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Optical Fiber Joining Technique

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*This paper describes a method of thermally fusing clad glass fibers, end to end, to obtain a good mechanical joint with low transmission loss. Methods of preparing fiber ends and aligning them for joining are discussed. Two sizes of fibers were joined (10.8-μm core and 20-μm core clad fibers with outside diameters of 75 μm and 150 μm respectively).**

I. INTRODUCTION

There is a great deal of interest in using glass fibers as optical waveguides to carry information in much the same way as wires or metallic waveguides do. If glass fibers are to be used in this way, they will need to be joined just as wires and metallic waveguides must be joined.

A method for joining single fibers was developed. Clad glass fibers were joined which had cores of 10.8-μm and 20-μm diameters and overall diameters of 75 μm and 150 μm respectively. The cores were Schott SSK-1 glass and the cladding of Schott SK-14 glass which have glass transition temperatures of 621°C and 649°C respectively. Good mechanical joints which can be made quickly with transmission losses as low as 11.5 percent were obtained, but lower losses should be possible with a little more effort.

II. FIBER END PREPARATION

To get a good joint, good fiber ends are needed. Polishing or etching the fiber ends has been suggested, but we have found that if a fiber is broken properly it will have an end that is suitably flat over most of its surface and perpendicular to the axis of the fiber as seen under a microscope. Figure 1 shows two good ends of 10.8-μm core, 75-μm o.d. fibers magnified 500X. The break can be made by scoring the fiber with a razor blade and breaking it or by laying the fiber across a sharp metallic edge and positioning a Tesla coil so that its discharge is con-

* The fibers were manufactured by DeBell and Richardson, Inc., of Hazardville, Connecticut.

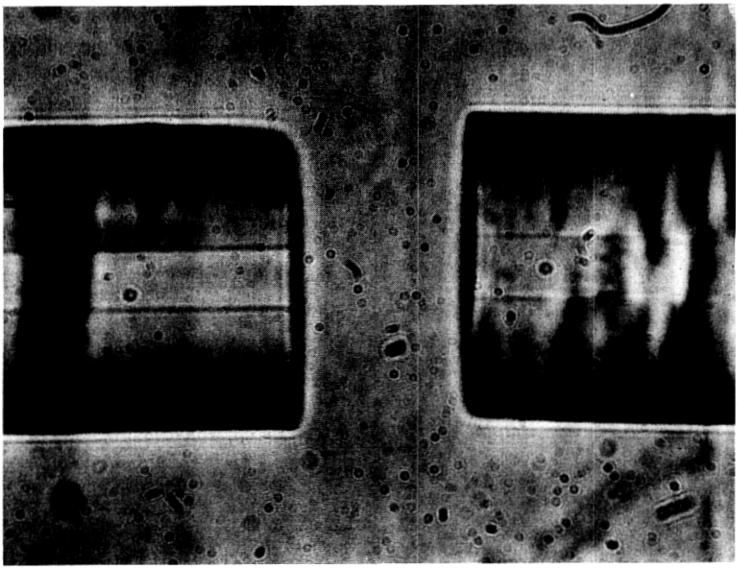

Fig. 1—Two cleanly broken ends of 10.8-μm core, 75-μm o.d. fibers magnified 500X.

centrated at the point where the fiber touches the metal, then breaking it by bending or pulling. The sparking must continue for several seconds with greater time for greater fiber diameter. To prevent the deposition of metal on the fiber because of the electrical discharge, platinum wire was used as the metallic contact. Fibers of 250-μm o.d. or greater can be scored with a file or diamond before breaking.

If the fiber is bent to the breaking point after it is scored or treated with an electrical discharge, one end will have a lip protruding and the other end will have a corresponding absence of material. This can be seen in Fig. 2. This lip is sometimes as long as the diameter of the fiber and would prevent the end from being brought close enough to another fiber end to permit joining them. If the fiber is pulled instead of bent until it breaks, the lip is not produced on most occasions, so this is the recommended procedure.

Very small fibers will sometimes soften and bend from the heat when the discharge from the Tesla coil strikes them, but with care, fibers as small as 25-μm o.d. have been broken with good ends suitable for joining.

III. ALIGNMENT

After the ends of the fiber have been prepared, they must be mounted so that they can be aligned. Teflon-coated tweezers to hold the fiber ends were mounted, one on a general purpose 3-dimensional micromanipulator and one on a precision 3-dimensional micromanipulator with a positioning resolution of 0.127 μm.

The Teflon-coated tweezers are gentle with the fiber and allow it to slip when the fiber contracts after having been heated, as will be discussed later.

From measurements of light output versus fiber end displacement we find that a misalignment of less than 2 μm in the 10.8-μm core fiber gives 10 percent less transmission than when the ends are aligned. Losses due to fiber offsets are covered in detail in Ref. 1.

One can determine when the ends are aligned by viewing them through a microscope and assuming that the core is concentric with the outside of the cladding. To get two perpendicular views of the fiber, a mirror can be mounted so the fiber can be viewed directly from the front and

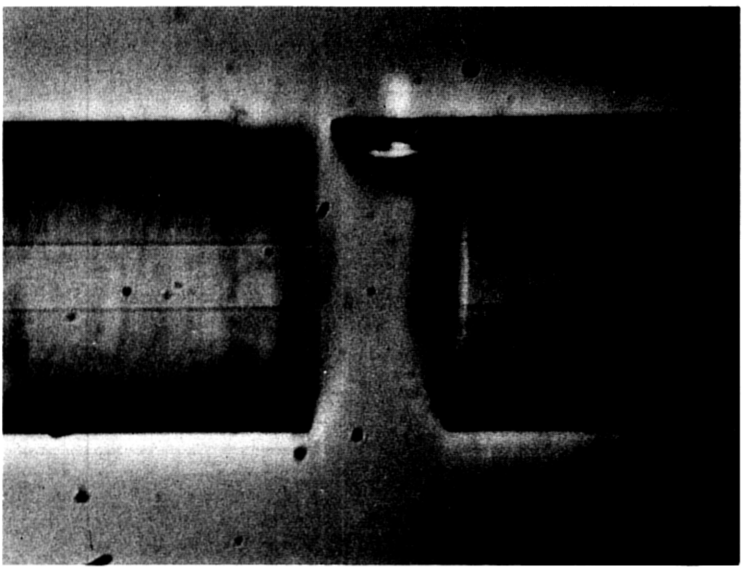

Fig. 2—A characteristic break in a 10.8-μm core, 75-μm o.d. fiber showing the protruding lip.

through the mirror from the side. Two problems in this method of alignment are, first, the core and cladding may not be concentric, and second, rather sophisticated optics are needed to see an alignment error of 1 μm or less. If the core and cladding are made concentric and if a microscope of 200X or greater is used, one can probably align them well enough by this means.

Another method we have used of determining optimum alignment is to send laser light down the fiber to a detector and adjust the fiber ends for maximum transmission. A problem with this method is that if the end of the fiber is broken at an angle with respect to the normal to the fiber axis, the maximum transmission will be obtained when the fiber ends are misaligned to compensate for the offset in the beam direction caused by the angle of refraction at the nonnormal surface. This offset is y in Fig. 3. This error is small, though, if the angle is small. With a fiber of 80-μm diameter, core index of 1.6, and a surface at the end that is 10 degrees from the normal, the ends of the fibers would have to be offset 0.73 μm to correct for the beam misalignment. This would introduce about 5 percent loss in our 10.8-μm core fiber. An angle of 10 degrees is large, so one should be able to do much better than that.

IV. JOINING THE FIBERS

Several unsuccessful attempts were made to join fibers with epoxy alone and epoxy in a glass sleeve. When using epoxy alone, the resultant joint was too weak to keep the fiber ends aligned when transverse pressure was applied. When using sleeves, the tolerance between sleeve i.d. and fiber o.d. had to be very close, of the order of 1 μm to keep the fibers aligned properly, and this tolerance is hard to obtain. Further, a bubble formed at the fiber junction inside several sleeve joints. Thus, this method was considered limited in practicality.

A method that worked was the fusing of the fiber ends. Number 24 nichrome wire was wound around two metal posts so as to leave an

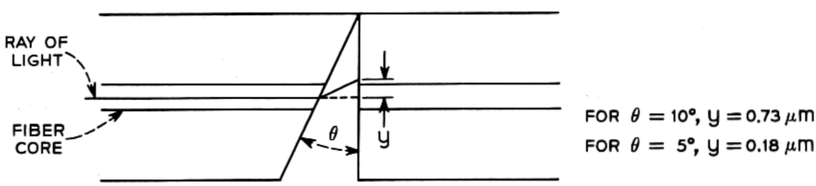

Fig. 3—Beam refraction at a nonnormal fiber end.

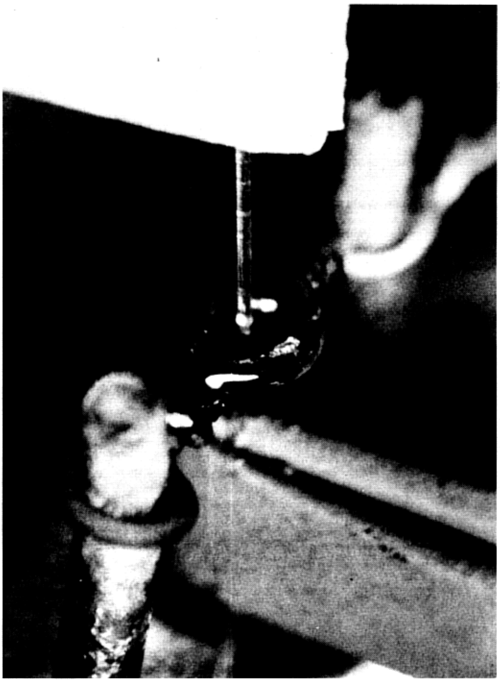

Fig. 4—Heating wire with fiber ends held in place by Teflon coated tweezers.

opening between the wires through which the fiber ends could pass as shown in Fig. 4.

The fiber ends were aligned, leaving a space of about 15 μm between them for thermal expansion. About 14 amperes of current were passed through the nichrome wire which surrounded the fiber ends causing the wire to heat up and fuse the fiber ends together. The longitudinal expansion of the fiber when heated closed the 15-μm gap that was left between the fiber ends. Of course, when the fiber cooled it shrank again, but the fiber could slip in the Teflon-coated tweezers when shrinking. The ends fused together in about 30 seconds after the heat was applied. To tell when the ends were fused, a lamp was placed so that the specular reflection from the fiber ends could be seen in the microscope. Disappearance of the reflection indicated the surface had vanished and the ends were fused. Figure 5 is a microphotograph of a fused joint in a 10.8-μm core, 75-μm o.d. fiber, at 500X magnification. Such joints exhibited losses as low as 11.5 percent.

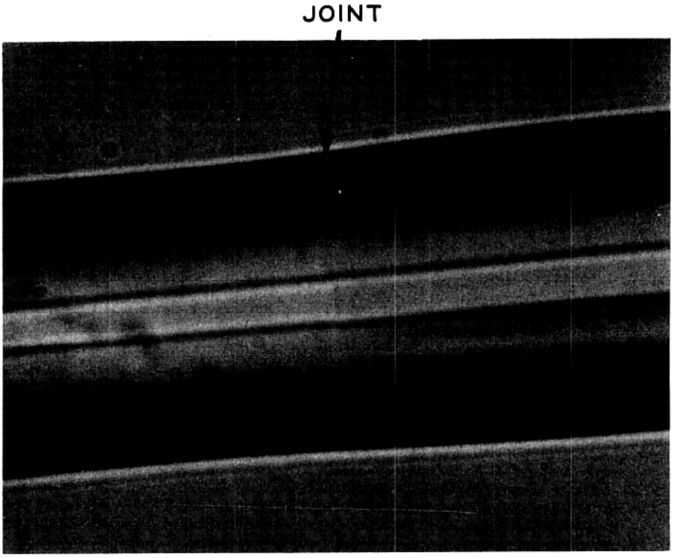

Fig. 5—A thermally fused joint in 10.8-μm core, 75-μm o.d. fiber.

V. CONCLUSIONS

After two fiber ends are carefully broken and properly aligned, they can be fused together by means of a heated wire to give a good mechanical joint with an acceptable amount of loss. Fibers of 10.8-μm core were joined and gave losses as low as 11.5 percent, but with a little more effort it is believed that joints could be made with considerably lower loss than this.

REFERENCES

1. Bisbee, D. L., "Measurements of Loss Due to Offsets and End Separations of Optical Fibers," B.S.T.J., this issue, pp. 3159–3168.