84-fiber MPO connector employing solid refractive index matching material formed on perpendicular polished MT ferrule end

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Abstract: We demonstrate 84-fiber MPO connector employing a perpendicular MT ferrule and solid refractive index matching material that can overcome the extreme difficulty posed by the design and manufacturing of multi-fiber connectors holding many fibers.

1. Introduction

The data transfer speed between data communication equipment in data centers has been increasing in recent years, and the use of multi-fiber optical links between such buildings is expanding. This demands the connection of multi-fiber cables. Multi-fiber cables are connected by either fusion splicing of individual fibers or multi-fiber connectors. As the number of connected fibers is increasing, demand is increasing for multi-fiber connectors that offer short construction times and ease of installation. The multi-fiber push-on (MPO) connector [1] is widely used as a standard multi-fiber connector. The MPO connector consists of a male plug, which contains pre-installed guide pins, a female plug with guide holes on the connector endface, and an adapter that couples the plugs. Inside the MPO connector plug, the fibers are fixed into fiber holes in an MT ferrule, and when one plug is connected to another, the MT ferrule is aligned with the opposite MT ferrule by guide pins and guide holes. The MT ferrule end is obliquely polished to suppress the Fresnel reflection and obtain a high return loss. To achieve a physical contact connection between the connected fiber endfaces, the ferrule is loaded by a spring in the plug. The MPO connector achieves a low connection loss as its design allows the MT ferrule to slide and axially shift when the obliquely polished ends come into contact with each other due to the compression force of the spring. The compression force of a typical 12-fiber MPO connector ranges from 7.8 to 11.8 N [2]. That of a 24-fiber MPO connector ranges from 18.0 to 22.0 N [3]. A 32-fiber MPO connector using compression force of 22 N has been reported for single-mode fiber [4]. Thus, as the number of connected fibers increases, the required compression force tends to increase as well. We can assume that this trend will increase difficulties in connector design and manufacturing, and will also make it more difficult to suppress the connection loss. To handle greater numbers of connected fibers in the near future, we proposed a connection structure that eliminates the need for an increase of the compression force regardless of the number of connected fibers [5]. In this report, we demonstrate an 84-fiber MPO connector using the proposed connection structure with a compression force of 10 N.

2. Multi-fiber connection with solid refractive index matching material

Figure 1 shows the proposed structure. The solid refractive index matching material is cured on the fiber ends in the MT ferrule. The refractive index of the material matches that of the optical fiber. The MT ferrule end is polished perpendicular to the optical fiber axis. This arrangement virtually eliminates sliding of the MT ferrules and thus any increase in the connection loss. The solid refractive index matching material suppresses the Fresnel reflection and attains high return loss without oblique polishing of the MT ferrule end. With the proposed structure, there is no need to increase the spring force even if more fibers are connected. Figure 2 shows a method for forming the layer of the refractive index matching material on the MT ferrule end. First, the appropriate amount of the liquid refractive index matching material is dropped onto the end of the MT ferrule. Next, a spacer with a rectangular hole equal to the area of the MT ferrule endface is centered on the ferrule. The thickness of the spacer controls the thickness of the layer of the refractive index matching material. UV light is used to cure the refractive index matching material. UV light is irradiated while the spacer is pressed against the ferrule endface with a transparent glass plate. Fig. 3 shows a model for the calculation where there is a gap between the optical fibers to be connected. There is no misalignments of the optical fibers in terms of offset and tilt. In our calculation, we assume that the gap is filled with the refractive index matching material with the refractive index n. n_1 is refractive index of the optical fiber's core, and S is the gap width between the optical fiber ends. We can calculate the return loss R and connection loss T between the coupled fibers in the model by using the next equations from references [6] and [7].

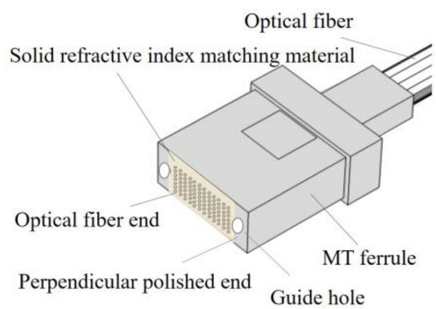


Fig. 1. Multi-fiber connection structure.

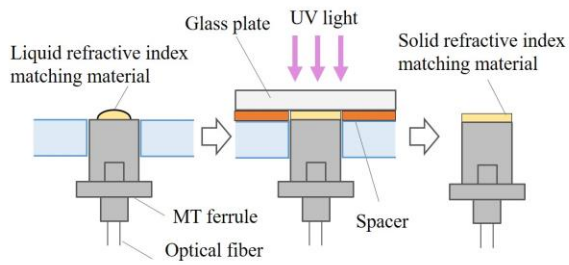


Fig. 2. Forming method.

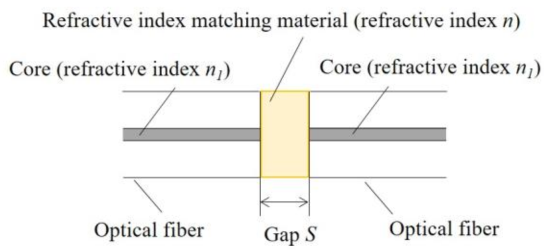


Fig. 3. Calculation model.

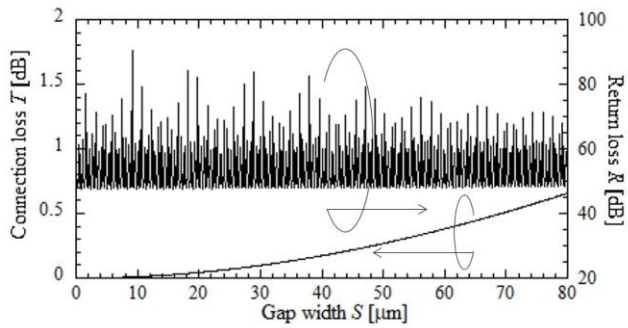


Fig. 4. Calculation results of connection and return losses.

$$T = \frac{(1-R_0)^2 A}{(1-AR_0)^2 + 4AR_0 \sin^2(2\pi n S/\lambda)} \qquad (1)$$

$$R = \frac{(1-A)^2 R_0 + 4AR_0 \sin^2(2\pi n S/\lambda)}{(1-AR_0)^2 + 4AR_0 \sin^2(2\pi n S/\lambda)} \qquad (2)$$

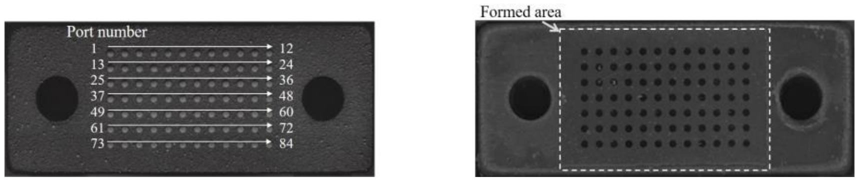
$$A = \left[\left(\frac{\lambda S}{2\pi n \omega^2}\right)^2 + 1\right]^{-1} \qquad (3)$$

$$R_0 = \left(\frac{n_1 - n}{n_1 + n}\right)^2 \qquad (4)$$

where λ and ω is the wavelength and the mode field diameter of the transmitted light, respectively. Fig. 4 shows the calculated results of R and T when S is varied. Here, n_1 is 1.454, n is 1.448, λ is 1.31 μm and ω is 4.94 μm. R remained above 40 dB regardless of the S value. By setting the refractive index of the refractive index matching material appropriately, we can obtain good return loss regardless of the thickness of the refractive index matching material. The calculated T values show that the thicker the layer of the refractive index matching material is, the larger the connection loss becomes. This result indicates that the layer of the refractive index matching material should be as thin as possible to reduce the connection loss.

3. Results

We made a prototype of an 84-fiber MT ferrule for an 84-fiber MPO connector. We estimated the maximum number of fibers that would fit into the size of a conventional MT ferrule, and developed the prototype 84-fiber MT ferrule accordingly. The 84-fiber MT ferrule has 84 fiber holes that hold seven 12-fiber ribbons. We first fabricated an 84-fiber MT connector using the 84-fiber MT ferrule. The 84-fiber MT ferrules were aligned by inserting the two guide pins into the two guide holes and pressed together by the clamp spring. The end of the MT ferrule was perpendicularly polished. We employed a gel refractive index matching material that is used in conventional MT connectors. We measured the connection and return losses of a pair of the 84-fiber MT connectors. The losses were measured at a wavelength of 1310 nm. The average and the maximum of the connection loss is 0.58 dB and 1.58 dB, respectively. This result reveals that the fiber-hole accuracy of the 84-fiber MT ferrule is inferior to that of MT ferrules with fewer fibers such as 4 or 8. The return loss was more than 40 dB for all connected fibers. By measuring the 84-fiber MT connector, we were able to confirm the accuracy of fiber-hole positioning of the 84-fiber MT ferrule and also obtain the loss value of the 84-fiber MT connector to form the pass/fail criteria that the 84-fiber



(a) Without solid refractive index matching material (b) With solid refractive index matching material

Fig. 5. Photographs of 84-fiber MT ferrule endface.

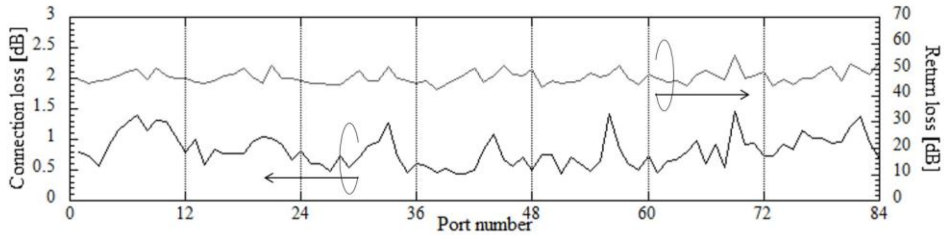


Fig. 6. Connection and return losses of 84-fiber MPO connector.

MPO connector should achieve. Next, we formed the layer of the solid refractive index matching material on only the 84-fiber MT ferrule end by using the forming method as shown in Fig. 2. We investigated the hardness of the refractive index matching material to achieve high return loss and obtained a guideline that the hardness should be less than 52 (Shore A value) [5]. We used the solid refractive index matching material with Shore A hardness of 45 and refractive index of 1.448. To reduce the connection loss, the thickness of the refractive index matching material should be as thin as possible. However, it was difficult to cover all 84 fibers with a thin thickness uniformly, so the 84 fibers ends were covered with a thickness of about 50 μm which yielded the excess loss of 0.27 dB from the calculation results in Fig. 4. Fig. 5 shows the photographs of the 84-fiber MT ferrule end without and with the solid refractive index matching material. The refractive index matching material covered the entire surface of the optical fiber ends. We fabricated a pair of 84-fiber MPO connectors by housing the 84-fiber MT ferrule and the spring with the compression force of about 10 N. Fig. 6 shows the measured values of the connection and return losses for each port of the 84-fiber MPO connectors. The losses were measured at a wavelength of 1310 nm. The average and the maximum of the connection loss is 0.82 dB and 1.45 dB, respectively. The connection loss satisfied our connection loss criterion because the average loss value was almost equal to the sum of the average loss value of the 84-fiber MT connector and the calculated excess loss. The return loss values were more than 42 dB. The results indicate that there was no air gap between the solid refractive index matching material and the opposing MT ferrule end. Our proposed multi-fiber connection structure enables us to attain high return loss without obliquely polishing of the MT ferrule end. We also verified that there is no need to increase the spring force even if the number of connected fibers with the proposed structure. We think that the connection loss can be reduced further by improving the accuracy of the fiber hole positioning in the 84-fiber MT ferrule.

3. Conclusions

We demonstrated an 84-fiber MPO connector that forms the solid refractive index matching material on the perpendicular polished MT ferrule end. The 84-fiber MPO connector provided sufficient return loss for practical use with a compression force of 10 N. We verified that our proposed multi-fiber connection structure eliminates the need for an increase of the compression force regardless of the number of connected fibers.

4. References

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