen Kern besitzt, der von einem Mantel umgeben ist, der einen Brechungsindex aufweist, welcher niedriger ist als derjenige des Kerns;
 wobei die erste Faser sich in Axialrichtung durch den inneren Bereich an den Mittelbereich des Körpers und über dessen erstes Ende hinaus erstreckt,
 wobei die Vielzahl an Fasern sich durch den Mittelbereich des Körpers und über dessen zweites Ende hinaus erstreckt, wobei die Vielzahl an Fasern sich zwischen dem inneren und äußeren Bereich des Körpers befindet und im wesentlichen gleichmäßig beabstandet um die erste Faser herum liegt,
 wobei der Mittelabschnitt (51) des Mittelbereiches einen Durchmesser besitzt, welcher kleiner ist als der Durchmesser des übrigen Glaskörpers, wobei die Kerne der optischen Fasern in dem Mittelabschnitt des Mittelbereiches näher zueinander liegen als in dem übrigen Glaskörper.
10. Koppler nach Anspruch 9, bei dem der Brechungsindex der Ummantelung der Vielzahl an Fasern (20) ungefähr gleich n_3 ist.
11. Koppler nach Anspruch 9, bei dem jede aus der Vielzahl an Fasern (20) mit zwei danebenliegenden aus der Vielzahl an Fasern in Kontakt ist.
12. Koppler nach den Ansprüchen 9, 10 oder 11, bei dem das Glas des inneren Bereiches eine Erweichungspunkttemperatur aufweist, welche niedriger ist als diejenige des Ummantelungsglases.
13. Koppler nach den Ansprüchen 9 - 12, bei dem der innere Bereich des Körpers sich über den äußeren Bereich des Körpers an dem zweiten Ende des Körpers hinaus erstreckt.

Revendications

1. Procédé de fabrication d'un coupleur pour fibres optiques comprenant les étapes suivantes :
 assemblage d'une préforme de coupleur (31) ayant des tubes de verre concentriques intérieur et extérieur (10, 13; 57, 58; 65, 67; 73, 74; 80, 82) entre lesquels il existe un intervalle (16, 58), avec une première fibre optique (19, 55, 72, 81) disposée dans le passage axial (11, 56) du tube intérieur (10, 57, 65, 73, 80) et une pluralité de fibres optiques (20, 61, 69, 77, 84,) disposée dans ledit intervalle et espacée régulièrement autour de l'axe dudit tube intérieur, ladite première fibre s'étendant à travers la région centrale longitudinale (27) située entre les première et deuxième extrémités de la préforme de coupleur obtenue, ladite première fibre partant de la première extrémité de ladite préforme et ladite pluralité de fibres s'étendant à travers ladite région centrale (27) et depuis la deuxième extrémité dudit tube,
 chauffage et, ensuite, écraser ladite région centrale de ladite préforme de coupleur sur lesdites fibres, et
 étirage de la partie centrale de ladite région centrale pour en diminuer le diamètre.
2. Procédé de fabrication d'un connecteur pour fibres optiques comprenant les étapes suivantes :
 disposition d'un tube de verre intérieur (10, 57, 65, 73, 80) ayant une première et une deuxième extrémités et un passage disposé axialement (11, 56),
 insertion d'une partie d'une première fibre optique (19, 55, 72, 81) dans ledit passage disposé axialement, le reste de ladite première fibre s'étendant depuis ladite première extrémité dudit tube intérieur,
 disposition d'un tube de verre extérieur (13, 58, 67, 74, 82) ayant un passage axial (11, 56),
 insertion dudit tube intérieur dans le passage dudit tube extérieur pour obtenir un intervalle (16, 85) entre lesdits tubes intérieur et extérieur,
 insertion des extrémités de la pluralité de



- fibres optiques (20, 61, 69, 77, 84) dans ledit intervalle, le dispositif ainsi formé constituant une préforme de coupleur, ladite première fibre et ladite pluralité de fibres s'étendant à travers la région centrale longitudinale (27) disposée entre les extrémités de ladite préforme de coupleur (31),
- chauffage et écraser ensuite ladite région centrale de préforme (27) sur lesdites fibres, et étirer la partie centrale de ladite région centrale pour en diminuer le diamètre.
3. Procédé selon la revendication 2, dans lequel l'opération d'assemblage d'une préforme de coupleur (31) comprend l'assemblage d'une préforme dans laquelle chacune des fibres de la pluralité de fibres (20, 61, 69, 77, 84) est disposée à proximité immédiate de deux autres fibres de ladite pluralité de fibres.
 4. Procédé selon la revendication 1 ou 2, dans lequel l'opération d'assemblage d'une préforme de coupleur (31) comprend l'assemblage d'une préforme dans laquelle ledit intervalle (16) a la même largeur radiale autour de l'axe dudit coupleur, son épaisseur pour toute position azimutale étant suffisante pour recevoir l'une des fibres de ladite pluralité de fibres (20), ou dans lequel ledit intervalle (85) présente une largeur radiale variable autour de l'axe dudit coupleur, dans lequel l'épaisseur de celui-ci à des positions azimutales également espacées est suffisante pour recevoir l'une des fibres de ladite pluralité de fibres (61, 69, 77, 84) mais dans lequel l'épaisseur dudit intervalle entre lesdites positions azimutales espacées est insuffisante pour recevoir l'une des fibres de ladite pluralité de fibres.
 5. Procédé selon la revendication 1 ou 2, dans lequel l'opération de disposer un tube extérieur consiste à disposer un tube (58) dont le passage contient une pluralité de saillies (60) également espacées sortant vers l'intérieur et orientées longitudinalement, et l'opération d'insérer ladite pluralité de fibres (61) comprend l'insertion d'une fibre de ladite pluralité de fibres dans ledit intervalle entre chacune desdites saillies et/ou dans lequel l'opération consistant à disposer un tube intérieur consiste à disposer un tube (65) de préférence avec une surface extérieure cylindrique, la surface extérieure de celui-ci contenant une pluralité de saillies également espacées sortant vers l'extérieur et orientées longitudinalement (66), et l'opération d'insertion de ladite pluralité de fibres (69) comprend l'insertion de l'une des fibres de ladite pluralité de fibres dans ledit intervalle entre chacune desdites saillies.
 6. Procédé selon la revendication 5, dans lequel ladite pluralité de fibres (20, 61, 69, 77, 84) comprend chaque fois une âme de verre entourée par un revêtement de verre ayant un indice de réfraction inférieur à celui de ladite âme de verre et dans lequel l'opération consistant à disposer un tube intérieur (10, 57, 65, 73, 80) consiste à disposer un tube formé d'un verre ayant une température de point de ramollissement inférieure à celle dudit revêtement de verre et ayant un indice de réfraction essentiellement égal à celui dudit revêtement de verre, et/ou dans lequel l'opération consistant à disposer un tube extérieur (13, 58, 67, 74, 82) consiste à disposer un tube formé d'un verre ayant un indice de réfraction inférieur à celui dudit revêtement de verre et formé de préférence d'un verre ayant une température de point de ramollissement inférieure à celle dudit tube intérieur.
 7. Procédé selon la revendication 5, dans lequel l'opération consistant à disposer un tube intérieur consiste à disposer un tube intérieur (10) qui est plus long que ledit tube extérieur (13), dans lequel l'opération d'insertion dudit tube intérieur dans le passage dudit tube extérieur permet d'obtenir un connecteur préformé dans lequel ladite deuxième extrémité dudit tube intérieur s'étend au-delà dudit tube extérieur, ledit procédé comprenant en outre l'opération d'assembler ladite pluralité de fibres (20) à la partie en saillie dudit tube intérieur.
 8. Procédé selon la revendication 7, dans lequel ladite pluralité de fibres de verre (20) est recouverte par des revêtements (22), ledit procédé comprenant en outre l'opération d'enlèvement, d'une extrémité de chaque fibre de ladite pluralité de fibres, d'une partie de son revêtement, et dans lequel l'opération d'insertion des extrémités d'une pluralité de fibres optiques dans ledit intervalle (16) donne lieu à la formation d'une préforme de coupleur (31) dans laquelle les parties revêtues de ladite pluralité de fibres se terminent au-delà de ladite deuxième extrémité dudit tube intérieur (10).
 9. Coupleur à fibres optiques comprenant :
un corps de verre allongé ayant une région centrale longitudinale massive (27) s'étendant entre les première et deuxième extrémités dudit corps, et des première et deuxième parties d'extrémité opposées s'étendant respectivement de ladite région centrale vers les première et deuxième extrémités dudit corps, ledit corps comprenant une région intérieure ayant une première composition de verre avec un indice de réfraction n_3 et une région extérieure avec une composition



de verre ayant un indice de réfraction n_4 , dans lequel n_4 est plus petit que n_3 ;

une première fibre optique en verre (19) et une pluralité de fibres optiques en verre (20), chacune desdites fibres optiques ayant une âme entourée par un revêtement ayant un indice de réfraction inférieur à celui de ladite âme;

ladite première fibre optique s'étendant axialement à travers ladite région intérieure dans la région centrale dudit corps et s'étendant au-delà de la première extrémité de celle-ci;

ladite pluralité de fibres s'étendant à travers la région centrale dudit corps et s'étendant au-delà de la deuxième extrémité de celui-ci, ladite pluralité de fibres étant située entre lesdites régions intérieure et extérieure dudit corps et étant espacée de manière essentiellement égale autour de ladite première fibre;

la partie centrale (51) de ladite région centrale ayant un diamètre plus petit que le diamètre du reste dudit corps de verre, les âmes desdites fibres optiques étant plus proches les unes des autres dans la partie centrale de ladite région centrale que dans le reste dudit corps de verre.

10. Coupleur selon la revendication 9, dans lequel l'indice de réfraction des revêtements de ladite pluralité de fibres (20) est approximativement égal à n_3 .

11. Coupleur selon la revendication 9, dans lequel chaque fibre de ladite pluralité de fibres (20) est en contact avec les deux fibres voisines de ladite pluralité de fibres.

12. Coupleur selon la revendication 9, 10 ou 11, dans lequel le verre de ladite région intérieure a une température de point de ramollissement inférieure à celle dudit verre du revêtement.

13. Coupleur selon les revendications 9 à 12, dans lequel la région intérieure dudit corps s'étend au-delà de la région extérieure dudit corps à ladite extrémité dudit corps.