

Description

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The present invention relates to a connector for optical fibres.

At present the connection between two optical fibres is generally effected by means of connectors formed from two male ferrules mounted at the end of each of the fibres and a female reconstituting connector having a longitudinal bore for supporting and aligning the two ferrules face to face (cf. by way of example, GB-A-2 058 392).

It is known that in order to obtain a good low-loss connection it is necessary for the connector to align the two fibres perfectly. In order to ensure this alignment the ferrules are positioned in the bore of the connector to bear by their sidefaces by applying transverse forces. The longitudinal fixing of the ferrules necessitates in addition the application of longitudinal forces.

The technological solutions for realizing such connectors whilst gauging as well as possible the longitudinal and transverse forces to be put into effect are complicated and incompatible with the realization of efficient connectors at reasonable cost. Again, the contact pressures between the male ferrules and the female connector cause wear to occur during the course of the manipulations of coupling and uncoupling. The wear phenomena progressively alter the alignment of the fibres and may be the source of pollution of the optical faces. Further, these wear phenomena limit the life of the connectors.

The present invention is aimed at alleviating the disadvantages of the connectors so far known, by providing a connector of high accuracy which enables interchangeable optical connections to be effected by bringing solely longitudinal forces into play for the alignment and positioning of the male ferrules in the female connector. The present invention proposes in addition to provide a connector capable by particularly simple means, of ensuring simultaneously an attenuation function of predetermined attenuation.

For this purpose the object of the present invention is a connector for optical fibres, characterized by the fact that the female connector has in the central portion of it inside its longitudinal bore an abutment body for the male ferrules, which exhibits an axial orifice passing



through it and round the latter a bearing surface opposite each of the male ferrules, each of the male ferrules exhibiting a tubular axial protuberance capable of engaging in the orifice in the said abutment body and a passage into which the optical fibre may be introduced with clearance and fixed in such a way that the end of it coincides with the end of the said protuberance, each of the ferrules including in addition, set back from the said protuberance and surrounding the rear portion of it, an annular recess the wall of which defines a bearing surface for contact with the opposing bearing surface of the abutment body in the female connector under the action of longitudinal pressure-means, the opposing bearing surfaces of the said abutment body in the said female connector and of each of the male ferrules being arranged in such a way that at the time of any relative movement of the bearing surfaces in contact the end of a fibre at the level of the endface of the protuberance from a male ferrule is kept at a constant predetermined distance from the centre of the said abutment body.

In a first embodiment the abutment member of the female connector is a sphere, the annular recess in each male ferrule exhibiting a wall of conical profile.

As a variant upon this embodiment the sphere may be replaced by a disc of the same diameter, supplementary positioning means having to be provided in order to ensure the angular orientation of each male ferrule with respect to the female connector.

In a second embodiment the abutment body is cylindrical, the annular recess in each male ferrule exhibiting a wall of spherical profile, the cylindrical body coming to bear against the spherical bearing surfaces of the male ferrules by the periphery of its plane endfaces, the spherical bearing surfaces being arranged so that the spherical bearing surfaces of two ferrules in the coupling position define a sphere the centre of which coincides with the centre of the cylindrical abutment body.

In another embodiment the abutment body is parallelepipedal, the annular recess in each male ferrule exhibiting a wall of spherical or conical profile. The angular orientation of a male ferrule with respect to the female connector may, for example, be ensured by conferring corresponding



polygonal cross-sections upon the protuberances from the male ferrules and upon the axial orifice in the abutment body.

If upon the connector so realized one tries to confer an attenuation capacity so as to add an attenuation function, it will be understood that it is sufficient to modify the dimensioning of the spherical aligning body in the first embodiment or the radius of the spherical bearing surface of each male ferrule in the second embodiment in order to move away from the centre of the abutment body the ends of the fibres being held at the level of the ends of the protuberances from the male ferrules. This solution is particularly interesting when the connector is employed in an installation the signal from which is required to be brought to a predetermined level.

The object of the present invention is equally a method of realization of a connector as described above, characterized by the fact that an optical fibre is put into position in a jig which includes an abutment piece exhibiting the form of half an abutment body from a female connector, that the said fibre is centred with respect to the said abutment piece and to a male ferrule put into position in the said jig, that the fibre so centred is fixed in the ferrule being held in the said jig, that the ferrule is then brought into a second jig which includes an abutment piece exhibiting the form of half an abutment body from a female connector, that the ends of the fibre and of the said ferrule are cut off and polished at a predetermined distance from the centre of the abutment piece of the second jig and that two male ferrules so produced are put into position in a female connector until the opposing bearing surfaces of each ferrule and of the abutment body in the female connector are brought into contact

In one mode of putting the method into effect, in order to carry out the stage of centring a fibre with respect to a male ferrule, a male ferrule is arranged in a jig which includes a front portion exhibiting the form of half a female connector, a central portion including an abutment piece exhibiting the form of half an abutment body from a female connector and a rear fibre-centring portion which preferably includes a cavity the shape of a re-entrant dihedron, an optical fibre is arranged in the axial passage in the ferrule and the optical fibre is centred with respect to the ferrule in the rear portion of the jig, in particular whilst keeping

it at the bottom of the said re-entrant dihedron of the jig by means of a corresponding wedge.

Once the fibre has been centred with respect to the male ferrule in the jig, it is advantageous to proceed with fixing it in the ferrule by injection of a resin through an orifice provided for this purpose in the front portion of the jig, the fibre thus centred becoming sealed in the ferrule upon hardening of the resin.

A jig is advantageously employed which consists of three portions which can be fitted together, namely : a front portion exhibiting the form of half a female connector, a central portion including an abutment piece exhibiting the form of half an abutment body from a female connector and a rear fibre-centreing portion which preferably includes a cavity the shape of a re-entrant dihedron and that a preadjustment of the jig is carried out, which consists in putting an optical fibre in place in the rear portion of the jig, in fitting onto the said rear portion of the jig the central portion including the abutment piece, in centreing the said abutment piece with respect to the optical fibre by optical aiming, in particular by means of an autocollimating telescope whilst moving the central and rear portions of the jig with respect to one another in contact with one another, and in putting the front portion of the jig in place on the central portion of it.

As a variant a one-piece jig may be employed.

The object of the present invention is equally a second mode of putting into effect a method of realization of a connector having the above-mentioned characteristics, characterized by the fact that an optical fibre is introduced into a male ferrule and fixed by mechanical locking means, that the end of the fibre is positioned axially with respect to the male ferrule by introducing the whole into a jig which includes an abutment piece exhibiting the form of half an abutment body from a female connector, that the ends of the fibre and of the ferrule are cut off and polished at a predetermined distance from the centre of the abutment piece on the jig, that the ferrule equipped with the optical fibre is put in position in a second jig exhibiting the form of half a female connector and including an abutment piece which exhibits the form of an abut-

ment body from a female connector, that the optical fibre is centred with respect to the said abutment piece by optical aiming, in particular by means of an autocollimating telescope whilst acting upon the said mechanical locking means and that two male ferrules so produced are put into position in a female connector until the opposing bearing surfaces of each ferrule and of the abutment body in the female connector are brought into contact.

The mechanical locking means advantageously include a plurality of metal balls seated in holes in the male ferrule by force and capable of being applied against a central metal tube which includes a recess in which the fibre is fixed, in particular by gluing, the said metal tube creating the tubular axial protuberance from the male ferrule.

Other advantages and characteristics of the invention will be made clear in the description which follows with reference to the attached drawing in which:

- Figure 1 represents partially in section a first embodiment of a connector in accordance with the invention;
- Figure 2 represents partially in section a second embodiment of a connector in accordance with the invention;
- Figure 3 is a section through a first embodiment of a jig for putting a fibre in position and centring it in a male ferrule from a connector of the embodiment as Figure 1;
- Figure 4 is a section along IV-IV in Figure 3;
- Figure 5 illustrates the second phase of preparation of this male ferrule in accordance with a first mode of putting it into effect;
- Figure 6 illustrates the end of the male ferrule ready for being introduced into the female connector;
- Figure 7 represents a second embodiment of a jig which may be employed for putting a fibre into position and centring it in a male ferrule from a connector of the embodiment as Figure 1;
- Figure 8 represents very diagrammatically an autocollimating telescope which may be employed for the preadjustment of the jig in accordance with Figure 7;
- Figure 9 illustrates the phase of preadjustment of the jig as Figure 7, employing the telescope as Figure 8;

- Figure 10 illustrates the image seen in the eyepiece during the phase of preadjustment of the jig as Figure 7;
- Figure 11 is a view similar to that of Figure 3 employing the jig as Figure 7;
- Figure 12 is a section through a variant upon the jig illustrated in Figure 5, for the second phase of preparation of a male ferrule;
- Figure 13 is a section through a variant embodiment of a male ferrule for realization of the connector in accordance with the invention;
- Figure 14 is a section along XIV-XIV in Figure 13;
- Figure 15 illustrates the phase of centring a fibre in a male ferrule in accordance with Figure 13 employing the telescope as Figure 8; and
- Figure 16 illustrates the image seen in the eyepiece of the telescope during the phase of centring illustrated in Figure 15.

The connector represented in Figure 1 includes in general two male ferrules 1 arranged in a female connector 2 which includes a central flange 3 equipped with holes 4 for fixing it onto a panel.

The male ferrules 1 are arranged in a longitudinal bore 5 in the female connector and are locked to it by means of rings 6 the threads 7 in which cooperate with corresponding threads 8 on the ends of the female connector 2.

In the longitudinal bore 5 in the female connector in the central zone of it at the level of the flange 3 a sphere 9 is put into position, which is equipped with an axial orifice 10 passing through it and cylindrical in the example illustrated.

The sphere may advantageously be a ground and pierced ball of steel, such a ball being realizable industrially with tolerances upon its diameter and sphericity less than a micrometre. The sphere is fixed by any suitable means, for example, by crimping or driving it hard into the inner wall of the female connector in the central zone of it.

It is equally possible in the case of less efficient connections to

produce the sphere in one piece with the female connector by conventional techniques of moulding or swaging.

Each of the male ferrules 1 exhibits a tubular axial protuberance 11 at the front end of which an axial passage 12 emerges, inside which an optical fibre 13 has been sealed by means of a resin 14. The optical fibre 13 is fixed in the ferrule by the resin 14 and channelled at the rear of the ferrule by a tubular cable 15.

Each of the male ferrules 1 exhibits, set back from the tubular protuberance 11, an annular recess which exhibits a wall 16 to the cavity of conical shape.

It may be seen in Figure 1 that the frustoconical bearing surface 16 so defined on each ferrule is in contact with a spherical bearing surface on the sphere 9, the contact pressure being maintained by compression springs 17 arranged between each ferrule and the corresponding locking ring 6.

It may be imagined that because of the shape of the bearing surfaces in contact, the frustoconical one on the ferrule and the other spherical one on the sphere 9, it is ensured that the end 13a of each optical fibre at the level of the endface of the protuberance 11 from each of the male ferrules is held constantly at a predetermined fixed distance from the centre of the sphere 9, where this distance may be kept very small, even zero if end to end contact between the fibres is desired. If, for example, the diameter of the sphere 9 is increased, the distance of the end 13a of each fibre from the centre of the sphere is increased, thus offering a capacity of attenuation. Hence the value of the attenuation is easily determined as a function of the diameter of the sphere employed.

Because of the great accuracy that may be obtained in the dimensional characteristics of the sphere, as called to mind above, it is not necessary to observe an excessive accuracy at the level of the frustoconical bearing surfaces of the male ferrules, an accuracy of a few degrees in the cone angles being sufficient. Similarly it is not necessary to observe very great accuracy at the level of the cylindrical

portions of the male ferrules and of the female connector, an accuracy of the order of 0.1 millimetres being sufficient.

A connector realized in accordance with the invention offers in addition the advantage of great insensitivity to knocks, the functional coupling faces, namely, the opposing bearing surfaces on the male ferrules and on the sphere in the female connector being protected. Again, there is practically no friction at the time of the manipulations of coupling or uncoupling, whence negligible wear and good longevity of the connectors in course of use.

Further, sealing of the connector is easy to effect.

Although in the embodiment as Figure 1 an optical connector has been represented having only one fibre it is quite obvious that the same principle of connection may be employed for optical cables having a number of fibres and similarly a number of ferrules may be put into position in one and the same connector.

The axial orifice 10 in the sphere 9 in the embodiment having a single fibre is advantageously cylindrical for the sake of ease of machining. However, this orifice 10 may exhibit any shape, in particular polygonal, and include, for example, a reentrant dihedron when one is trying to ensure a complementary function of angular orientation of the ferrules, in particular when the sphere 9 is replaced by a disc of the same diameter, arranged so that in longitudinal section the arrangement as Figure 1 is met again.

Reference will now be made to Figure 2 which illustrates a second embodiment of connector in accordance with the invention, the portions identical with those of the connector as Figure 1 bearing the same reference numbers.

In this embodiment the sphere 9 of the first embodiment is replaced by a cylinder 18 having an axial orifice 19 passing through it, the recess in each of the ferrules 1 exhibiting in this embodiment a wall of spherical profile 20.

Reference will now be made to Figures 3 to 6 which illustrate the preparation of a male ferrule before putting it into position in a female connector in order to carry out in accordance with a first mode of implementation, the connector illustrated in Figure 1.

In Figure 3 the ferrule 1 may be seen, equipped with its locking ring 6 and put into position inside a first onepiece jig having a front portion 21a, a central portion 21b and a rear portion 22. The front portion 21a reproduces the characteristics of one half of a female connector intended for cooperating with the male ferrule, and is prolonged by a central portion 21b including a hemisphere 23 of the same size as the sphere 9 in the connector, equipped with an axial orifice 24, the relative arrangement of the ferrule in the jig reproducing identically the conditions of the later coupling of the ferrule into the connector, the frustoconical bearing surface 16 being applied against the corresponding bearing surface on the hemisphere 23 under the action of the compression spring 17.

The rear portion 22 of the jig includes as may best be seen in Figure 4, a cavity in the shape of a reentrant dihedron 25 in which a wedge-shaped piece 26 becomes engaged.

The structure of the jig is such that when an optical fibre 13 is lying at the bottom of the cavity 25 under pressure from the wedge 26 it is perfectly centred with respect to the frustoconical bearing surface of the ferrule and to the hemisphere 23 in the central portion of the jig 21b.

Hence for obtaining centreing of the fibre in the ferrule it suffices to put a fibre into position in the ferrule when fixed in the jig and to apply the piece 26 so as to bring the fibre 13 into the portion 22 of the jig at the bottom of the groove 25. One then proceeds to an injection of resin through a funnel-shaped orifice 27 arranged for this purpose in the front portion 21a of the jig, this orifice being aligned with an orifice 28 in the male ferrule.

The ferrule in which the fibre 13 has been sealed by the resin 14 is then arranged in a second jig 29 which as may be seen in Figure 5 exhibits the same characteristics as the front portion 21 of the jig illustrated in

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Figure 3. Once the ferrule is held in the jig 29 in the same way as it was held in the front portion 21a of the jig as Figure 3, one proceeds to cut it to length and polish it by means of an abrasive grindstone 30 which levels the optical fibre 13 and the end of the protuberance 11 from the male ferrule 1 so that the end of the fibre is lying in a transverse plane at a predetermined distance of, for example, from a few micrometres to some tens of micrometres, depending upon the size of the fibre which is to be connected and the admissible attenuation in the connection, to the rear of the centre of the hemisphere provided in the jig 29.

This arrangement is illustrated in Figure 6 which represents the finished ferrule and in which is shown diagrammatically in broken line on the one hand the sphere in the female connector and on the other hand the transverse plane diametral to the latter and parallel with the end of the protuberance 11 and hence with the end 13a of the optical fibre.

In practice when very low attenuation is desired the distance between the end 13a of the fibre and the centre of the sphere is from 0.01 to 0.05 times the diameter of the heart of the fibre.

In order to assemble the connector it is sufficient to put into position in a female connector two male ferrules as illustrated in Figure 6 until the configuration of Figure 1 is obtained in which the frustoconical bearing surfaces of the male ferrules are in contact with the spherical bearing surfaces of the sphere mounted inside the female connector.

The jig illustrated in Figure 7 exhibits as a whole a structure very similar to that of the jig illustrated in Figure 3 with the exception of the fact that its several components are distributed in three separable portions, that is, a front portion 21a exhibiting the shape of half a female connector, a central portion 21b including an abutment piece exhibiting the shape of half an abutment body from a female connector, in the case represented a hemisphere 23 equipped with an axial orifice 24, and a rear portion 22 including a cavity in the form of a reentrant dihedron 25. Orifices 31 are provided in the three portions of the jig for passing through locking rods enabling the three portions of the jig to be fixed in position.

The jig in the assembled state is illustrated in Figure 11, the parts identical with or having a function similar to those of the jig as Figure 3 bearing the same reference numbers. In order to ensure preadjustment of such a jig an autocollimating telescope 32 is employed such as that illustrated in Figure 8.

This includes an eyepiece 33, eyepiece cross-wires 34, a lamp 35 the light from which passes through a condenser lens 36, source cross-wires 37, a separator 38 and an objective 39.

Besides these components which are the components of a conventional autocollimating telescope, in accordance with the invention provision is made to arrange in front of the objective of the telescope an objective 40 similar to a microscope objective. The function of this objective 40 is to make the parallel rays arriving from the objective 39 converge at its focus outside the telescope.

Thus if one places at the focus of the objective 40 the centre of a spherical ball the surface of which is reflective, the image of the source cross-wires is reformed in the eyepiece.

The offset between the image of the source cross-wires 36 and the eyepiece cross-wires 34 is approximately proportional to the distance from the centre of the reflective sphere so placed and the optical axis of the autocollimating telescope. One may thus visualize the position of a reflective sphere with respect to the axis of the telescope.

Such a telescope may thus be employed for centreing the hemisphere 23 on the central portion of the jig as Figure 7 upon its rear portion 22.

For this purpose, as illustrated in Figure 9, the central portion 21b and the rear portion 22 are assembled opposite the objective of the autocollimating telescope 32. A section of optical fibre 130 the end of which has been carefully prepared, is placed in the cavity 25 in the portion 22 of the jig so that its endface coincides with the face of the portion 22 bearing against the portion 21b.

The autocollimating telescope is centred on the face of the fibre in

order to have the image of this face well centred upon the eyepiece cross-wires 34.

The image of the source cross-wires 36 is likewise obtained in the eyepiece to represent the position of the centre of the pierced hemisphere 23.

It is then sufficient to move the portion 21b by sliding plane against plane by means of microscopic movements or jarring until the image of the source cross-wires 36 is brought to the centre of the fibre 13 and of the eyepiece cross-wires 34.

Thanks to such optical aiming accuracies of the order of a micrometre may be obtained.

With the hemisphere 23 thus centred the jig is completed as illustrated in Figure 11 with the front portion 21a.

After having employed this jig for centreing a fibre 13 in a male ferrule as previously described for the embodiment as Figure 3, one proceeds to the levelling and polishing of the end of the male ferrule and the fibre, either by employing the jig illustrated in Figure 5 or the jig illustrated in Figure 12.

This jig 41 includes a body 42 similar to half a female connector and an abutment body, in this case a hemisphere 43 equipped with a longitudinal bore 44 and aligned in a plane 45 set back a few micrometres, for example of the order of 3 to 4 micrometres, with respect to its centre 46.

After putting the ferrule into position in this jig 41 and polishing it against an abrasive surface, an axial positioning of the fibre with respect to the male ferrule is obtained which is similar to that represented in Figure 6.

The jig represented in Figure 12 may equally well be employed in a variant upon the method of realization of the connector in accordance with the invention illustrated in Figures 13 to 16.

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For this purpose a male ferrule is employed such as that illustrated in Figure 13, having a ferrule body 1' equipped at the end of it with an annular recess having a conical wall 16', the ferrule body 1' having a plurality of radial holes 47 for mounting balls 48 by force.

In the example illustrated four balls 48 are provided, housed in corresponding holes arranged on a cross.

The ferrule includes in addition an inner tubular element, especially one of steel, 49, the end 50 of which corresponds with the protuberance 11 of the embodiment as Figure 1.

For the realization of a connector in accordance with the invention with such male ferrules, a fibre 13 is mounted in the tubular piece 49, fixing it by gluing.

Then the longitudinal positioning of the end 50 of the piece 49 and of the fibre 13 with respect to the conical annular recess 16' is carried out by employing a jig such as that represented in Figure 12.

For the centreing of the fibre with respect to the male ferrule a jig is employed such as that illustrated in Figure 15, having a body 51 which reproduces the characteristics of half a female connector and a sphere 52 equipped with a longitudinal bore 53, the ferrule mounted in the jig being placed before the objective of an autocollimating telescope 32.

The autocollimating telescope is focussed upon the sphere 52 in order that the image of the source cross-wires 36 representing the sphere are centred upon the eyepiece cross-wires 34 as may be seen in Figure 16.

In the eyepiece the image is obtained simultaneously of the face of the optical fibre 13 off centre with respect to the eyepiece cross-wires 34.

One then acts upon the balls 48 as illustrated in Figure 15 by means of a micrometric or impact device (not shown) in the direction of the arrows shown in Figure 15 for correcting the position of the fibre contained in the tubular piece 49 with respect to the centre of the sphere 52, the position of definite centreing being obtained when the image of the fibre

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13 in the eyepiece is lying centred with respect to the cross-wires 34 and 36.

Both in this embodiment and in the embodiments previously described one may proceed to a checking of each finished male ferrule by employing the autocollimating telescope 32 after having put the ferrule into position in a jig similar to the jig 51, the autocollimating telescope being then focussed upon the face of the fibre. The image of the source cross-wires which represent the centre of the sphere gives by its position with respect to the eyepiece cross-wires which may then be graduated, the position of the centre of the sphere with respect to the centre of the fibre, the accuracy being of the order of a micrometre.