Stripping-free Physical Contact Optical Connector

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Abstract: We propose a new stripping-free optical connector that enables us to realize physical contact (PC) connection and facilitate assembly, and demonstrate PC connection with a low average connection loss of 0.16 dB.

OCIS codes: (060.0060) Fiber optics and optical communications; (060.2340) Fiber optics components

1. Introduction

Optical fiber is being widely introduced as a communication medium to handle the expansion of broadband services. Many ways of connecting optical fiber including the fusion splice, mechanical splice and optical connector have also been developed and are being used in fiber to the home (FTTH) systems. Conventional connection methods achieve good optical performance by aligning bare glass fibers once their coatings have been removed.

However, all these connection methods require the careful handling of bare glass fiber, which is fragile. This has led to the need for a coated fiber connection method that does not require a stripping process. Such a stripping-free fiber connection method would also enable us to simplify the assembly procedure. For instance, a mechanical splicer with refractive index matching material has been reported that aligns fibers by bringing their coatings into contact inside a capillary [1]. However, there is a concentricity error between the core and coating diameter in the coated fiber, and this causes a large misalignment between the mated fiber cores in the capillary.

In this paper, we propose a new physical contact (PC) optical connector that uses a stripping-free connection method. The assembly procedure with the proposed connector does not require the coated fiber to be stripped or cleaved, thus facilitating assembly. We designed the connection structure and fiber endface shape to realize PC connection and developed a method for forming the required fiber endface. We also report the optical performance.

2. Principle of stripping-free PC connector

We propose a PC connector that does not require the coated fiber to be stripped thus simplifying the assembly procedure. The PC connector must realize the PC connection of coated fibers with a low connection loss. Figure 1 shows a cross-sectional view of the proposed connector. We employ a ferrule and a split sleeve. This is because we can realize a connector that is compatible with SC and MU connectors when the outer dimensions of their ferrules are the same. To achieve a PC connection, axial compression force is required between the mated fiber endfaces. We employ the axial compression force generated by the buckled fiber to simplify the connector structure. As shown in Fig. 1 (a), the fiber end protrudes from the ferrule end and the fiber is fixed to the clamp part. This structure enables us to buckle the fiber inside the flange when we connect the ferrules, as shown in Fig. 1 (b). We can control the buckling force by setting the buckled fiber length [2].

We designed the coated fiber alignment structure to achieve a low connection loss. The conventional ferrule is designed so that the glass fiber is inserted only after its coating has been stripped off. Therefore, we designed a new ferrule for the coated fiber, as shown in Fig.2. The new ferrule consists of a micro-hole to align the glass fiber, a crinkle-hole to crinkle the coating of the fiber and a coating-hole to align the coated fiber, as shown in Fig. 2 (a). When we insert the coated fiber into the ferrule, the fiber end reaches the micro-hole located at the ferrule end through the coating-hole. Then, by pushing the fiber into the micro-hole, the fiber coating is pushed back slightly at the entrance of the micro-hole and only the glass enters into the micro-hole, as shown in Fig. 2 (b). The crinkle-hole is a space for accommodating the crinkled coating. The proposed connector enables us to obtain the same low connection loss as a conventional connector where the glass fiber is aligned by the micro-hole.

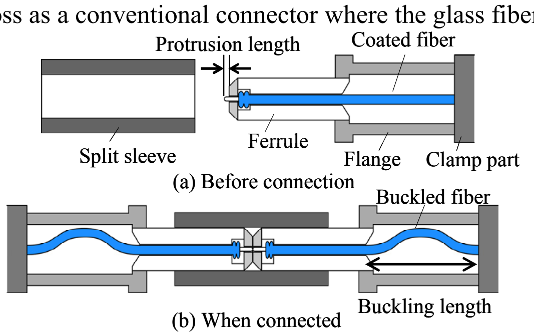


Fig. 1 Cross-sectional view of connector

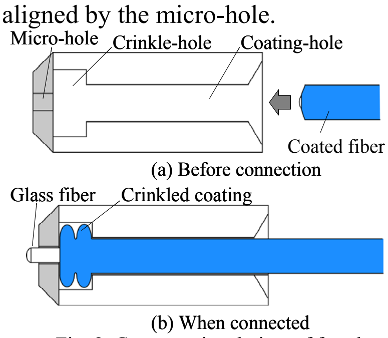


Fig. 2 Cross-sectional view of ferrule

3. Fiber endface design

We also designed the fiber endface shape for PC connection. We calculated the axial compression force F_p needed to realize PC connection with single-mode fibers (SMF) with a curved endface, as shown in Fig. 3. F_p is given by the following equation with the curvature radius R [3]:

$$Fp = \frac{4a^3E}{3(1-\nu^2)R} \qquad (1)$$

where a is the core radius, R is the curvature radius of the fiber endface, and E and ν are Young's modulus and the Poisson ratio of a fiber, respectively. The calculated result is shown in Fig. 4. The required F_p value increases as R decreases. The estimated maximum axial compression force that we obtain with the buckled fiber is 0.9 N [4]. As shown in Fig. 4, the axial compression force of less than 0.9 N that we obtain indicates that we must form the fiber endface with a curvature radius of more than 23 μm.

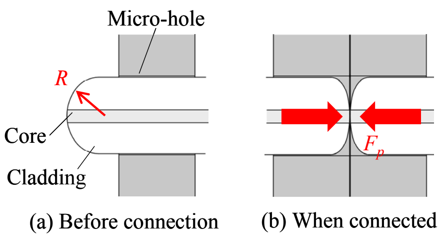


Fig. 3 Fiber endface shape

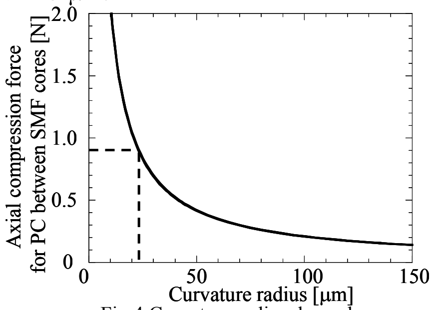


Fig.4 Curvature radius dependence on axial compression force

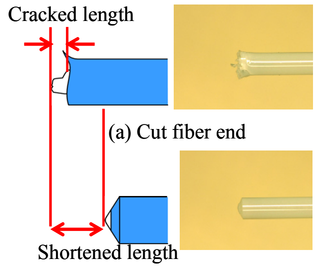


Fig. 5 Cut and sharpened fiber end

4. Fiber endface forming technique

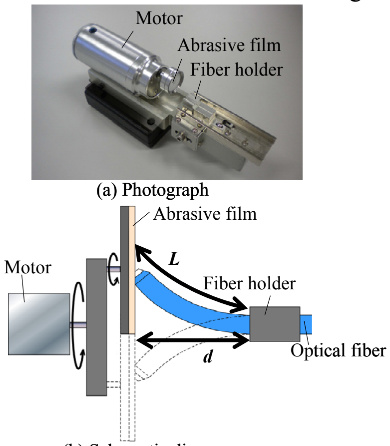
With the assembly procedure, we form the cut fiber endface into a curved polished endface. We do not require the cleaver that used as the special tool in the conventional fiber preparation method. We cut the coated fiber with an ordinary tool such as wire cutters. We propose a new technique for forming the cut fiber endface that comprises a sharpening process and a polishing process. The sharpening process is designed to eliminate the cracked fiber end generated by the blade of the wire cutters when we cut the coated fiber, as shown in Fig. 5. The polishing process is designed to realize a curved fiber endface for PC connection.

First, we measured the end shape of a fiber cut with wire cutters. We measured the cracked length from the cut ends of 90 fibers after we cut the coated fiber with the wire cutters, as shown in Fig. 5 (a). The average cracked length was 0.214 mm with a σ value of 0.094 mm. From this result, we estimated that the possible cracked length is about 0.5 mm (average + 3 σ value). Therefore, we shortened the fiber by more than 0.5 mm in the sharpening process so that the formed fiber endface was not cracked, as shown in Fig. 5 (b).

Figure 6 shows a photograph and a schematic diagram of the forming tool, which mainly consists of an abrasive film, a motor and a fiber holder. The fiber is held mechanically in the fiber holder. When we move the fiber toward the abrasive film, the fiber end makes contact with the film and is pressed it against the abrasive film with bending. The motor rotates the abrasive film, and the fiber endface is formed by employing the bending force of the fiber.

In the sharpening process, the shortened length of the coated fiber is determined by the processing time, the grain size of the abrasive film and bending shape of the fiber. The bending shape of the fiber is determined by the protrusion length from the fiber holder L and the distance between the abrasive film and the fiber holder d, as shown in Fig. 6. We measured the relationship between the shortened length of the coated fiber and the processing conditions when using the forming tool. Here, we varied the processing time and the bending shape of the fiber. The grain size of the abrasive film was 40 μm. The distance between the abrasive film and the fiber holder was 10 mm. Figure 7 shows the experimental results we obtained for the shortened length of coated fiber. The shortened length increased as the processing time and the L value increased. The results indicate that we can achieve a shortened length of more than 0.5 mm by controlling the bending shape of the fiber and the processing time.

We polish the sharpened endface by using the forming tool, as shown in Fig.6. In the polishing process, L is smaller than the length in the sharpening process. The slightly bent shape of the fiber enables us to form the sharpened endface into the convex endface. We measured the relationship between the bending shape of the fiber and the curvature radius of the convex endface when we changed the bending shape of the fiber. We used an abrasive film with a grain size of less than 1 μm. The distance between the abrasive film and the fiber holder was 10 mm. Figure 8 shows the experimental results we obtained for the curvature radius of the polished endface. The results reveal that we can achieve the target curvature radius of more than 23 µm by controlling the bending shape of the fiber. We also measured the return loss when we connected the polished endface using the axial compression force, as shown in Fig. 8. We confirmed that the polished endface achieved PC connection with return loss of more than 40 dB when we used a bending condition with an *L*-*d* value of less than 0.2.



(b) Schematic diagram
Fig. 6 Fiber endface forming tool

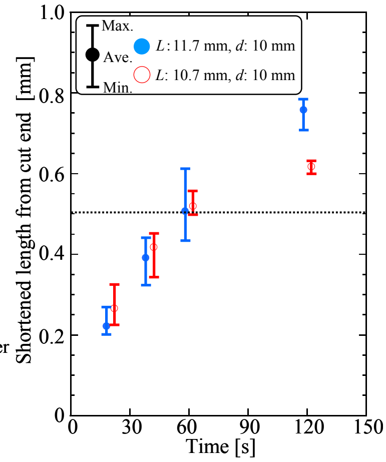


Fig.7 Processing condition dependence on shortened length

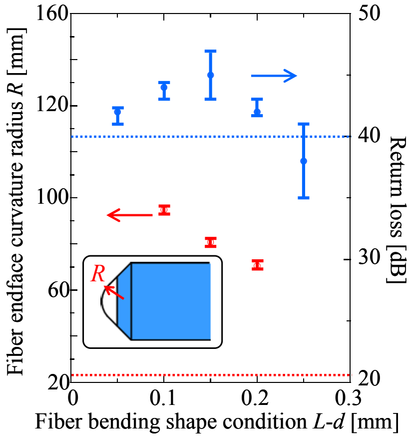


Fig. 8 Fiber bending shape condition dependence on curvature radius and return loss

5. Optical performance

The proposed connector aligns the glass fibers inside a micro-hole located at a ferrule end, and the buckled fiber generates axial compression force between the aligned fiber endfaces, as shown in Fig. 1. We prepared a connector that had a 100 µm-length micro-hole and a flange with a buckling length of 8 mm based on the design for PC connection. We measured the optical performance of the SMFs with the endface formed with the forming tool. When we inserted the coated fiber into the micro-hole, we confirmed that the coating was pushed back and that only the glass was inserted into the micro-hole in accordance with the proposed structure, as shown in Figs. 1 and 2. Figures 9 and 10, respectively, show histograms of the connection and return losses for 20 pairs of the connected fibers. The connection losses for SMFs were less than 0.31 dB with an average value of 0.16 dB and a σ value of 0.09 dB. The minimum return loss was 42 dB, which confirmed that all the connected fibers achieved PC connections. The results meet with the performance requirements stipulated in IEC 61753-2-1, which sets the performance standard for SMF connection for an uncontrolled environment.

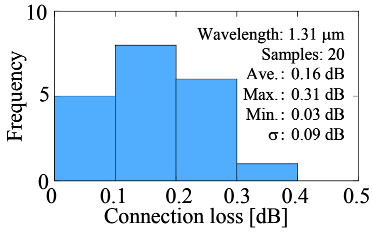


Fig. 9 Connection loss histogram

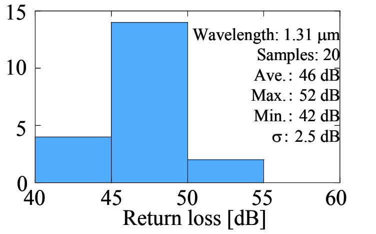


Fig.10 Return loss histogram

6. Conclusions

We proposed a new physical contact optical connector that uses a stripping-free connection method. The proposed connector does not require the coated fiber to be stripped and cleaved thus facilitating assembly. We designed the connection structure and clarified the fiber endface shape needed to realize PC connection. We also designed a method for forming the required fiber endface. We conformed that our stripping-free connection method achieved PC connection with a return loss of more than 42 dB and an average connection loss of 0.16 dB.

7. References

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