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PATENT SPECIFICATION

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(54) OPTICAL FIBRES

(71) We, N. V. PHILIPS GLOEILAMPENFABRIEKEN, a limited liability Company, organised and established under the laws of the Kingdom of the Netherlands, of Emmasingel 29, Eindhoven, the Netherlands, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a method of breaking optical fibre so that the optical fibre is suitable for use in optical communication systems, the method being of the type in which a fibre to be broken is fixed in position, and a part of the circumference of the fibre is scored with the aid of a scoring instrument, after which a predetermined axial tensile force is applied to the fibre and finally the fibre is broken at the location of the score.

Glass fibres destined for optical communication systems must comply with stringent requirements, so as to minimize losses at couplings between, for example, laser-fibre, fibre-fibre, and fibre-optical receiver. The end faces of the fibres, for example, need to have a surface of the highest optical surface quality; furthermore, the end faces, in particular those of monomode fibres, need to be perpendicular to the fibre axes to the highest possible degree.

Glass rods and glass fibres, scored and broken in accordance with one of the conventional methods, exhibit a characteristic morphology at the fracture surface, with a so-called mirror zone, mist zone, and hackle zone; the mirror zone is a fracture surface portion of optical surface quality adjacent to the score; the hackle zone is a fracture surface portion where the fracture has separated the specimen into at least three distinct pieces; the mist zone is a fracture surface portion formed by a transition between the mirror zone and hackle zone. This phenomenon is described comprehensively in the article by Johnson and Holloway: "On the Shape and Size of the Fracture Zones on Glass Fracture Surfaces" published in "Philosophical Magazine", No. 14, October 1966, pages 731 to 743.

For most applications in optical communication systems the entire fracture surface of the fibre must be constituted by a mirror zone, whilst in many cases stringent requirements are imposed on the perpendicular orientation of the fracture surface relative to the fibre axis.

From the previously cited publication a simple, empirical equation is known, which relates the shape and size of the mirror zone to the stress distribution over the cross-section of a fibre before the initiation of fracture. In this equation for a point P of the mirror boundary:

$$Z_p r^{1/2} = C [N/mm^{3/2}]$$

where Zp is the stress component expressed in N/mm^2, normal to the fracture plane of the local stress at a point P at the mirror boundary before fracture begins; *r* is the distance from the original of fracture to the point P; C is a material constant.

For example for lead glass C has a value of approximately 5.5, for soda lime glass 6.0 and for quartz (vitreous silica) glass 6.5.

In order to obtain a fracture surface solely having a mirror zone, each point P on the fracture surface should meet the requirement:

$$Zp.r^{1/2} < C [N/mm^{3/2}]$$

wherein Zp, r and C are defined as above.

Another limiting factor is that the value of Zp for an arbitrary point P should not decrease to zero or even become negative, because otherwise fracture will continue in a direction which is not perpendicular to the fibre axis. In that case a so-called lip may be produced at one of the fibre ends.

A method in accordance with the preamble is known from the article by

Gloge *et al*: "Optical Fibre End Preparation for Low-Loss Splices" published in the American Journal "The Bell System Technical Journal", Vol. 52, No. 9, November 1973, pages 1579 to 1588; in accordance with this known method a specific decreasing stress distribution over the cross-section of the fibre is obtained by bending the fibre over a convex surface in order to obtain a low value of Zp $r^{1/2}$ and thus to ensure that solely a mirror zone is produced on the fracture surface; fracture is then initiated by scoring the bent portion of the fibre at the location of maximum stress.

A disadvantage of this known method is that the perpendicular orientation of the fracture surface may be unsatisfactory and that a comparatively high stress of the order of magnitude of 250 N/mm² is required to initiate fracture. Moreover, the scoring instrument must be manipulated with care so as to minimize the disturbed area in the vicinity of the score.

One object of the present invention is to provide a method which enables one or more fibres to be broken in such a way that a substantially accurate and reproducible perpendicular orientation of the fracture surface is obtained and to enable a fracture surface which solely has a mirror zone as herein defined to be formed. Furthermore, fibres may be fractured of a diameter greater than previously attainable with the known method.

According to the present invention there is provided a method of breaking optical fibre so that the optical fibre is suitable for use in optical communication systems, wherein the fibre to be broken is fixed in position, the entire circumference of the fibre in a plane perpendicular to the fibre axis is then scored with the aid of a scoring instrument, after which a predetermined axial tensile force is applied to the fibre followed by breaking the fibre at the location of the score.

For the purpose of the invention the word, "score" is to be understood to mean any deformation of the fibre surface, such as, an incision obtained with for example a cutter, or other instrument to create an impression, or a hair crack etc.

The maximum diameter (Df) of a fibre which can be broken with a mirror zone across the entire fracture area is defined by the equation:

$$Zi.Df^{1/2}=C$$

where Zi is the stress necessary to initiate fracture. The value of Zi is generally higher than 250 N/mm² for fibres which have only been scored locally; consequently, the maximum diameter Df will have to be smaller than 100 μm.

It has been found that by scoring the fibre over the entire circumference, a smaller value of Zi suffices to initiate fracture, which value is approximately half the value of Zi in the case of local scoring of the fibre. Owing to the smaller value of Zi fibres with a larger diameter than attainable so far can be broken with the required accuracy; moreover, the fibre can be fixed less firmly so that the risk of damage is reduced.

Another significant advantage obtained by scoring the fibre over the entire circumference is that fracture is initiated over substantially the entire circumference, so that the distance over which the crack must propagate is smaller than in the case of local scoring and equals approximately half the fibre diameter; this limits the value of *r* resulting in low values of $Zp.r^{1/2}$ even for comparatively thick fibres.

Finally, circumferential scoring in a plane perpendicular to the fibre axis defines in the orientation of the plane of fracture; an accurate and reproducible perpendicular orientation therefore merely depends on the scoring accuracy and can thus be kept under control.

In one variant of the method in accordance with the invention the fibre and a scoring instrument with a straight cutting edge are positioned for scoring with their longitudinal axes perpendicular to each other and are subsequently moved relative to each other in such a way that a rolling movement of the fibre and the scoring instrument relative to each other, is obtained through a 360° angle, the fibre and the scoring element being pressed against each other with a predetermined pressure. Owing to this step circumferential scoring with the required accuracy is possible in a comparatively simple manner. For example by rolling the scoring instrument around the stationary fibre in a plane perpendicular to the fibre axis it is ensured that a continuous scoring path is obtained.

Equally satisfactory results can be obtained in a simpler manner is by rolling the fibre over a taut wire between two parallel surfaces. If the wire portion used for scribing becomes worn and/or is damaged, a new wire portion can easily be employed, thus maintaining good reproducibility of the scoring action.

The width of the score is determined by the diameter of the wire. The wire diameter may vary between a few μm and some tens of μm; preferably, the wire diameter should not exceed the fibre diameter.

In another variant of the method of the invention the fibre is rolled over the cutting edge of a sapphire cutter between two parallel surfaces. The sapphire cutter is less susceptible to wear than a wire and is not deformed, so that even after frequent use scoring can be effected with the required accuracy.

In a further variant of the method of the invention the fibre is axially passed through the opening of a diaphragm with a sharp inner edge and the fibre and the diaphragm are moved relative to each other so as to obtain an eccentric oscillating movement of the diaphragm and fibre relative to each other through a 360° angle, the fibre and the inner edge of the diaphragm being pressed against each other with a pressure of changing direction. This step enables a closed circumferential scoring of the fibre in a reproducible manner. However, the oscillating movement does not result in a kinematically pure rolling movement of the fibre and inner edge of the diaphagm. Nevertheless, if the diameters of the fibre and the diaphragm opening do not differ excessively from each other, this substantially yields a rolling movement of the fibre and the inner edge of the diaphragm opening. This variant ensures that during scoring the fibre is not subject to torsion, so that the fibre can be clamped in position in the immediate vicinity of the diaphragm.

Glass fibres broken with the method in accordance with the invention exhibit a mirror zone of optical surface quality across the entire area of fracture, with a smoothness better than 0.1 μm, whilst the fracture surface meets very stringent requirements in respect of the perpendicular orientation; deviations from the perpendicular orientation were not measurable. Equally satisfactory results were obtained with fibres having a diameter of 60 μm and with fibres having a diameter of 110 μm.

By way of illustration the invention will now be described in more detail with reference to the drawing. In the drawing:—

Figure 1 is a schematic side view of a device for carrying out a variant of the method in accordance with the invention,

Figure 2 is a front view of the device in accordance with the arrow A in Figure 1;

Figure 3 shows a part of the device on an enlarged scale;

Figure 4 schematically shows a device for carrying out another variant of the method in accordance with the invention,

Figure 5 shows a further variant of the method in accordance with the invention and

Figure 6 is a section along line VI—VI of Figure 5.

The device 1 shown in Figures 1, 2 and 3 comprises a base plate 3 to which a supporting block 5 and a guide 7 are secured. On the guide 7 a carrier 9 is journalled which is movable by means of a micrometer screw 11 and on which a supporting plate 13, preferably of glass, is disposed. The top surface 15 of the supporting plate serves as a supporting surface. A hold-down plate 17, preferably also of glass, is pivotably connected to the supporting block 5 by means of a hinge 19.

The lower surface 21 of the hold-down plate 17 serves as a pressure surface. In the carrier 9 and the supporting plate 13 a recess 25 is formed in which a sapphire cutter 27 is placed.

The cutting edge 29 of the sapphire cutter, which has an apex angle a of 90°, should be adjusted to the correct height. In view of the hardness of the sapphire cutter and the sharpness of the cutting edge a comparatively low pressure suffices for scoring a fibre and the cutting edge of the sapphire cutter need not project from the supporting surface 15. The sapphire cutter is adjusted so that the cutting edge 29 is substantially disposed in the plane of the supporting surface. As is shown in Figure 3 the hold-down plane 17 is raised for this purpose; on the supporting surface 15 a glass plate 31 is placed; a spring 33 urges the sapphire cutter 27 with the cutting edge 29 against the underside of the glass plate 31; the sapphire cutter 27 is fixed in this position by means of a screw 35 in a bore 37 of the carrier 9.

Circumferential scoring of a fibre 39 is effected as follows:

The fibre 39 is placed on the supporting surface 15 so that the axis X—X of the fibre is perpendicular to the longitudinal axis Y—Y of the cutting edge 29. For this purpose the fibre is clamped in position in two pairs of adjustable clamping blocks 41 on both sides of the carrier 9, in such a way that the fibre follows a straight line and is disposed in one horizontal plane. Subsequently the hold-down plate 17 is lowered. A predetermined pressure P is exerted on the hold-down plate, for example by means of a weight 43 which is movable on the hold-down plate. By means of the micrometer screw 11 the carrier 9 with the sapphire cutter 27 is moved in a direction parallel to the longitudinal axis of the cutting edge 29 and over a distance which at least equals the circumference of the fibre; owing to the rectilinear movement of the carrier 9 the fibre is rolled over the cutting edge 29 between the supporting surface 15 and the hold-down surface 21 in such a way that a closed, continuous score is formed on the circumference of the fibre. In view of the extremely small displacement the accompanying torsion of the fibre is negligible. After the weight 43 has been removed, a predetermined purely axial tensile force T is applied to the fibre 39 by displacement of one of the pairs of clamps

41, so that the fibre breaks at the location of the score.

As previously stated, the fibre may also be scored with the aid of a wire.

Figure 4 schematically shows a device 101 for implementing this variant of the method, elements which are identical to those of the device 1 bearing the same reference numerals. The device 101 also comprises a base plate 3, a supporting block 5, a guide 7, a micrometer screw 11, a carrier 109 with a supporting plate 113 and a hold-down plate 17 which is pivotably secured to the supporting block 5. In this device the carrier 109 and the supporting plate 113 need not have a recess and are solid. A wire 127 is arranged across the supporting plate 113; the wire must be of a wear-resistant material with a high degree of hardness, preferably tungsten. By means of weights 129 the wire is kept taut and is oriented so that the axis Z—Z of the wire is parallel to the direction of movement of the carrier 109.

For scoring a fibre 139 the previously described operations are carried out.

Figure 5 in side view and Figure 6 in cross-sectional view on the line VI—VI of Figure 5 show a device 201 which mainly comprises a diaphragm 203 with an opening 205 whose inner edge 227 takes the form of a cutting edge, and two pairs of clamps 241. The clamps and the diaphragm can describe an eccentric oscillating movement relative to each other. A fibre to be prepared bears the reference numeral 239. For circumferential scoring of the fibre 239 said fibre is fixed in the clamps 241 in such a way that the fibre is pressed against the cutting edge 227 with a predetermined force P. In the example shown the clamps with the fibre perform an oscillating movement in accordance with the arrow B relative to the stationary diaphram, so that the pressure P is continuously perpendicular to the tangent R—R of fibre and cutting edge. After a continuous circumferential score has thus been formed on the circumference of the fibre an axial tensile force T is applied to the fibre, for example by moving one of the pairs of clamps 241 in a direction perpendicular to the fibre axis.

During experiments soda lime glass fibres with a diameter of 110 μm were treated in accordance with the method described with reference to Figures 1 through 3; satisfactorily results were then obtained with a pressure $P=20.10^{-2}$N; the required tensile stress Zi in this case was only 125 N/mm^2.

Equally satisfactory results were obtained with the method in accordance with Figure 4; the fibres were of soda lime glass and also had a diameter of 110 μm, the pressure P was 50.10^{-2}N, the tensile stress Zi was also 125 N/mm^2. For equal values of the pressure P and the tensile stress Zi satisfactory fracture surfaces were obtained, both when using a tungsten wire with a diameter of 5 μm and a wire with a diameter of 25 μm.

WHAT WE CLAIM IS:—

1. A method of breaking optical fibre so that the optical fibre is suitable for use in optical communication systems, wherein the fibre to be broken is fixed in position, the entire circumference of the fibre in a plane perpendicular to the fibre axis is then scored with the aid of a scoring instrument, after which a predetermined axial tensile force is applied to the fibre followed by breaking the fibre at the location of the score.

2. A method as claimed in Claim 1, characterized in that the fibre and a scoring instrument with a straight cutting edge are positioned for scoring the fibre with their with their longitudinal axes perpendicular to each other and are subsequently moved relative to each other in such a way that a rolling movement of the fibre and the scoring instrument, relative to each other, is obtained through a 360° angle, the fibre and the scoring instrument being pressed against each other with a predetermined pressure.

3. A method as claimed in Claim 1 or 2, characterized in that the fibre is rolled over a taut wire between two parallel surfaces.

4. A method as claimed in Claim 3, characterized in that the wire has a diameter which at the most equals the diameter of the fibre to be broken.

5. A method as claimed in Claim 1 or 2, characterized in that the fibre is rolled over the cutting edge of a sapphire cutter between two parallel surfaces.

6. A method as claimed in Claim 1, characterized in that the fibre is axially passed through the opening of a diaphragm with a sharp inner edge and the fibre and the diaphragm are moved relative to each other so as to obtain an eccentric oscillating movement of the diaphragm and the fibre relative to each other through an angle of 360°, the fibre and the inner edge of the diaphragm being pressed against each other with a pressure of changing direction.

7. An optical fibre, which is suitable for use in optical communication systems, when prepared in accordance with the method as claimed in any of the Claims 1 to 6.

8. A method of breaking optical fibre substantially as hereinbefore described.

9. An apparatus for breaking optical fibre according to the method as claimed in any one of Claims 1 to 6 substantially as hereinbefore described with reference to Figures 1 to 6 of the accompanying drawings.

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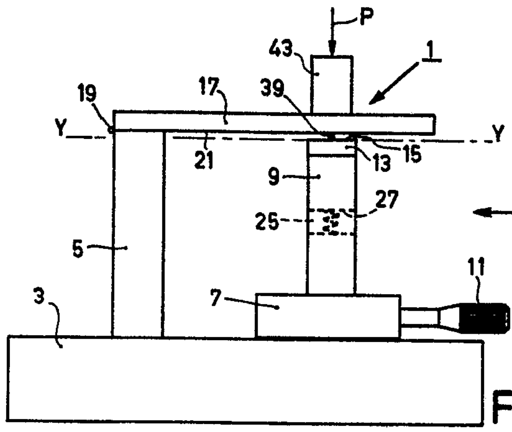
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19
17
39
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15
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25
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11
7
3

Fig.1

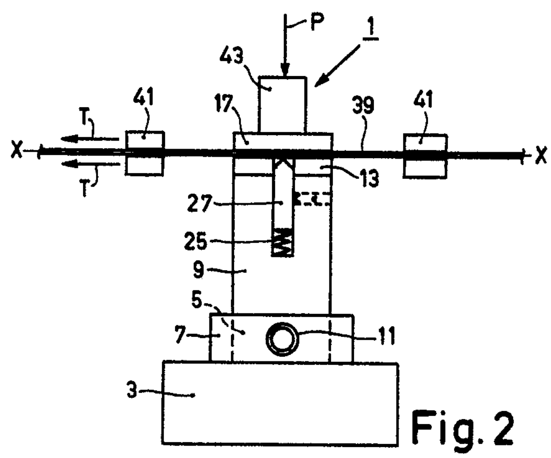
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Fig.2

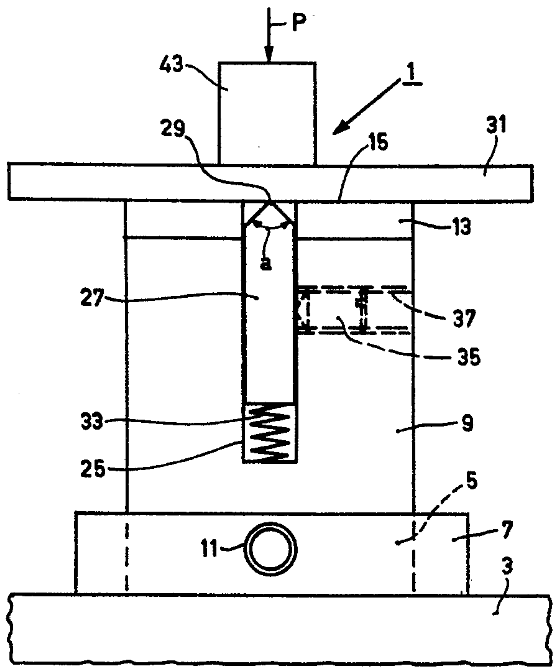
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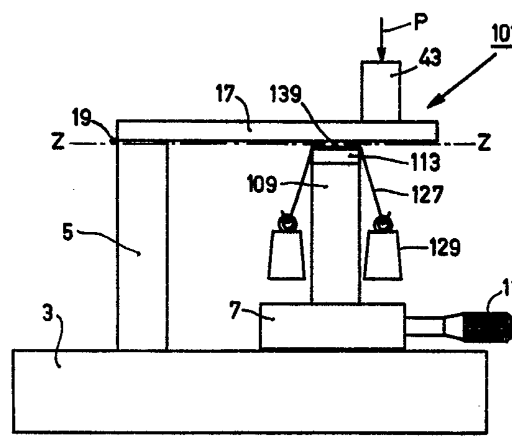
Fig.3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139
19
Z
Z
113
109
127
5
129
11
7
3

Fig. 4

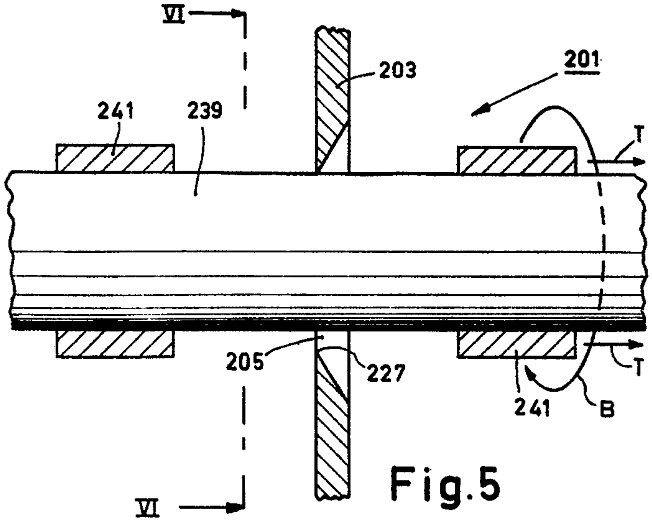
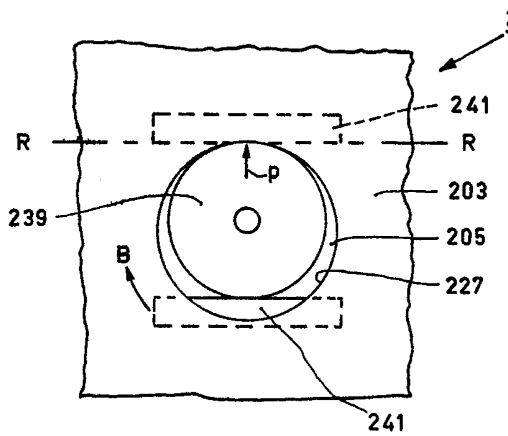

VI
VI
203
201
241
239
T
205
227
T
241
B

Fig.5


201
241
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239
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205
B
227
241

Fig.6