

Description

This invention relates to a connector mounted on an end of an optical fiber for transmitting a high energy beam, such as a laser beam, used for industries such as welding and soldering and for medical treatment such as cutting out affected parts.

Generally, on the incident and outgoing ends of optical fiber used for transmitting this kind of high energy laser beam are mounted connector plugs respectively so that the plugs are adapted to connect with receptacles one of which is at the incident end and contains a lens attached to a laser system and other of which at the outgoing end contains a lens opposite to an object to be processed.

Such a plug of the conventional connector for the high energy beam is constructed as follows: Fig. 1 is a sectional view exemplary of a plug at the incident end side of the conventional connector for the high energy beam and Fig. 2 is a front view exemplary of the plug when viewed on the line II - II in the direction of the arrow in Fig. 1, in which reference numeral 1 designates a cable containing therein a single optical fiber 1a, 2 designates a plug, and 3 designates a receptacle containing a lens 3a therein.

The cable 1 is cut out at a sheath 1b of polyvinylchloride (P.V.C.), a Kevlar (trade mark of Dupont) 1c, and a jacket 1d of nylon to expose the Kevlar 1c, jacket 1d and an optical fiber 1a in a desired length, so that a plug body 21 is sleeved across an axially intermediate portion of the bared optical fiber 1a and the end of the bared jacket 1d.

The plug body 21 is made from stainless steel, formed in a cylindrical shape, provided at the outer periphery of an axially intermediate portion with a flange 21a, sleeved across the bared optical fiber 1a and jacket 1d, and fixed concentrically and integrally to the optical fiber 1a and jacket 1d through epoxy resin 21b filled between the inner periphery of body 21 and the outer periphery of optical fiber 1a. The bared Kevlar 1c covers the outer periphery of the end of plug body 21, and a skirt member 22 of stainless steel is sleeved on the sheath 1b and the end of plug body 21 so that the Kevlar 1c is sandwiched between the skirt member 22 and the outer periphery of the plug body 21 and fixed integrally thereto through a binder. In addition, reference numeral 23 designates a cap nut, which is screwably tightened to the outer periphery of the receptacle 3 in condition of inserting therein the utmost end portion of plug body 21, thereby insertably holding the plug body 21 to the receptacle 3.

Such conventional optical fiber connector, as shown in Fig. 2, exposes at the utmost end face of the plug 2 the epoxy resin 21b which concentrically integrally fixes the optical fiber 1a and plug body 21. Hence, when the laser system, lens 3a and optical fiber 1a are insufficient in alignment, the laser beam

shifts from the incident end face at the optical fiber 1a so as to be projected on the epoxy resin 21b, whereby there is a fear that the epoxy resin 21b burns to cause an escape or damage of the plug.

For a countermeasure for the above, an optical connector for the high energy beam has already been disclosed in the Japanese Utility Model Application No. 59-20148 (1984) by the inventors of the present invention, the optical connector being so constructed that the plug body 21 is divided into a holder and a sleeve and combustibles are eliminated from the vicinity of the laser beam incident end face of the sleeve supporting the fore end of optical fiber, so that even when the incident laser beam shifts, the plug can be prevented from being damaged.

Fig. 3 is a partially cutaway side view of the connector disclosed in the above application and Fig. 4 is a schematic front view of the connector when viewed on the line IV - IV in the direction of the arrow in Fig. 3, in which reference numeral 31 designates a skirt member, 32 designates a holder, 33 designates a sleeve, and 34 designates a cap nut.

The sleeve 33 is cylindrical and made from copper, has at an axially intermediate portion an optical fiber support portion 33a of an inner diameter about equal to a diameter of the optical fiber 1a, has both axial end portions somewhat larger in an inner diameter than the optical fiber support portion 33a, and screws at a screw thread 33b formed at the inner periphery of the end with an utmost end of the holder 32 so that the sleeve 33 is connected thereto. The optical fiber 1a is held by the skirt member 31, holder 32, and optical fiber support portion 33a at the intermediate portion of sleeve 33, and level at the utmost end face with the front end face of sleeve 33. In such construction, an annular gap 33c having a desired axial length from the end of optical fiber 1a is formed between the sleeve 33 and the optical fiber 1a. Accordingly, even when the laser beam is incident shifting from the end face of optical fiber 1a, since there are no combustibles around the optical fiber 1a, the inconvenience of burning the connector can be prevented.

The optical connector constructed as foregoing, however, allows the laser beam shifting from the end face of optical fiber 1a to be incident through the aforesaid gap 33c on the outer periphery of optical fiber 1a or the inner periphery of the larger diameter portion at the fore end of sleeve 33. When the laser beam is incident on the outer periphery of optical fiber 1a, some fusion is created on the same, but leads to less breakage. However, when the laser beam is incident on the inner periphery of sleeve 33, copper of material for the sleeve 33 is molten and scattered to strike the outer periphery of optical fiber 1a, thereby creating the problem in that the optical fiber 1a may be cracked on the outer periphery so as to be breakable.

In the light of the above circumstances, this in-

vention has been designed.

A first object of the invention is to provide a connector for high energy beam of high quality and high reliability and free from a breakage when in use.

A second object of the invention is to provide a connector for high energy beam, which eliminates organic substances from around the laser beam incident portion as to have no fear of burning.

A third object of the invention is to provide a connector for high energy beam, which has no fear of melting and scattering metallic material at the laser beam incident portion.

A fourth object of the invention is to provide a connector for high energy beam, which has no fear that the optical fiber is broken at a junction between a plug and a receptacle.

A fifth object of the invention is to provide a connector for high energy beam, which is easy to adjust an incident angle of the beam when the plug is coupled with the receptacle.

A sixth object of the invention is to provide a connector for high energy beam, which can be small-sized and lightweight as a whole.

An object of a preferred embodiment of the invention is to provide a connector for high energy beam, which uses a transparent member or a translucent member, processed to give roughened surface to absorb or diffuse the laser beam shifting from the end face of optical fiber, thereby avoiding burning or breakage of the connector.

Another object of a preferred embodiment of the invention is to provide a connector for high energy beam, which allows the laser beam shifting from the end face of the optical fiber to reflect in the direction of moving away from the periphery of the optical fiber, thereby avoiding breakage of the optical fiber.

According to the present invention there is provided a connector for an optical fibre which can transmit a high energy beam, namely an optical fibre of a diameter of 150 μ m to 1250 μ m, the connector to be provided at the end of an optical fibre on which said high energy beam is to be incident, the connector comprising a sleeve with:

- a) a portion of relatively large inner diameter; and
- b) a fibre support portion;

whereby the sleeve can in use be fitted on the end of said optical fibre so that a gap is formed between the inner periphery of said portion of relatively large inner diameter of the sleeve and the outer periphery of said optical fibre along a desired axial distance from the end face of said optical fibre to the fibre support portion and so that said optical fibre support portion supports the optical fibre and has an inner diameter which is about equal to the diameter of the optical fibre, the connector being characterised in that at least said optical fibre support portion is formed of sapphire which has a melting point of 2030°C, a refractive index of 1.76 and which has a transmission such that

it transmits therethrough more than 5% of the incident light in a 1mm transmission distance.

The above and further objects and features of the invention will more fully be apparent from the following detailed description with reference to accompanying drawings.

Fig. 1 is a partially cutaway structural side view of a conventional optical connector,

Fig. 2 is a front view of the connector when viewed on the line II - II in Fig. 1,

Fig. 3 is a partially cutaway structural side view of the conventional optical connector having a sleeve,

Fig. 4 is a front view of the connector when viewed on the line IV - IV in Fig. 3,

Fig. 5 is a partially cutaway structural side view of a first embodiment of a connector for high energy beam of the invention.

Fig. 6 is a sectional side view of a sleeve at the first embodiment of the invention in Fig. 5, and Figs. 7 through 12 are sectional structural side views of sleeves of the second to the seventh embodiments of the invention.

Next, embodiments of a connector for high energy beam of the invention will concretely be described in accordance with the drawings.

Referring to Figs. 5 and 6, reference numeral 1 designates a cable containing therein a single core optical fiber 1a, 2 designates a plug, and 5 designates a receptacle.

The cable 1 is cut out at a sheath 1b of polyvinyl-chloride (P.V.C.), a Kevlar 1c and a jacket 1d of nylon, so that the jacket 1d, Kevlar 1c and optical fiber 1a are bared each in a desired length. A holder 41 is fixedly sleeved across an axially intermediate portion of the bared portion of optical fiber 1a and the end of the bared portion of jacket 1d, a skirt member 42 is fixed across the end of the holder 41 and the outer periphery of the utmost end of sheath 1b, a sleeve 43 is fixed across the utmost end of the bared portion of optical fiber 1a and the utmost end of holder 41, and a cap nut 44 is axially movably sleeved across the holder 41, skirt member 42 and sleeve 43.

The holder 41 is made from brass, formed in a cylinder whose inner diameter is slightly larger than a diameter of jacket 1d, reduced in an outer diameter at the end to form a shoulder 41b, provided at the outer periphery near the utmost end with a larger diameter flange 41a and at the outer periphery ahead of the flange 41a with a screw thread 41c. Also, the holder 41 is sleeved across near the end portion of the bared portion of jacket 1d and an intermediate portion of the bared portion of optical fiber 1a and covered at the outer periphery of the smaller outer diameter portion of the end with the bared Kevlar 1c.

Between the inner periphery of the holder 41 and the outer periphery of the optical fiber 1a is interposed a metallic sleeve 41d in relation of abutting at

the end against the utmost end of jacket 1d and of somewhat projecting at the utmost end from the fore end of holder 41. Epoxy series binders 41e and 41f are filled between the metallic sleeve 41d and the inner periphery of holder 41, and the metallic sleeve 41d and the outer periphery of optical fiber 1a, the holder 41 being concentrically and integrally bonded with the optical fiber 1a through the binders 41e and 41f and metallic sleeve 41d.

The skirt member 42 is made from brass as the same as the holder 41, formed in a cylindrical shape of an inner diameter of the portion other than the fore end, slightly larger than an outer diameter of the reduced diameter portion at the end of holder 41, and sleeved across the outer periphery of the fore end of sheath 1b and that of the end of holder 41 covered by the Kevlar 1c. The outer periphery of the end of holder 41 covered by the Kevlar 1c, the inner periphery thereof, and the inner periphery of the fore end of skirt member 42, are coated with a binder, so that the fore end portion of skirt member 42 and the end of holder 41 sandwich therebetween the Kevlar 1c, the three members being fixed integrally with each other by the binder.

The sleeve 43 is cylindrical, has at an axially intermediate portion an optical fiber support portion 43f of an inner diameter equal to or slightly larger than a diameter of optical fiber 1a, formed at both axial sides of the support portion 43f to be somewhat larger in an inner diameter than the optical fiber support portion 43f so as to form gaps 43c and 43d between the inner peripheries of sleeve 43 and the outer periphery of optical fiber 1a, and provided at the inner periphery of the end with a screw thread 43a. The screw thread 43a is coated with a binder and screws with the screw thread 41c at the fore end of holder 41, thereby connecting the sleeve 43 concentrically and integrally with the fore end of holder 41 in condition of being sleeved on the optical fiber 1a.

In addition, the sleeve 43, as enlarged in Fig. 6, is formed at the optical fiber support portion 43f only of sapphire and press-fitted into the depth of gap 43c and other portions are made from copper as in the conventional connector shown in Fig. 3. In Fig. 6, reference numeral 43g designates a positioning stopper for optical fiber support portion 43f when fitted into the sleeve 43.

The Sapphire has a melting point of 2030°C and a refractive index of 1.76 regardless of it being natural or synthetic and has a refractive index higher than that of the cladding of the optical fibre. The connector using sapphire of the invention was mounted on quartz series optical fiber of a core diameter of 400µm and a clad diameter of 500µm and applied with pulse of 20J, 8 millisec and 5 pps for one minute in condition of delaying an incident axis by 30' (minutes), but no trouble was not found. However, even in the same condition as the above, the use of molten quartz of

the melting point at 1710°C and refractive index of 1.45 heated the connector, and that of silver chloride of the refractive index of 1.9 and the melting point at 457°C vaporized.

Incidentally, Sapphire needs only transmit 5 % or more of the quantity of the incident light in a transmission distance of 1 mm.

Also, Sapphire has a coefficient of thermal expansion near to that of glass. The desirability of this is that otherwise the optical fiber support portion 43f thermally expands to press hard the optical fiber 1a and give it stress, whereby the microbending loss (deterioration in the light transmission efficiency by the stress applied to the optical fiber) is created, and if the microbends further are repeated, the optical fiber may be damaged.

The optical fiber 1a is 150 to 1250µm in diameter, projects from the utmost end of metallic sleeve 41d into the sleeve 43, passes through a bore 43b provided at inside of the optical fiber support portion 43f of the sleeve 43 and having a diameter about equal to that of the optical fiber, and positioned at the end at the incident side concentrically with the sleeve 43 and to be level with the utmost end face thereof. The gaps 43c and 43d formed between the end of sleeve 43 and the inner periphery thereof and the outer periphery of optical fiber 1a, contain air only and any combustible, for example, an organic material does not at all exist in the gaps 43c and 43d.

The reason for keeping the end face of optical fiber 1a level with the utmost end face of sleeve 43 is that when the optical fiber 1a projects at its end face from the utmost end face of sleeve 43, there is a fear of breaking the optical fiber 1a, and when the end face thereof is recessed, it is difficult to clean the same. Hence, the end face of optical fiber 1a is preferably, but not necessarily, level with the utmost end face of sleeve 43.

The cap nut 44 is made of stainless steel or brass and provided at the inner periphery of the fore end portion with a screw thread 44a tightly screwable with a screw thread 5b formed at the outer periphery of receptacle 5 at the laser beam outgoing side and at the inner periphery near the rear end with an inner flange 44b of an inner diameter smaller than a diameter of the flange 41a at the holder 41. A coil spring 45 is interposed between the inner flange 44b and the flange 41a at the holder 41 and biases the cap nut 44 to move away from the receptacle 5.

The receptacle 5 is made cylindrical as the same as the conventional one shown in Figs. 1 and 3 and contains a lens 5a fixed to face the laser beam outlet at a laser system (not shown).

In the connector for the high energy beam of the invention constructed foregoing, the laser beam output from the laser system (not shown) is incident on the lens 5a as shown by the unshaded arrow in Fig. 5 so as to be converged and thereafter is incident on

the end face of optical fiber 1a to thereby be propagated therein. In this case, even when the laser beam is incident on the position out of the end face of optical fiber 1a, the gap 43c therearound contains air only, whereby the air of course does not burn. Also, even when the laser beam is incident on the inner periphery of the fore end portion of sleeve 43, the inner periphery is high in heat resistance not to be molten or vaporized.

With the optical fiber support portion 43f being sapphire the laser beam incident on the optical fiber support portion 43f is transmitted through the optical fiber support portion 43f while being attenuated, is reflected by the stopper 43g made by metal and then just a little laser beam travels toward the rear gap 43d, thereby not heating the optical fiber 1a up to a high temperature at the rear gap 43d side. Also, it is hard for the laser beam incident on the optical fiber support portion 43f to enter the optical fiber 1a because sapphire constituting the optical fiber support portion 43f has a refractive index higher than that of the cladding of optical fiber 1a. Furthermore, the laser beam incident on the clad at the utmost end of optical fiber 1a, or entering from the core to the clad, easily enters the optical fiber support portion 43f higher in refractive index than the cladding so that no laser beam transmits through the cladding of optical fiber 1a to the rear gap 43d, thereby restricting a temperature rise thereof.

The connector for high energy beam of the invention constructed as shown in Fig. 5 and using sapphire of refractive index of 1.76, was mounted on the incident end of a step index type quartz series optical fiber of a core diameter of 400 μ m and a clad diameter of 500 μ m and radiated by several tens of thousand pulses the YAG laser beam of pulse width of 8 m sec and output of 20J. As a result, there has not at all occurred a breakage fault in the optical fiber and also even when the incident axis shifts at an angle of 14 to 15°, the connector of the invention has not been broken. Incidentally, the conventional connector shown in Fig. 1 has at once been unusable, and that shown in Fig. 3, only when shifted by at an angle of 20 to 30°, leads to a breakage of optical fiber.

Figs. 7 and 8 are sectional side views of sleeves 43 in second and third embodiments of the invention.

In the second embodiment in Fig. 7, the optical fiber support portion 43f of the sleeve 43 and the inner peripheral portion thereof facing the gap 43c at the fore end side of optical fiber 1a are formed of sapphire, other portions of sleeve 43 being made from copper as in the first embodiment. The above portion of sapphire is press-fitted into the copper-made portion and positioned by a stopper 43g provided at the sleeve 43 as the same as the first embodiment.

In the third embodiment in Fig. 8, the optical fiber support portion 43f only is formed of sapphire and is subjected to roughened surface processing at the

outer periphery and end surface in contact with the inner periphery of the copper portion of sleeve 43 and with the stopper 43g, thereby forming the diffusing surfaces respectively.

Next, explanation will be given on the particular effects of the second and third embodiments as follows:

In the second embodiment in Fig. 7, even when the laser beam is incident on the inner periphery facing the front gap 43c, the inner periphery is formed of the heat resistant inorganic substance, thereby creating no fusion on the inner periphery.

In the third embodiment in Fig. 8, the laser beam intended to transmit the optical fiber support portion 43 toward the holder 41, or transmit other copper-made portions, is irregularly reflected or diffused by the diffusion surfaces 43h to expect energy attenuation, whereby there is no fear of heating the optical fiber 1a and stopper 43g and so on at a high temperature.

Fig. 9 is a sectional side view of a sleeve 43 in a fourth embodiment of the invention, in which whole of the sleeve 43 is formed of sapphire and other portions are the same in construction as the sleeve 43 in the first embodiment (refer to Fig. 5).

Incidentally, the sleeve 43 in this embodiment can be molded integrally by use of the opaque substance, especially Al_2O_3 , SiC, $3\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$, of the so-called fine ceramics, thereby enabling mass production in a low manufacturing cost.

Fig. 10 is a sectional side view of a sleeve 43 in a fifth embodiment of the invention, which as a whole is formed integrally of sapphire as in the fourth embodiment, but differs therefrom in that the fore end of the optical fiber support portion 43f, i.e., the end face 43e at the laser beam incident side, of the sleeve 43 is tapered at an angle Θ like a truncated cone whose diameter at the end side face of the optical fiber 1a is smallest, the angle Θ of inclination being desirable to be set to satisfy the following equation:

$$\Theta \leq 90^\circ - \arctan(a/b),$$

where

- a: a half of a difference between the inner diameter of the sleeve 43 and the diameter of the optical fiber, and
- b: a distance between the fore end face of the sleeve 43 and the end face 43b of the optical fiber support portion 43f.

Upon satisfying the above equation, an incident angle Θ of the laser beam being out of the utmost end of optical fiber 1a is 90° or more even when the smallest, with respect to end face 43e.

Also, in the fifth embodiment in Fig. 10, the laser beam incident on the end face 43e of the optical fiber support portion 43f is reflected toward the inner periphery of sleeve 43 facing the gap 43c, thereby avoiding inconvenience of fusing the optical fiber 1a.

In addition, the sleeve 43 in this embodiment, when formed of the fine ceramics, is easy to mold in-

tegrally as the same as the fourth embodiment.

Alternatively, the sleeve 43 in the fourth embodiment may be formed itself only of copper as the same as the conventional one and be coated on the inner periphery facing the front gap 43c with a high heat resistant inorganic substance, or a cylinder thereof may be fitted into the sleeve 43.

Fig. 11 is a sectional side view of a sleeve 43 in a sixth embodiment of the invention, in which the sleeve 43, as a whole, including the supporting portion 43f is formed of copper as in a conventional one and provided at the fore end face of the supporting portion 43f with a fibre support portion 46 in the form of a chip formed of sapphire, the chip 46 being formed in a cylindrical shape of an inner diameter about equal to a diameter of optical fiber 1a and insertably fixed in the front gap 43c in condition of abutting against the end face 43e of the optical fiber support portion 43f.

Also, the chip 46, as in the fourth embodiment (refer to Fig. 9), is tapered like a truncated cone whose diameter at the end side face of the optical fiber 1a is smallest, thereby forming an inclined surface 46a (at an angle Θ). The angle Θ of inclination, when formed to satisfy the same condition as that in the fourth embodiment, will demonstrate the same effect as the above.

Fig. 12 is a sectional side view of a sleeve 43 in a seventh embodiment of the invention, which is the same in basic construction as the sixth embodiment in Fig. 11, but differs therefrom in that the fibre support portion or chip 46 is not tapered at the overall end face at the front side, but only at about a half of the front end face to thereby form an inclined surface 46a' at an angle Θ of inclination. The angle Θ of inclination of the tapered surface 46a', when set in the same condition as the fourth and sixth embodiments, will demonstrate about the same effect as the above embodiments.

In addition, it is of course possible in the sixth and seventh embodiments not to form the inclined surface 46a or 46a' at the front end face of the chip 46 of high heat resistant inorganic substance at the laser beam incident side.

Furthermore, in the sixth and seventh embodiments of the invention in Figs. 11 and 12, a plug having a sleeve set to be a: 0.75 mm, b: 3mm and $\Theta = 76^\circ$, was mounted on the incident end of the step index type quartz series optical fiber of core diameter 400 μ m and clad diameter of 500 μ m and radiated with the YAG laser beam of pulse width of 8 ms and output 20J in several tens of thousands pulses, resulting in no breakage on the optical fiber.

The scope of the invention is defined by the appended claims rather than by the description preceding them.

Claims

1. A connector for an optical fibre which can transmit a high energy beam, namely an optical fibre of a diameter of 150 μ m to 1250 μ m, the connector to be provided at the end of an optical fibre (1a) on which said high energy beam is to be incident, the connector comprising a sleeve (43) with:
 - a) a portion of relatively large inner diameter; and
 - b) a fibre support portion (43f, 46);
 whereby the sleeve can, in use, be fitted on the end of said optical fibre (1a) so that a gap (43c, 43d) is formed between the inner periphery of said portion of relatively large inner diameter of the sleeve (43) and the outer periphery of said optical fibre (1a) along a desired axial distance from the end face of said optical fibre (1a) to the fibre support portion (43f, 46), and so that said optical fibre support portion (43f, 46) supports the optical fibre (1a) and has an inner diameter which is about equal to the diameter of the optical fibre, the connector being characterised in that at least said optical fibre support portion (43f, 46) is formed of sapphire which has a melting point of 2030°C, a refractive index of 1.76 and which has a transmission such that it transmits there-through more than 5% of the incident light in a 1mm transmission distance.
2. A connector as set forth in Claim 1, wherein an end face of said optical fibre support portion (43f) at the high energy beam outgoing side is roughened by surface-processing so as to make the high energy beam reflect irregularly from said end face.
3. A connector as set forth in Claim 1, wherein said optical fibre support portion (43f, 46) is tapered at an end face (46a) thereof facing said gap like a truncated cone which tapers in a direction towards the end face of said optical fibre (1a).
4. A connector as set forth in Claim 3, wherein an angle Θ of inclination of said tapered face (46a) satisfies the following equation:

$$\Theta \leq 90^\circ - \arctan a/b$$
 where
 - a: half of the difference between the inner diameter of said portion of relatively large inner diameter of the sleeve (43) and the inner diameter of said optical fibre support portion (43f, 46) and
 - b: the distance from the utmost end face of said sleeve (43) to the end face of said optical fibre support portion (43f, 46).

tegrally as the same as the fourth embodiment.

Alternatively, the sleeve 43 in the fourth embodiment may be formed itself only of copper as the same as the conventional one and be coated on the inner periphery facing the front gap 43c with a high heat resistant inorganic substance, or a cylinder thereof may be fitted into the sleeve 43.

Fig. 11 is a sectional side view of a sleeve 43 in a sixth embodiment of the invention, in which the sleeve 43, as a whole, including the supporting portion 43f is formed of copper as in a conventional one and provided at the fore end face of the supporting portion 43f with a fibre support portion 46 in the form of a chip formed of sapphire, the chip 46 being formed in a cylindrical shape of an inner diameter about equal to a diameter of optical fiber 1a and insertably fixed in the front gap 43c in condition of abutting against the end face 43e of the optical fiber support portion 43f.

Also, the chip 46, as in the fourth embodiment (refer to Fig. 9), is tapered like a truncated cone whose diameter at the end side face of the optical fiber 1a is smallest, thereby forming an inclined surface 46a (at an angle Θ). The angle Θ of inclination, when formed to satisfy the same condition as that in the fourth embodiment, will demonstrate the same effect as the above.

Fig. 12 is a sectional side view of a sleeve 43 in a seventh embodiment of the invention, which is the same in basic construction as the sixth embodiment in Fig. 11, but differs therefrom in that the fibre support portion or chip 46 is not tapered at the overall end face at the front side, but only at about a half of the front end face to thereby form an inclined surface 46a' at an angle Θ of inclination. The angle Θ of inclination of the tapered surface 46a', when set in the same condition as the fourth and sixth embodiments, will demonstrate about the same effect as the above embodiments.

In addition, it is of course possible in the sixth and seventh embodiments not to form the inclined surface 46a or 46a' at the front end face of the chip 46 of high heat resistant inorganic substance at the laser beam incident side.

Furthermore, in the sixth and seventh embodiments of the invention in Figs. 11 and 12, a plug having a sleeve set to be a: 0.75 mm, b: 3mm and $\Theta = 76^\circ$, was mounted on the incident end of the step index type quartz series optical fiber of core diameter 400 μ m and clad diameter of 500 μ m and radiated with the YAG laser beam of pulse width of 8 ms and output 20J in several tens of thousands pulses, resulting in no breakage on the optical fiber.

The scope of the invention is defined by the appended claims rather than by the description preceding them.

Claims

1. A connector for an optical fibre which can transmit a high energy beam, namely an optical fibre of a diameter of 150 μ m to 1250 μ m, the connector to be provided at the end of an optical fibre (1a) on which said high energy beam is to be incident, the connector comprising a sleeve (43) with:
 - a) a portion of relatively large inner diameter; and
 - b) a fibre support portion (43f, 46);
 whereby the sleeve can, in use, be fitted on the end of said optical fibre (1a) so that a gap (43c, 43d) is formed between the inner periphery of said portion of relatively large inner diameter of the sleeve (43) and the outer periphery of said optical fibre (1a) along a desired axial distance from the end face of said optical fibre (1a) to the fibre support portion (43f, 46), and so that said optical fibre support portion (43f, 46) supports the optical fibre (1a) and has an inner diameter which is about equal to the diameter of the optical fibre, the connector being characterised in that at least said optical fibre support portion (43f, 46) is formed of sapphire which has a melting point of 2030°C, a refractive index of 1.76 and which has a transmission such that it transmits there-through more than 5% of the incident light in a 1mm transmission distance.
2. A connector as set forth in Claim 1, wherein an end face of said optical fibre support portion (43f) at the high energy beam outgoing side is roughened by surface-processing so as to make the high energy beam reflect irregularly from said end face.
3. A connector as set forth in Claim 1, wherein said optical fibre support portion (43f, 46) is tapered at an end face (46a) thereof facing said gap like a truncated cone which tapers in a direction towards the end face of said optical fibre (1a).
4. A connector as set forth in Claim 3, wherein an angle Θ of inclination of said tapered face (46a) satisfies the following equation:

$$\Theta \leq 90^\circ - \arctan a/b$$
 where
 - a: half of the difference between the inner diameter of said portion of relatively large inner diameter of the sleeve (43) and the inner diameter of said optical fibre support portion (43f, 46) and
 - b: the distance from the utmost end face of said sleeve (43) to the end face of said optical fibre support portion (43f, 46).



5. A connector as set forth in any preceding claim, wherein said portion of relatively large inner diameter of the sleeve (43) is made of copper.

Patentansprüche

1. Verbinder für eine zum Übertragen eines Hochleistungsstrahls geeignete optische Faser, nämlich eine optische Faser mit einem Durchmesser zwischen 150µm und 1250µm, wobei der Verbinder am Ende einer optischen Faser (1a) vorgesehen ist, auf das der Hochleistungsstrahl auftrifft, wobei der Verbinder eine Hülse (43) aufweist, mit:
 - a) einen Bereich mit verhältnismäßig großem Innendurchmesser; und
 - b) einem Faserstützbereich (43f, 46);
 wodurch die Hülse im Gebrauch derart an dem Ende der optischen Faser (1a) anbringbar ist, daß ein Zwischenraum (43c, 43d) zwischen dem Innenumfang des einen verhältnismäßig großen Innendurchmesser aufweisenden Bereichs der Hülse (43) und dem Außendurchmesser der optischen Faser (1a) über eine gewünschte axiale Strecke von der Stirnfläche der optischen Faser (1a) zum Faserstützbereich (43f, 46) gebildet ist, und derart, daß der Bereich (43f, 46) zum Stützen der optischen Faser die optische Faser (1a) stützt und einen Innendurchmesser aufweist, der ungefähr gleich dem Durchmesser der optischen Faser ist, wobei der Verbinder dadurch gekennzeichnet ist, daß wenigstens der Bereich (43f, 46) zum Stützen der optischen Faser aus Saphir mit einem Schmelzpunkt von 2030°C und einem Brechungsindex von 1,76 besteht und der eine derartige Durchlässigkeit aufweist, daß er mehr als 5% des in einer Übertragungsdistanz von 1mm einfallenden Lichts durchläßt.
2. Verbinder nach Anspruch 1, bei dem eine Stirnfläche des Bereichs (43f) zum Stützen der optischen Faser auf der Hochleistungsstrahlaustrittsseite durch Oberflächenbearbeitung derart angeraut ist, daß der Hochleistungsstrahl unregelmäßig von der Stirnfläche reflektiert wird.
3. Verbinder nach Anspruch 1, bei dem der Bereich (43f, 46) zum Stützen der optischen Faser an einer dem Zwischenraum gegenüberliegenden Stirnfläche (46a) nach Art eines in Richtung der Stirnfläche der optischen Faser (1a) zulaufenden Kegelstumpfs verjüngt ist.
4. Verbinder nach Anspruch 3, bei dem der Neigungswinkel θ der sich verjüngenden Fläche (46a) die folgende Gleichung erfüllt:

$$\theta \leq 90^\circ - \arctan a/b$$

wobei

- a: die Hälfte der Differenz zwischen dem Innendurchmesser des Bereichs der Hülse (43) mit verhältnismäßig großem Innendurchmesser und dem Innendurchmesser des Bereichs (43f, 46) zum Stützen der optischen Faser und die Entfernung von der äußersten Stirnfläche der Hülse (43) zur Stirnfläche des Bereichs (43f, 46) zum Stützen der optischen Faser bezeichnet.

5. Verbinder nach einem der vorhergehenden Ansprüche, bei dem der Bereich der Hülse (43) mit verhältnismäßig großem Innendurchmesser aus Kupfer besteht.

Revendications

1. Connecteur pour une fibre optique qui peut transmettre un faisceau à haute énergie, à savoir une fibre optique d'un diamètre de 150 µm à 1250 µm, ledit connecteur étant disposé à l'extrémité d'une fibre optique (1a) sur laquelle ledit faisceau à haute énergie doit être incident, ledit connecteur comprenant un manchon (43) comportant :
 - a) une partie de diamètre intérieur relativement grand ; et
 - b) une partie (43f, 46) de support de fibre ;
 moyennant quoi le manchon peut, en fonctionnement, être placé sur l'extrémité de ladite fibre optique (1a) de sorte qu'un intervalle (43c, 43d) est formé entre la périphérie intérieure de ladite partie de diamètre intérieur relativement grand du manchon (43) et la périphérie extérieure de ladite fibre optique (1a) le long d'une distance axiale souhaitée à partir de la face d'extrémité de ladite fibre optique (1a) jusqu'à la partie (43f, 46) de support de fibre, et de sorte que ladite partie (43f, 46) de support de fibre optique supporte la fibre optique (1a) et a un diamètre intérieur qui est approximativement égal au diamètre de la fibre optique, ledit connecteur étant caractérisé en ce qu'au moins ladite partie (43f, 46) de support de fibre optique est constituée de saphir qui a un point de fusion de 2030°C, un indice de réfraction de 1,76 et qui présente une transmission telle qu'il transmet plus de 5 % de la lumière incidente sur une distance de transmission de 1 mm.
2. Connecteur selon la revendication 1, dans lequel une face d'extrémité de ladite partie (43f) de support de fibre optique du côté de sortie du faisceau à haute énergie est rendue rugueuse par un traitement de surface de façon à réfléchir le faisceau à haute énergie irrégulièrement à partir de ladite face d'extrémité.



3. Connecteur selon la revendication 1, dans lequel ladite partie (43f, 46) de support de fibre optique est tronconique à l'une (46a) de ses faces d'extrémité en regard dudit intervalle comme un tronc de cône qui converge en direction de la face d'extrémité de ladite fibre optique (1a). 5
4. Connecteur selon la revendication 3, dans lequel un angle θ d'inclinaison de ladite face tronconique (46a) satisfait l'équation suivante : 10
- $$\theta \leq 90^\circ - \text{Arctg } a/b$$
- où
- a : la moitié de la différence entre le diamètre intérieur de ladite partie de diamètre intérieur relativement grand du manchon (43) et le diamètre intérieur de ladite partie (43f, 46) de support de fibre optique et 15
- b : distance de la face frontale extrême dudit manchon (43) à la face d'extrémité de ladite partie (43f, 46) de support de fibre optique. 20
5. Connecteur selon l'une quelconque des revendications précédentes, dans lequel ladite partie de diamètre intérieur relativement grand du manchon (43) est constituée de cuivre. 25

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