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(71) Applicant
Corning Glass Works (USA-New York)
Corning, New York, N Y 14831, United States of America
(72) Inventor
Frederic J-Y Quan
(74) Agent and/or Address for Service
Elkington and Fife,
High Holborn House, 52/54 High Holborn, London
WC1V 6SH

(54) Optical waveguide splicing method and apparatus

(57) A method and an apparatus are disclosed for splicing optical waveguide fibre to achieve a splice with minimum attenuation. Light providing an alignment signal is injected through the cladding at 5 and into the core of a first end section (1) transmitted into the core of the second end section (2), and extracted, through the cladding (at 6), from, and monitored at, the second end section (2). Splicing is accomplished (using arc welding 8) after the ends have been moved (3, 4) to a position providing an intensity maximum (7) in the extracted signal. Light is injected into the first section and or extracted from the second section through portions of the fibre which are looped. (See Figs. 2-4 not shown).

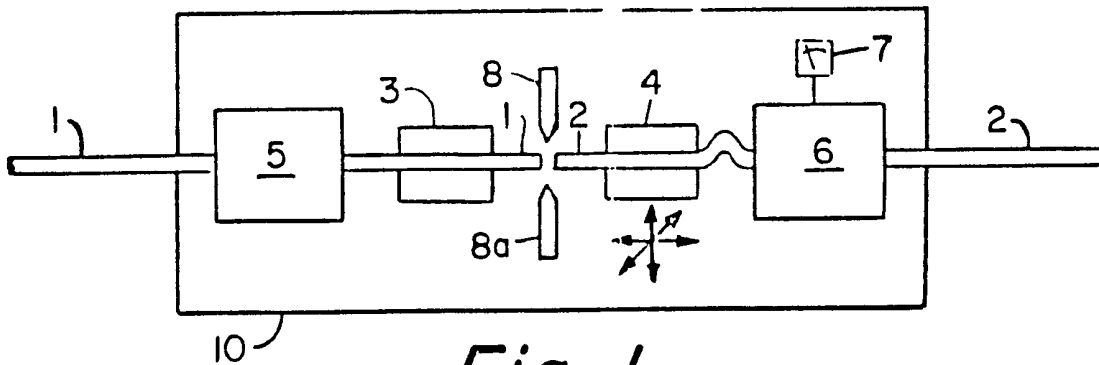


Fig. 1

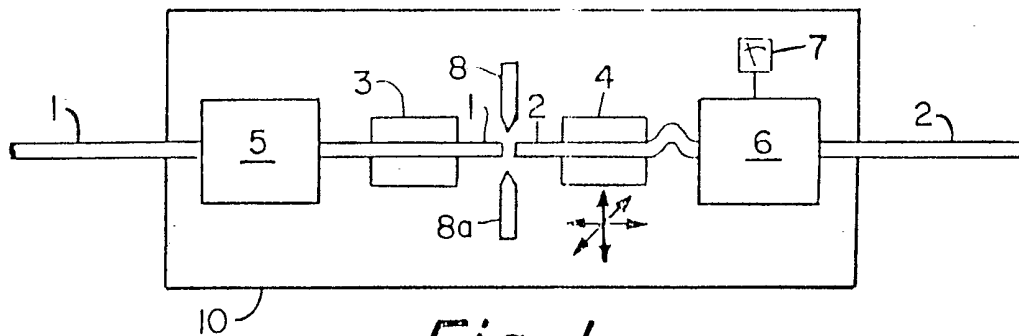


Fig. 1

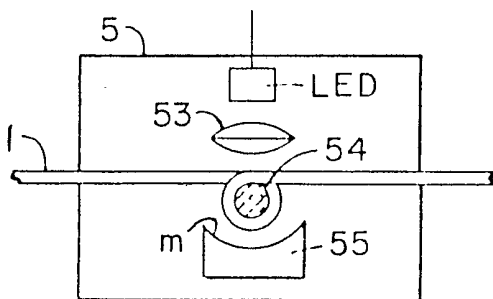


Fig. 2

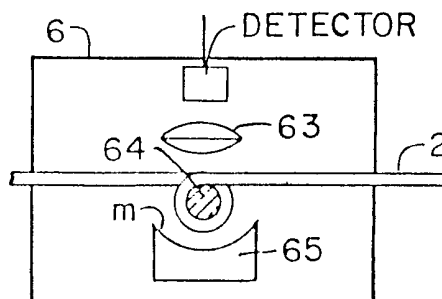


Fig. 3

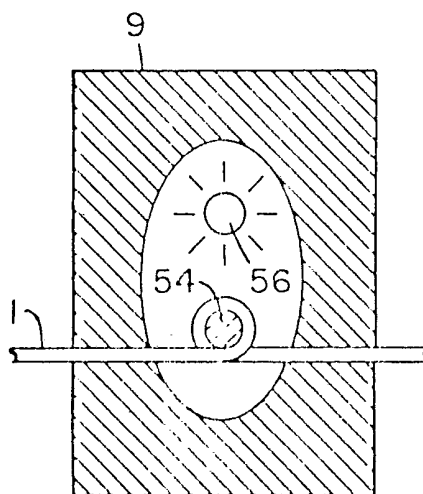


Fig. 4

SPECIFICATION

Optical waveguide splicing method and apparatus

5 This invention relates to a method and apparatus for forming permanent splices in optical waveguide fibre, more particularly to apparatus for forming such splices under field conditions where access to the distant ends of the fibre to be spliced is difficult.

10 A variety of mechanical bonding and glass fusion methods for splicing optical waveguide fibres, and apparatus for carrying out such methods, have been developed. One suitable technique involves an arc-fusion procedure wherein an electric arc is struck across adjacent ends of fibres to be spliced, to melt and permanently fuse the adjacent end sections.

15 U.S. Patent No. 3,960,531 discloses apparatus suitable for practising this method.

20 Exact alignment of the cores of the fibres to be fused is important if a low-loss splice is to be obtained. Field splicing apparatus is available wherein alignment of the fibre end faces can be checked by microscope examination of the joint, but this does not ensure optimum core alignment for minimum splicing-loss in cases where the fibre core is not centred in the waveguide. In addition, only one alignment plane at a time can be checked.

25 Variable-position connectors have been designed which are adjustable to maximize light transmission through the connection. U.S. Patent No. 3,800,388 shows a connector for use in an optical transmission line wherein the relative positions of the fibre ends can be changed and the optimum relative position of the fibre ends established by monitoring the intensity of light transmitted through the link. However, these do not provide a permanent joint and disadvantageously require access to at least one end of the link to introduce the test signal for alignment.

30 For the above reasons a need exists for optical waveguide splicing apparatus which is capable of being made in the form of a portable instrument which permits field splicing with optical monitoring to ensure optimum core alignment and without any need for peripheral supporting equipment or access to far ends of a cable or waveguide fibre being spliced.

35 In accordance with the invention there is provided a method of splicing first and second sections of optical waveguide fibre having a core and a cladding, which comprises the steps of:

40 (a) aligning the end portions of first and second fibre sections so that the axes thereof are substantially parallel and the end faces thereof are in close proximity;

45 (b) injecting light through the cladding and into the core of the first section at a position proximate to the end portion so that some of

the injected light propagates within the core, through the end face, and into the core of the second section;

50 (c) extracting at least a portion of the light propagating along the core of the second section through the cladding at a position proximate to the end portion thereof;

55 (d) sensing the relative intensity of the extracted light;

60 (e) changing the position of at least one end face relative to the other end face until a maximum in the relative intensity of the extracted light is sensed; and

65 (f) splicing the first and second sections together without changing the relative position of the end faces thereof.

The invention further provides an apparatus for splicing first and second sections of optical waveguide fibre having a core and a cladding, which comprises:

70 (a) first and second fibre retaining means for retaining end portions of the first and second sections, respectively, so that the axes of the sections are substantially parallel and the fibre end faces are in close proximity, at least one of said retaining means being movable such that the end face of its retained end portion can be moved relative to the end face of the other retained end portion;

75 (b) light injection means positioned adjacent the the first fibre retaining means, adapted to inject light through the cladding and into the core of the first section such that a portion of the injected light propagates within the core, through the end faces, and into the core of the second section;

80 (c) optical power tapping means positioned adjacent the second fibre retaining means, adapted to extract a portion of said light from the core through the cladding of the second section;

85 (d) photodetector means positioned adjacent the tapping means and adapted to sense the relative intensity of the extracted portion of light as a function of the relative position of the fibre end faces; and

90 (e) splicing means positioned adjacent the fibre end faces adapted to form a permanent junction between the end sections after a relative end face position producing an intensity maximum in the extracted portion of light is detected.

In the accompanying drawings:

95 Figure 1 is a schematic plan view of an apparatus in accordance with the invention;

100 Figure 2 schematically illustrates light injection means suitable for use in accordance with the invention;

105 Figure 3 schematically illustrates optical power tapping and sensing means provided in accordance with the invention; and

110 Figure 4 schematically illustrates alternative light injection means suitable for use in the invention.

115 Referring to Figure 1 of the drawings, an

apparatus 10 for splicing optical waveguide sections 1 and 2 includes first and second fibre retaining means 3 and 4, respectively, which holds the end portions of the fibre sections so that their end faces are in proximity. In the illustrative apparatus shown, retainer 4 may be micromanipulated in three dimensions, as indicated by the adjacent arrows, to move the end face of section 2 with respect to the other end face.

Adjacent to retainer 3 are light injection means 5 through which fibre section 1 is passed before attachment to the retainer. Within injection means 5 are a light source and a coupler to couple light from the source into the fibre as hereinafter more fully described.

Fibre section 2 passes through light monitoring enclosure 6 prior to engagement by movable retainer 4. Light monitoring enclosure 6 is adapted to prevent the ingress of light and includes both optical power tapping means and photodetector means as hereinafter more fully described. The output of the photodetector is fed to meter 7 which indicates the relative amount of light extracted from fibre section 2.

Apparatus 10 also comprises fibre splicing means which, in the embodiment shown, are arc electrodes 8 and 8a. These electrodes are conventionally connected to a high voltage power supply, not shown, and an electric arc can be struck across electrodes 8 and 8a as desired, thereby fusing the end faces of fibre sections 1 and 2 together for a permanent splice.

An example of a suitable arrangement for light injection means 5 is schematically shown in Figure 2. This means uses fibre bending to inject light into the fibre core. The fibre is bent to a radius such that light traversing the cladding and entering the fibre core at the point of bending will be trapped in the core and propagated down the fibre.

In Figure 2 the injection means comprises an LED light source and a lens 53 collimating light from the source and directing it toward reflector 55. Fibre section 1 is looped to form several turns around transparent rod 54 which is at the focus of reflector 55. Thus some light reflected from 55 enters the fibre and is propagated along the core toward the end face of the first section. Enclosure 5 is not essential in Figure 2 since ambient light does not interfere with the injection of light from the sources.

An alternative device for injecting light into the fibre is shown in Figure 4 of the drawing. In Figure 4 the injection means includes an enclosure 9 consisting of a hollow metallized plastic or metal block, e.g. of aluminium, forming an elliptical cavity. Fibre section 1 is looped to make several turns around a low refractive index transparent rod 54 which is positioned at one focus of the elliptical cavity,

and a point light source 56, e.g. an incandescent lamp, is positioned at the other focus. Thus light from source 56 is concentrated by reflection from the elliptical walls of the cavity onto the fibre section encircling rod 54, and is thereby injected into the fibre.

An example of a suitable arrangement for an optical power tap and the combination thereof with a photo-detector is schematically illustrated in Figure 3.

In the combination power tap and detector of Figure 3, fibre section 2 is wrapped several times around transparent rod 64 permitting light to escape the fibre core through the cladding. Some of the escaping light is reflected by reflector 65 and is focused by lens 63 onto the detector.

In the power tap-detector combination above described the detector can be a PIN diode, an avalanche photo-diode, a cadmium sulphide cell, a photo multiplier tube or other device, depending on the light wavelength to be sensed. If desired, the detector may be separate from the power tap but connected thereto by a conventional light guide.

In light injecting means such as shown in Figure 2 the LED light source can be replaced by other known light sources, for example incandescent or laser diode sources or the like, depending upon the configuration of the coupler used to couple light into the fibre core. Alternative coupling devices may also be substituted, both for light injection and light extraction, provided they are operative without breaking or damaging the fibre.

An enclosure for waveguide splicing apparatus provided according to the invention can contain additional equipment useful for fibre alignment and/or splicing, including a battery power supply for applying voltage to the light source of the apparatus. This battery might also supply high voltage to the fusion arc if a high efficiency inverter can be employed. Of course, provision may be made for connecting the apparatus to an external power source if desired. Similarly, a mechanism for applying an adhesive bonding substance between the fibre end faces may be substituted for the arc fusion system as the splicing means for the apparatus; although fusion splicing is clearly preferred.

A particularly advantageous feature of apparatus provided in accordance with the invention is that microscope-type optical systems for visually aligning the fibre ends to be spliced are not required. Once the relative position of the fibre retainers has been approximately fixed, micromanipulation thereof with reference to the detector output is sufficient to ensure low-loss splicing on a rapid and repeatable basis.

CLAIMS

1. A method of splicing first and second sections of optical waveguide fibre having a

core and a cladding, which comprises the steps of:

- 5 (a) aligning the end portions of first and second fibre sections so that the axes thereof are substantially parallel and the end faces thereof are in close proximity;
- 10 (b) injecting light through the cladding and into the core of the first section at a position proximate to the end portion so that some of the injected light propagates within the core, through the end face, and into the core of the second section;
- 15 (c) extracting at least a portion of the light propagating along the core of the second section through the cladding at a position proximate to the end portion thereof;
- 20 (d) sensing the relative intensity of the extracted light;
- 25 (e) changing the position of at least one end face relative to the other end face until a maximum in the relative intensity of the extracted light is sensed; and
- (f) splicing the first and second sections together without changing the relative position of the end faces thereof.
2. An apparatus for splicing first and second sections of optical waveguide fibre having a core and a cladding, which comprises:
- 30 (a) first and second fibre retaining means for retaining end portions of the first and second sections, respectively, so that the axes of the sections are substantially parallel and the fibre end faces are in close proximity, at least one of said retaining means being movable such that the end face of its retained end portion can be moved relative to the end face of the other retained end portion;
- 35 (b) light injection means positioned adjacent the first fibre retaining means, adapted to inject light through the cladding and into the core of the first section such that a portion of the injected light propagates within the core, through the end faces, and into the core of the second section;
- 40 (c) optical power tapping means positioned adjacent the second fibre retaining means, adapted to extract a portion of said light from the core through the cladding of the second section;
- 45 (d) photodetector means positioned adjacent the tapping means and adapted to sense the relative intensity of the extracted portion of light as a function of the relative position of the fibre end faces; and
- 50 (e) splicing means positioned adjacent the fibre end faces adapted to form a permanent junction between the end sections after a relative end face position producing an intensity maximum in the extracted portion of light is detected.
- 60

CLAIMS (22 Aug 84)

- 65 1. A method of splicing first and second sections of optical waveguide fibre having a core and a cladding, which comprises the

steps of:

- (a) aligning the end portions of first and second fibre sections so that the axes thereof are substantially parallel and the end faces thereof are in close proximity;
- 70 (b) injecting light through the cladding and into the core of the first section at a position where the first section is looped, the position being proximate to the end portion, so that some of the injected light propagates within the core, through the end face, and into the core of the second section;
- 75 (c) extracting at least a portion of the light propagating along the core of the second section through the cladding at a position proximate to the end portion thereof;
- 80 (d) sensing the relative intensity of the extracted light;
- 85 (e) changing the position of at least one end face relative to the other end face until a maximum in the relative intensity of the extracted light is sensed; and
- 90 (f) splicing the first and second sections together without changing the relative position of the end faces thereof.
2. A method of splicing first and second sections of optical waveguide fibre having a core and a cladding, which comprises the steps of:
- 95 (a) aligning the end portions of first and second fibre sections so that the axes thereof are substantially parallel and the end faces thereof are in close proximity;
- 100 (b) injecting light through the cladding and into the core of the first section at a position proximate to the end portion so that some of the injected light propagates within the core, through the end face, and into the core of the second section;
- 105 (c) extracting at least a portion of the light propagating along the core of the second section through the cladding at a position where the second section is looped, the position being proximate to the end portion thereof;
- 110 (d) sensing the relative intensity of the extracted light;
- 115 (e) changing the position of at least one end face relative to the other end face until a maximum in the relative intensity of the extracted light is sensed; and
- 120 (f) splicing the first and second sections together without changing the relative position of the end faces thereof.
3. A method of splicing first and second sections of optical waveguide fibre having a core and a cladding, which comprises the steps of:
- 125 (a) aligning the end portions of first and second fibre sections so that the axes thereof are substantially parallel and the end faces thereof are in close proximity;
- 130 (b) injecting light through the cladding and into the core of the first section at a position where the first section is looped, the position

being proximate to the end portion, so that some of the injected light propagates within the core, through the end face, and into the core of the second section;

5 (c) extracting at least a portion of the light propagating along the core of the second section through the cladding at a position where the second section is looped, the position being proximate to the end portion
10 thereof;

(d) sensing the relative intensity of the extracted light;

(e) changing the position of at least one end face relative to the other end face until a maximum in the relative intensity of the extracted light is sensed; and
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(f) splicing the first and second sections together without changing the relative position of the end faces thereof.

20 4. A method according to claim 1 or 3, wherein the first section is looped to form a plurality of turns.

5. A method according to claims 1, 3 or 4, wherein the first section is looped around a
25 transparent rod.

6. A method according to claim 5, wherein the transparent rod is at the focus of a reflector arranged to direct collimated light to the rod.

30 7. A method according to claim 5, wherein the transparent rod and a light source are located at respective foci of a reflective elliptical cavity.

8. A method according to claim 2 or 3, wherein the second section is looped to form a plurality of turns.

9. A method according to claim 2, 3 or 8, wherein the second section is looped around a transparent rod.

40 10. A method according to claim 9, wherein the transparent rod is at the focus of a reflector arranged to direct light extracted from the second section to a collimator.

45 11. A method of splicing first and second sections of optical waveguide fibre, substantially as herein described with reference to the accompanying drawings.

50 12. An apparatus for splicing first and second sections of optical waveguide fibre having a core and a cladding, which comprises:

(a) first and second fibre retaining means for retaining end portions of the first and second sections, respectively, so that the axes of the sections are substantially parallel and the fibre end faces are in close proximity, at least one of said retaining means being movable such that the end face of its retained end portion can be moved relative to the end face of the other retained end portion;

60 (b) light injection means positioned adjacent the first fibre retaining means and comprising means for constraining the first section to follow a looped path, and a light source corrugated to direct light to the looped path,
65 the injection means being adapted to inject

light through the cladding and into the core of the first section such that a portion of the injected light propagates within the core, through the end faces, and into the core of the second section,;

70 (c) optical power tapping means positioned adjacent the second fibre retaining means, adapted to extract a portion of said light from the core through the cladding of the second section;

75 (d) photodetector means positioned adjacent the tapping means and adapted to sense the relative intensity of the extracted portion of light as a function of the relative position of the fibre end faces; and
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(e) splicing means positioned adjacent the fibre end faces adapted to form a permanent junction between the end sections after a relative end face position producing an intensity maximum in the extracted portion of light is detected.
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13. An apparatus for splicing first and second sections of optical waveguide fibre having a core and a cladding, which comprises:

90 (a) first and second fibre retaining means for retaining end portions of the first and second sections, respectively, so that the axes of the sections are substantially parallel and the fibre end faces are in close proximity, at least one of said retaining means being movable such that the end face of its retained end portion can be moved relative to the end face of the other retained end portion;

(b) light injection means positioned adjacent the first fibre retaining means, adapted to inject light through the cladding and into the core of the first section such that a portion of the injected light propagates within the core, through the end faces, and into the core of the second section;

105 (c) optical power tapping means positioned adjacent the second fibre retaining means, the tapping means comprising means for constraining the second section to follow a looped path, the tapping means being adapted to extract a portion of said light from the core through the cladding of the second section;

(d) photodetector means positioned adjacent the tapping means and adapted to sense the relative intensity of the extracted portion of light as a function of the relative position of the fibre end faces; and
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(e) splicing means positioned adjacent the fibre end faces adapted to form a permanent junction between the end sections after a relative end face position producing an intensity maximum in the extracted portion of light is detected.

14. An apparatus for splicing first and second sections of optical waveguide fibre having a core and a cladding, which comprises:

(a) first and second fibre retaining means for retaining end portions of the first and second sections, respectively, so that the axes of the sections are substantially parallel and
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the fibre end faces are in close proximity, at least one of said retaining means being movable such that the end face of its retained end portion can be moved relative to the end face of the other retained end portion;

5 (b) light injection means positioned adjacent the first fibre retaining means, and comprising means for constraining the first section to follow a looped path, and a light source
10 arranged to direct light to the looped path, the injection means being adapted to inject light through the cladding and into the core of the first section such that a portion of the injected light propagates within the core, through the
15 end faces, and into the core of the second section;

(c) optical power tapping means positioned adjacent the second fibre retaining means, the tapping means comprising means for con-
20 straining the second section to follow a looped path, the tapping means being adapted to extract a portion of said light from the core through the cladding of the second section;

(d) photodetector means positioned adjacent
25 the tapping means and adapted to sense the relative intensity of the extracted portion of light as a function of the relative position of the fibre end faces; and

(e) splicing means positioned adjacent the
30 fibre end faces adapted to form a permanent junction between the end sections after a relative end face position producing an intensity maximum in the extracted portion of light is detected.

35 15. An apparatus according to claim 12 or 14, wherein the means for constraining the first section to follow a looped path is a transparent rod.

40 16. An apparatus according to claim 15, wherein the transparent rod is at the focus of a reflector arranged to direct collimated light to the rod.

45 17. An apparatus according to claim 15, wherein the transparent rod and the light source are located at respective foci of a reflective elliptical cavity.

50 18. An apparatus according to claim 13 or 14 wherein the means for constraining the second section to follow a looped path is a transparent rod.

55 19. An apparatus according to claim 18, wherein the transparent rod for constraining the second section is at the focus of a reflector arranged to direct light extracted from the second section to a collimator.

20. An apparatus for splicing first and second sections of optical waveguide fibre, substantially as herein described with reference to the accompanying drawings.