96-Core MPO-APC Connector using 4-core fiber with SMF Standard Insertion Loss Grade

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Abstract: We developed 96-core MCF-MPO connector with 8-degree angled endface. Fabricated connectors achieved 0.12 dB average insertion loss and all core PC, and passed Telcordia GR 1435-CORE Durability and Humidity Condensation Cycling Test. © 2024 The Authors

1. Introduction

The demand for high bandwidth optical interconnects in data centers has been increasing due to the rapid growth of optical network traffic [1]. Today, optical fiber cables using small diameter fibers [2] and multi-fiber MPO connectors which enable the connection of multiple optical channels and create higher density have been widely deployed to meet this demand. In order to address future growth for the demand for higher channel count, multi-core fiber (MCF) and multi-MCF connector can play an important role since MCF can increase the channel count. Multi-MCF connectors with an insertion loss (IL) of ≤ 1 dB have been studied and realized [3-5], as summarized in Table 1. To realize low IL, previously reported multi-MCF connectors adopted "fiber rotation alignment members (FRAM)", where MCFs were rotationally aligned and fixed. However, only a small number of multi-MCF connectors using FRAM have been evaluated and their reliability of the connector has not been evaluated. In addition, the return loss (RL) of multi-MCF connectors with 8-degree angled polish have not been measured.

In this paper, 5-pairs of 96-core MPO-APC connectors with 10N mating force were fabricated and their characteristics evaluated. The connectors were made possible by the MT-insertable MCF array method [5], MCF-optimized polishing, standard 24MT ferrules and 125-μm-cladding 4-core fibers [6]. We confirmed the IL of the fabricated connectors were 0.12 dB in average and 0.34 dB at a probability of 97%. We also confirmed the RL of the connectors were 55.0 dB at minimum which mean all cores achieved physical-contact (PC). These results are compatible to IEC 61753-1 Grade C / Grade 1. We also conducted Telcordia GR 1435-CORE Durability test and Humidity Condensation Cycling Test. We confirmed the IL of the fabricated connector were sufficiently suppressed and compatible to Telcordia GR 1435-CORE standard performance.

Table 1. Comparison of reported and present multi-MCF connector using FRAM with the IL of ≤ 1 dB

Ref.	Connector type	Core count	Number of evaluated pair	IL (dB) Avg.	IL (dB) 97%	IL (dB) Max.	RL (dB)	Contact method
[3]	MPO	56 (7-core ×8-fiber)	1	n/a	n/a	0.85†	>40†	PC, 18N
[4]	MT	84 (7-core × 12-fiber)	3	n/a	n/a	0.8†	n/a	Index matching gel
[5]	MPO	96 (8-core × 12-fiber)	1	0.29‡	n/a	0.57‡	n/a	Angled PC, 22N
[5]	MT	256 (8-core × 32-fiber)	1	0.26‡	n/a	0.93‡	n/a	Index matching gel
This work	**MPO**	**96 (4-core × 24-fiber)**	**5**	**0.12‡**	**0.34‡**	**0.55‡**	**>55‡**	**Angled PC, 10N**

† Measured at 1550 nm, ‡Measured at 1310 nm.

2. Structure of multi-MCF connector

There are two major challenges to realize multi-MCF connectors since MCF has outer cores located in the non-center part of the cladding. The first challenge is the simultaneous precise rotational alignment of multiple MCFs in a MT ferrule for low IL, and the second one is the suppression of the mating force for PC for achieving low reflection. In order to realize precise rotational alignment, suppression of the effect of twisting MCF in the fiber hole of the MT ferrule due to friction is required. One possible solution for suppression of the effect is the MT-insertable MCF array method which we have developed and reported [5]. This method has two processes for avoiding twisting MCFs, which are a process to fabricate the MCF array and a process to insert the MCF array into the MT ferrule, as shown in Figure 1. To fabricate an MCF array with precise rotational alignment, we have developed a technique to hold the MCF precisely to maintain the rotational angle of the aligned MCF. We have also developed a technique to insert an MCF array into a MT ferrule without twisting it in order to reduce rotation of the MCF caused by the friction between the MCF and the fiber hole in the MT ferrule. Figure 2 shows the result of rotational misalignment of 10 fabricated 24-MPO connectors. By utilizing the above techniques, we succeeded in fabricating multi-MCF connectors with less than ± 0.84-degree misalignment.

In multi-MCF connectors, PC is achieved by the deformation of the MT ferrule, epoxy adhesive and MCF. In order to suppress the mating force for PC, reducing the difference between fiber protrusions is important since high pressing force is required to achieve PC with the lowest-protrusion fiber if the difference is large. In addition, flat MCF-endfaces are required to achieve the outer cores of PC with low pressing force. To reduce the mating force of PC, we numerically investigated the PC condition for a 96-core (125-μm-cladding 4-core fiber × 24-MT ferrule) MPO connector with 8-degree angled endface using a finite element method. Figure 3(a) shows the schematic of the calculation model. In this calculation, as shown in Figure 3(b), we modeled the connector with the maximum difference between the fiber protrusions *d*, and MCF curvature radius *R*. We also set the core position from the fiber center as 28μm and the SM core diameter as 10μm, and defined the required PC radius as 33μm, which was the minimum distance from the fiber center to achieve PC for all cores. The relationship between *d* and *R* for 96-core PC is shown in Figure 4. We confirmed that a larger R is required for all the 96-core PCs compared to the *R* in single core fiber (SCF) MPO connectors which is around 10 mm. To realize larger *R* and the PC condition, we have developed an MCF-optimized polishing method by reviewing the final polishing condition of SCF-MPO connector.

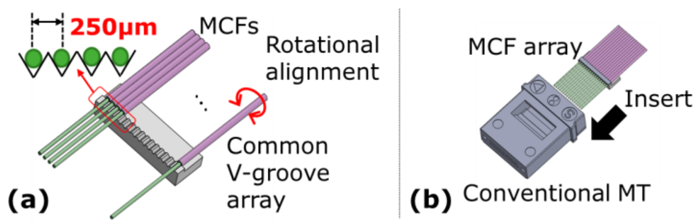

Fig. 1. MT-insertable MCF array method [5]
(a) Fabrication of MCF array process (b)Inserting MCF array process.

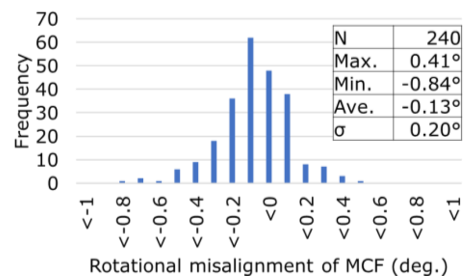

Fig.2. Rotational misalignment of MCF at 10 fabricated 24-MPOconnectors.

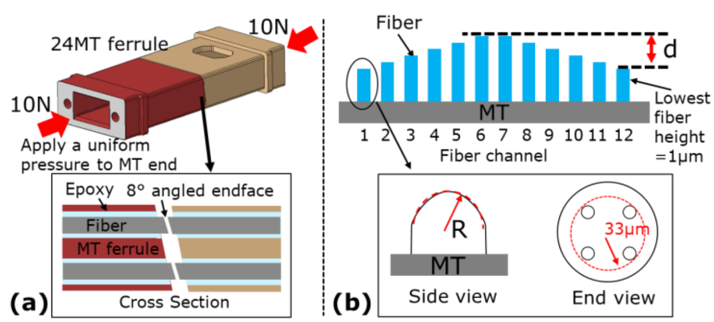

Fig. 3. (a)The calculation model. (b) The definitions of the parameters.

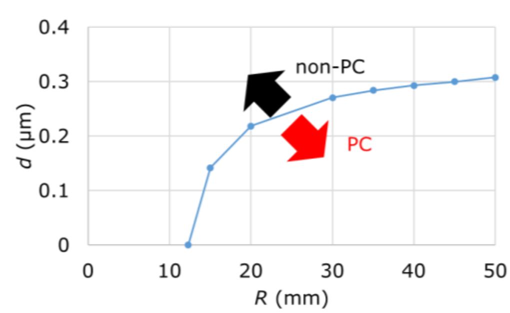

Fig. 4. PC condition of 96-core connector.

3. Evaluation of optical characteristics of multi-MCF connector

We fabricated 5-pairs of 96-core MCF-MPO connectors with 8-degree angled endface and 10N mating force to evaluate the IL and RL distribution. The connector used a 125-μm-cladding 4-core fiber, conventional 24MT ferrules, and MPO housing. Figure 5 shows the IL and RL distribution of the fabricated connectors. The IL at λ of 1.31μm were 0.12 dB in average and 0.34 dB at a probability of 97%. The RL at λ of 1.31μm was more than 55.0 dB, which means all cores achieved PC. The result was compatible to IEC 61753-1 Grade C and Grade 1.

To evaluate the reliability of the fabricated connectors, we conducted Telcordia GR-1435-CORE Durability test and Humidity Condensation Cycling test with one pair of the fabricated connectors. Figure 6 shows the results of the Durability test. The IL was less than 0.72 dB and the IL change was less than 0.18 dB. These results were compatible to the standard performance of Telcordia GR1435-CORE. Figure 7 shows the results of the Humidity Condensation Cycling test. The IL was less than 0.70 dB and the IL change was less than 0.24 dB. This result also meets standard performance and we confirmed the fabricated connectors have good reliability.

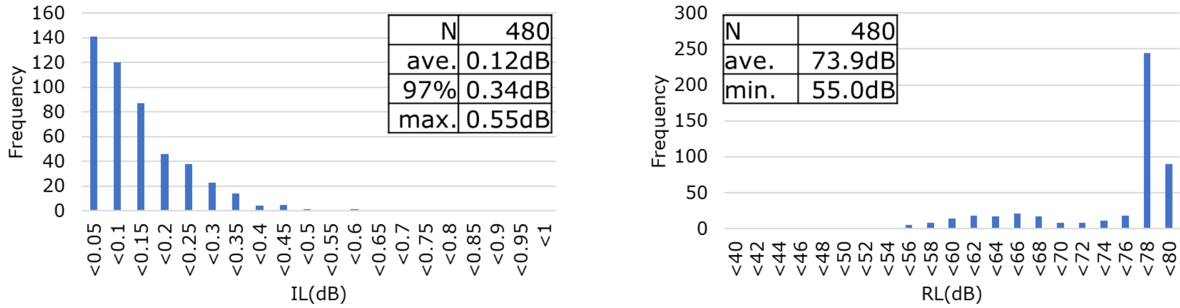

Fig. 5. IL and RL distribution of 5-pairs 96-core MCF-MPO-APC connectors.

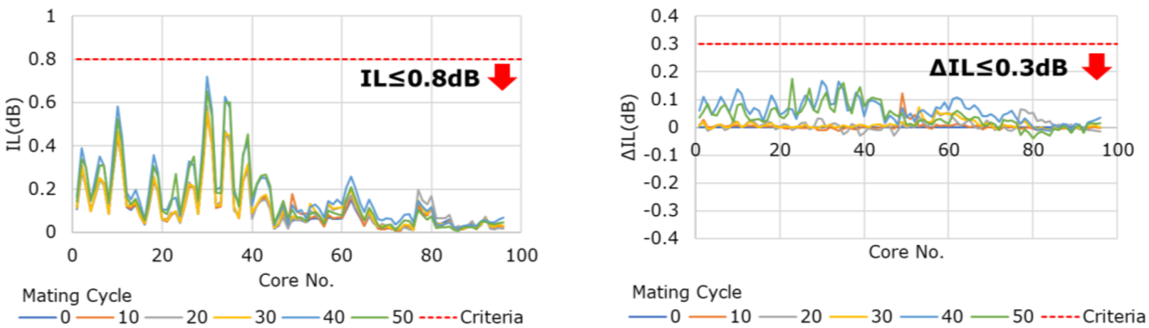

Fig. 6. Results of Durability Test.

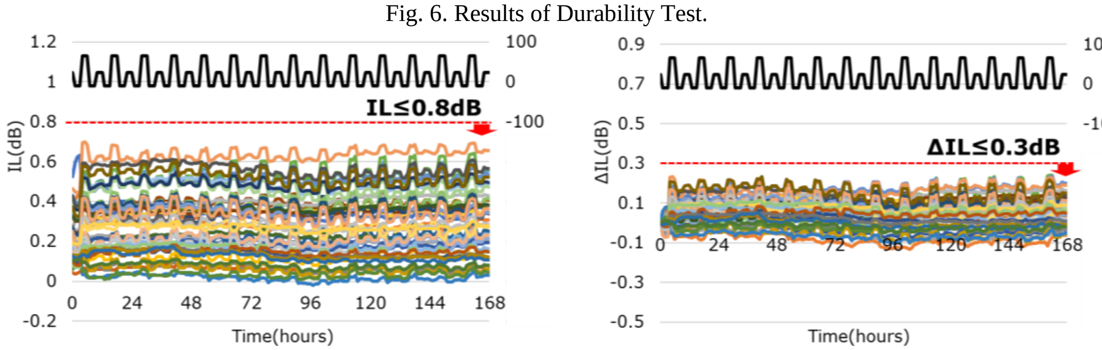

Fig. 7. Results of Humidity Condensation Cycling Test.

4. Conclusion

We fabricated and evaluated 5-pairs of 96-core MPO-APC connector using 4-core fiber with 10N mating force. We confirmed an IL at λ of 1.31μm was 0.12 dB in average, 0.34 dB at a probability of 97% and the RL at λ of 1.31μm was more than 55.0 dB. These good IL and RL values were realized by our MT-insertable MCF array method and MCF-optimized polishing. We also confirmed the IL of the fabricated connectors were sufficiently suppressed under Telcordia GR-1435-CORE Durability test and Humidity Condensation Cycling test. The results of the tests were compatible to Telcordia GR 1435-CORE standard performance.

Acknowledgments

This research is supported in part by the National Institute of Information and Communications Technology (NICT), Japan under commissioned research No. 2030103.

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