CONNECTIONS

Well-designed splices, connectors must align fibers exactly

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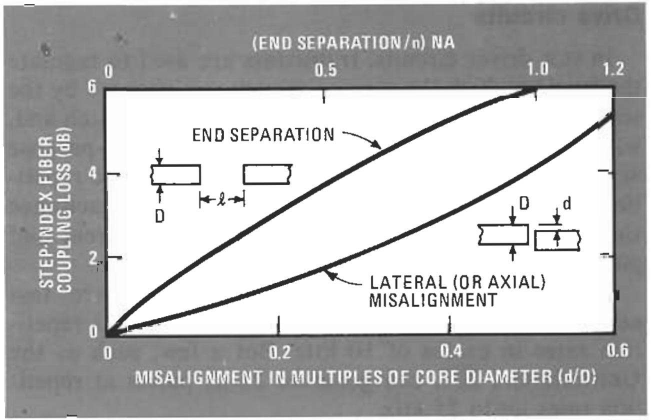
Splices for joining lengths of optical-communications cable in the field must provide low-loss, quick but permanent connections, and also be small, lightweight, and rugged. Except for the permanency, the same requirements hold for the connectors that couple the cable to terminal equipment.

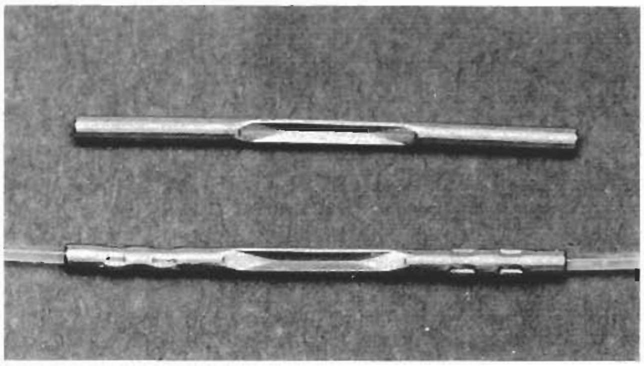
Single-fiber splicing losses of less than 0.1 decibel have been reported in the laboratory but have yet to be demonstrated in the field. Nevertheless, total splicing loss in a given length of fiber both can and should be much less than the fiber attenuation.

The most critical parameter, variously called axial or lateral alignment, is also one of the most difficult to control. Slight offset between the two fiber ends dramatically increases optical loss (Fig. 1). Alignment accuracy in the order of micrometers is needed, thus requiring similar machining tolerances of the associated hardware.

One splicing technique in widespread use is the preci-



1. Fiber offset causes loss. Any slight offset between two fiber ends increases optical coupling loss. An axial displacement equal to half the fiber core diameter causes greater than a 4-dB loss; separating the fiber by that amount produces a 6-dB loss.

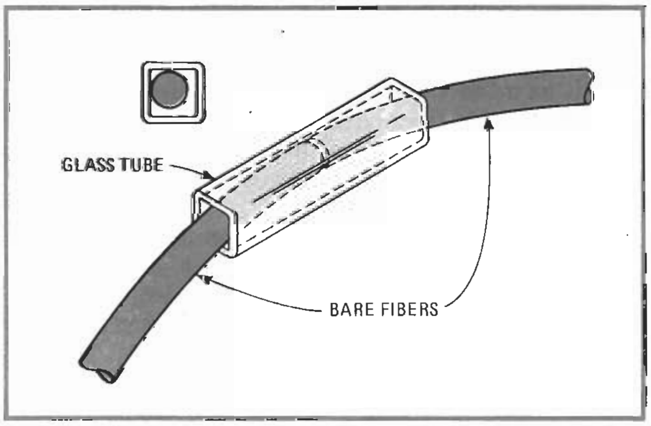


2. Fiber guide. A precision sleeve or tube that conforms exactly to the outer fiber diameter positions both fibers. Once both fiber ends are butted together in the splice sleeve, the sleeve ends are crimped into the fiber's plastic coating.

sion sleeve or tube, which, by conforming precisely to the outer diameter of the fiber, guides it into position and then holds it there. This requires individual handling of fibers and is most suitable for single fibers or small cables. Sleeves may be of metal or glass, and an entrance funnel aids fiber insertion. Once the fiber ends are prepared and the two fibers butted together in the splice, the outer jacket of the fiber is clamped or, in some cases, a metal sleeve is crimped around it.

A fiber splice developed by Bell Northern Research is based on this technique (Fig. 2). A stainless steel preform tube has a center alignment bore that fits the bare fiber diameter closely. The prepared fiber ends are guided into the alignment bore by tapered sections, and the ends of the splicing element are then crimped into the fibers' plastic coating for permanent assembly. Because the plastic coating extends inside the tube, no other mechanical protection is needed. With a silicone fluid pre-injected into the splicing element, insertion losses average 0.3 decibel from a LED source.

Another technique reported by Bell Telephone Laboratories—the loose tube splice—may be suitable for field use because it uses inexpensive components. It exploits the self-aligning tendency of fibers in a "V" groove (Fig. 3). Prepared fiber ends are inserted into a rectangular tube already filled with index-matching epoxy. The fibers are slightly bent, forcing the tube to rotate so that their ends travel along a corner. Once butted together, the ends are held in place until the epoxy cures. Losses average about 0.1 dB when a laser source is used.

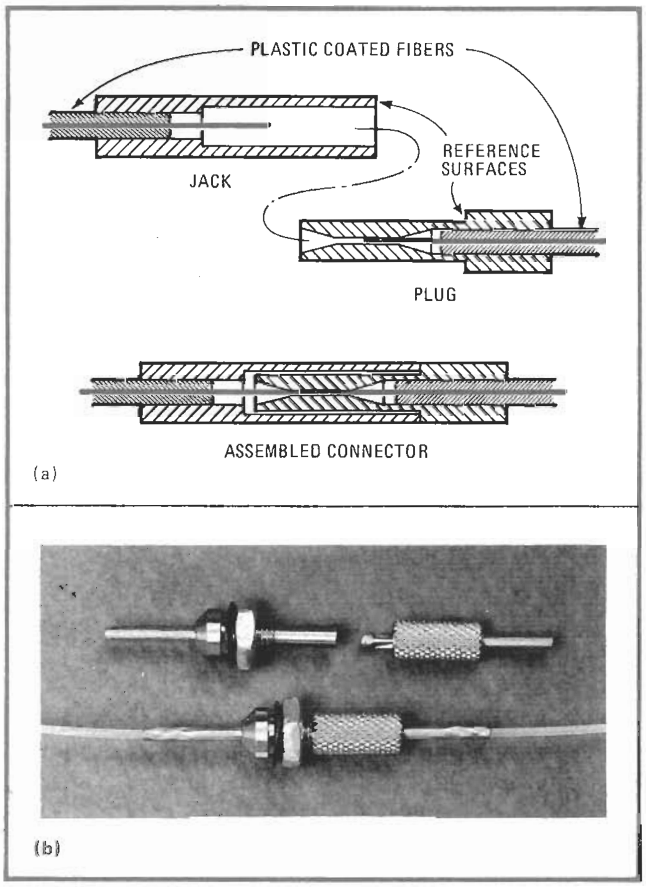


3. Self-aligning. The loose-tube splice, as it's called, makes use of the self-aligning tendency of the fibers. When the fibers within the tube are slightly bent, the tube rotates, holding the fiber ends in place until an epoxy positions them permanently.

Connectors have an added requirement: they must be able to mate repeatedly without degrading too much in coupling efficiency or mechanical integrity. They should also be simple to use, like electrical connectors.

A single-fiber connector, developed by Bell Northern Research for use with plastic-coated multimode fibers, is a variation in the precision-sleeve splicing element (Fig. 4). The connector plug has tapered funnels at each end leading into a central alignment bore (the only critical dimension). The longitudinal position of each fiber is accurately located with respect to a reference surface on each housing. This is done using a special fixture. Both the plug and its mating jack are mounted separately on a fixture, and prepared fiber ends are inserted into each connector half until they butt against the fixture's stops. Crimping the stainless-steel tubing into the fibers' plastic coating holds them firm. When mated, the reference surfaces are in contact and the fibers are separated by a small gap.

During mating, the fit between plug and jack insures that the jack fiber enters the tapered opening of the plug. Once mated, the plug and the jack are



4. Variation on a theme. Bell Northern Research's single-fiber connector adapts the precision-sleeve splicing principle. Once mated, the connector is only 2 centimeters long and, when unmated, the plug and jack housings protect the fiber as shown.

held together with a knurled coupling nut (a bulkhead panel mount is provided on the jack). When unmated, the housing configurations of both the jack and plug sections are such as to protect the fiber ends.

Typically, rematable insertion loss of the connector is 1 dB when an index-matching fluid and a LED source are used. Smaller losses have been reported with experimental connectors, but this device is more practical, in that its standard-diameter alignment bore can accommodate manufacturing tolerances in fiber diameter. When installed in prototype fiber-optic systems, both with and without index-matching fluid, these connectors showed typical insertion loss variations of less than 0.2 dB, after being remated up to 100 times.