Small Footprint Air-gap Multi Fiber Connector with Low Loss and Low Mating Force

Hajime Arao, Sho Yakabe, Fumiya Uehara, Dai Sasaki, and Takayuki Shimazu
Sumitomo Electric Industries, Ltd., 1, Taya-cho, Sakae-ku, Yokohama, 244-8588 Japan
arao-hajime@sei.co.jp

Abstract: Multi-fiber connector with low mating force (3N) has been developed by applying gap between fibers. The proposed multi-mode/single-mode connector has achieved an average loss of 0.49dB/0.67dB and more than 38dB/60dB return loss without anti-reflection coating.
OCIS codes: (060.2340) Fiber optics components; (200.4650) Optical interconnects; (060.0060) Fiber optics and optical communications.

1. Introduction

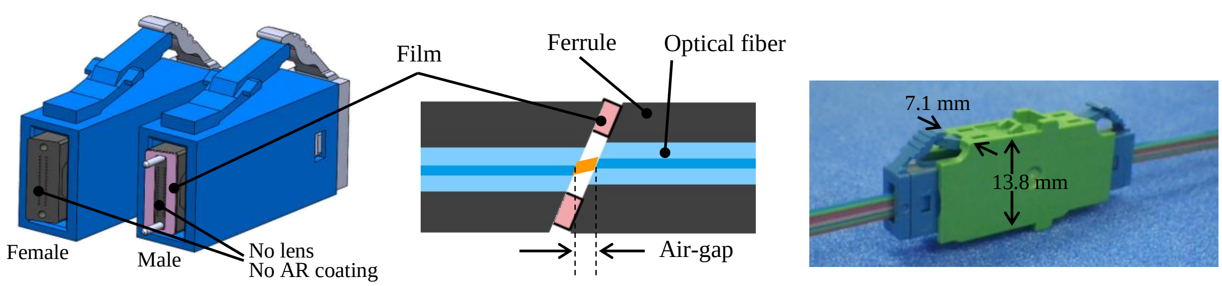
A recent increase of data traffic in data centers creates a requirement of high density optical connector like the MPO connector [1]. Nowadays higher fiber count MPO connectors that needs physical contact (PC) mating has been developed and reported [2]. However, further increase of fiber count for MPO connector would increase the mating force to sustain PC condition [3]. According to the IEC standard for MPO connector, the compression force of 24-fiber MPO connector is 20 N (IEC 61754-7-2), while that of 12-fiber MPO connector is 9.8 N (IEC 61754-7-1). Today this force is accepted, but becomes a serious challenge when multiple connectors are ganged at once. Another challenge for MPO connector is control of cleanness at the end face, dust can permanently interfere with the light path and increase the insertion loss (IL). Therefore careful end face cleaning is necessary for MPO connector.

To overcome these challenges, new types of connectors without PC mating have been widely studied. Most widely studied non-PC connectors are lensed connectors [4-8]. The mating force of lensed connectors is less than that of MPO connector and is not dependent on fiber count since they do not require a PC mating. Since the beam is expanded, the increase of IL caused by dust rarely occurs. Air-gap connectors [9] apply a tiny air gap between the fiber faces of mated connectors and have the ability to reduce a mating force. The possibility of an interruption due to dust may be higher than lensed connector but the end face cleaning is easier than MPO connector because of non-contact mating. If the air gap is very tiny, the optical interference between input beam and reflected beam will occur and IL will vary with wavelength or gap thickness, but they can be suppressed by anti-reflection (AR) coating [9].

In this paper, we propose a new type of air-gap multi-fiber connector. The manufacturing process of this connector is completed by the simple process of adding a fixed gap to the surface of the male ferrule. By optimizing the thickness of the gap and the angle of the ferrule end face, stable optical characteristics have been achieved without AR coating. This means that an apparatus such as a vacuum chamber is not necessary. In addition, as mentioned above, it has a low mating force and easy end face cleaning. We fabricated the connectors for multi-mode fiber (MMF), evaluated the optical characteristics and did reliability tests. We also fabricated the connectors for single-mode fiber (SMF) and evaluated the optical characteristics.

2. Structure and Optical design

The proposed structure of air-gap 24-fiber connector is shown in Fig. 1. The manufacturing process of this connector is completed by adding a process for fixing film on the surface of the male ferrule. Since this film is made by same material as the ferrule, they can be firmly fixed even if the temperature changes. The mating force of these connectors is 3 N and this load is about one-seventh versus the MPO connector. This low mating force can be made



(a) Perspective view (b) Cross-sectional view (c) Picture of mated connectors and adaptor

Fig. 1. Structure of proposed connector

with a simple housing design, the cross sectional area ratio can be reduced by 65% versus the MPO while at the same time the MPO connector needs to have additional robustness to withstand this heavy insertion force.

In this connector, the relationship between the thickness of the gap, loss and optical interference is important, that is shown in Fig. 2. According to the graph, the larger the gap, the larger the propagation loss becomes. These values are obtained experimentally for MMF and calculated by propagation theory of Gaussian beam for SMF. According to the pictures, propagation of the reflected beam is increased as the gap becomes smaller. The propagation of the reflected beam causes the optical interference and the IL variation with wavelength or gap thickness. The red rectangular frame in the graph indicates the area where the optical interference occurs. For MMF, this area is obtained experimentally as shown in the graph, whereas for SMF it was theoretically calculated as the value that WDL becomes more than 0.025 dB at peak to peak. We designed for “low propagation loss (< 0.15 dB)” and “interference suppression without AR coating” by optimizing the “gap between the fiber faces of the mated connectors” and “face angle of the ferrule”. At 8° end faces, commonly used for MPO connectors, the value of the gap satisfying all the conditions exists for MMF but not for SMF. A similar calculation was made by changing the angle to 16° for SMF. At this angle, the value of the gap satisfying all the conditions is obtained. In consideration of these results and manufacturing variation, the face angle is 8° and the gap between the fiber faces of the connectors is 25 μm for MMF, meanwhile for SMF the face angle is 16° and the gap between the fiber faces of the connectors is 16 μm. Red dots in Fig. 2 show the design value.

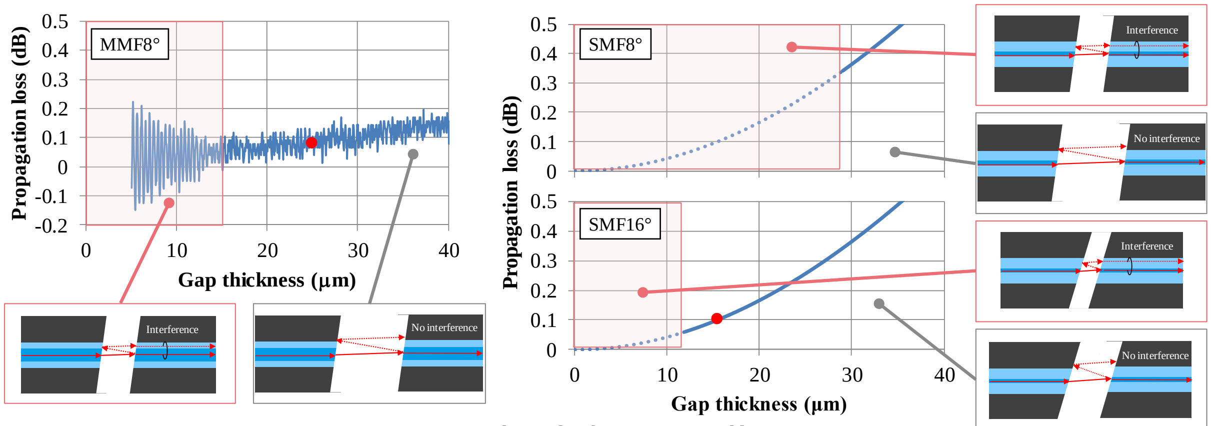
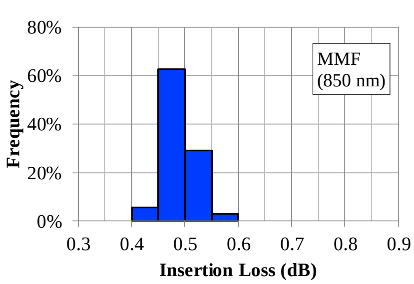


Fig. 2. Relationship between gap and loss

3. Evaluation of optical characteristics

MM 24-fiber air-gap connectors were fabricated and their optical properties were measured. The insertion loss is summarized in Fig. 3. This data was measured by random connection of 6 male connectors and 6 female connectors (N = 288 channels). The IL at the wavelength (WL) of 0.85 μm and 1.30 μm is less than 0.55 dB and 0.54 dB with a probability of 97%, respectively. The average IL at the WL of 0.85 μm and 1.30 μm is 0.49 dB and 0.47 dB respectively. The loss due to alignment is low, instead it is mainly composed with Fresnel loss at the end face (about 0.31 dB per 2 surfaces) and the diffraction loss traveling in the air between the fibers. The return loss (RL) was also measured to be more than 38 dB for the WL of 0.85 μm and 1.30 μm. This high return loss is obtained by the higher end face angle. Fig. 4 shows the repeatability test results. The loss fluctuation could be suppressed to less than 0.08 dB during 1,000 mating. The cleaning was done by only blowing air onto the connector surface every 5 mates and did not use conventional dry / wet cleaning tools. Because of non-contact connection, the dust does not stick on the surface, therefore air blowing cleaning works well to clean the end face. Finally, reliability test was performed based



WL	850 nm	1300 nm
Ave.	0.489 dB	0.472 dB
SD	0.027 dB	0.028 dB
97%	0.548 dB	0.536 dB

Fig. 3. Measured IL distribution (MMF)

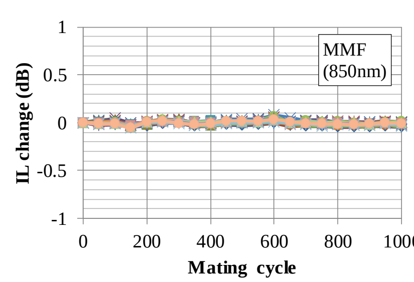


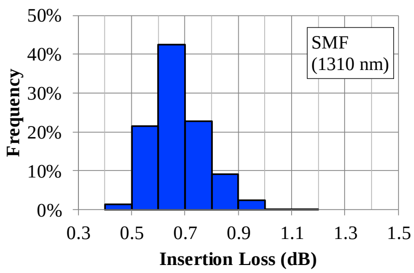
Fig. 4. Repeatability test results (MMF)

on the Telcordia GR-1435-CORE (Uncontrolled condition). 15 pairs of MMF connectors were tested and the IL for 3 channels of each connector were constantly monitored. The results are summarized in Table 1. The IL changes are measured to be less than 0.22 dB with good reliability.

Table 1. Summary of environmental and mechanical test results (MMF)

Item	Condition	Max IL change
Thermal Aging	85°C, 168 hr	0.09 dB
Humidity Aging	95%RH at 75°C, 168 hr	0.22 dB
Thermal Cycle	-40 to 75°C, 168 hr (21 cycles)	0.19 dB
Humidity Cycle	-10 to 65°C 95%RH, 168 hr (14 cycles)	0.20 dB
Vibration	10 to 55 Hz , 2 hr / Axis for 3 axis	0.02 dB
Flex	2.2 N, ±90°, 100 times	0.02 dB
Twist	2.2 N, ±360°, 10 times	0.02 dB
Transmission Under The Load	2.2 N, 0°	0.05 dB
Impact	1.5 m, 8 cycles	0.14 dB
Durability	50 cycles	0.01 dB

SM 24-fiber air-gap connectors were also fabricated and their optical properties were measured. The insertion loss is summarized in Fig. 5. This data was measured by random connection of 8 male connectors and 8 female connectors (N = 1,152 channels). The ILs at the WL of 1.31 μm and 1.55 μm are less than 0.90 dB and 0.82dB with a probability of 97%, respectively. The average ILs at the WL of 1.31 μm and 1.55 μm are 0.67 dB and 0.64 dB, respectively. The return loss was also measured to be more than 60 dB for the WL of 1.31 μm and 1.55 μm. A repeatability test was done with same scheme of MM connectors. The result is summarized in Fig. 6 and the loss fluctuation could be suppressed to less than 0.19 dB during 200 mating.



WL	1310 nm	1550 nm
Ave.	0.675 dB	0.642 dB
SD	0.099 dB	0.077 dB
97%	0.896 dB	0.820 dB

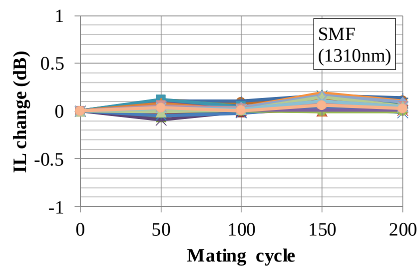


Fig. 5. Measured IL distribution (SMF)

Fig. 6. Repeatability test results (SMF)

4. Conclusion

We proposed and demonstrated a new type multi-fiber connector with air-gap that does not have AR coating. The proposed connector only adds a film fixing step in the manufacturing process and has a simple structure similar to MPO connector. Compared to the MPO connector, the air-gap mating force is one-seventh and the cross-sectional area ratio can be reduced by 65%. Proposed Air-gap connectors can dramatically increase the port density when multiple connectors are ganged at once. By optimizing "gap between the fiber faces of the mated connectors" and "face angle of the ferrule", "low propagation loss" and "interference suppression without AR coating" good performance can be achieved. For MM connectors using 0.85 μm and 1.30 μm wavelengths, a low average IL of 0.49 dB and 0.47 dB and a RL of more than 38 dB without AR coating have been achieved. For SM connectors using 1.31 μm and 1.55 μm wavelengths, a low average IL of 0.67 dB and 0.64 dB and a RL of more than 60 dB without AR coating have been achieved. To-date these are the best results for a non-PC connector without AR coating reported. The air-gap connector were cleaned by only using an air blowing process. For MM connectors a 1,000 times mating process achieved an IL change of less than 0.08 dB. For SM connectors a 200 times mating achieved an IL change less than 0.19 dB. Reliability tests based on the Telcordia GR-1435-CORE (Uncontrolled condition) was performed with 15 pairs of the MM connectors and IL changes are measured to be less than 0.22 dB.

5. Reference

[1] S. Nagasawa et al., "A high-performance single-mode multifiber connector using oblique and direct endface contact between multiple fibers arranged in a plastic ferrule," IEEE Photonics Technol. Lett., vol. 3, no. 10, pp. 937-939, 1991
[2] F. Uehara et al., "Highly Precise MT Ferrule Enabling Single-Mode 32-Fiber MPO Connector," Proc. IWCS2016, 13-4.
[3] S. Kato et al., "Condition for making physical contact of multi mode 2D MPO connector," Proc. IWCS2010, P-16.
[4] D. Childers et al., "Next-generation, high-density, low-cost, multimode optical backplane interconnect," Proc. SPIE, vol. 8267, 82670O, 2012
[5] A. Nakama et al., "High Density Optical Connector with Unibody Lensed Resin Ferrule," Proc. IWCS2015, 8-3.
[6] D. Childers et al., "New, single-mode, multi-fiber, expanded beam, passive optical interconnect," Proc. SPIE, vol. 8991, 89910J, 2014
[7] O. Shimakawa et al., "Single-mode 24-fiber connector with GI fiber lens array," Proc. OFC2015, W4B.2
[8] H. Arao et al., "Single-mode 32-fiber connector with GI fiber lens array," 2015 IEEE Optical Interconnect Conference, WB4
[9] B. Jian, "The Non-Contact Connector: A New Category of Optical Fiber Connector," Proc. OFC2015, W2A.1