16F/24F, low-loss, Ferrule for MMC High-Density Optical Connector

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In recent years, the application of multi-fiber optical connectors has been expanding rapidly. In particular, some data center operators apply cutting-edge technologies such as AI and ML (machine learning) to their servers for increasing the speed and capacity of data transmission, and the number of connection points is expected to increase exponentially. There are problems for the limitation of server rack space to accommodate high-density connection and the control of connection loss. As a solution to these issues, Fujikura and US Conec have jointly developed a group of MMC connectors with ultra-compactness and low loss. The developed products have optical characteristics comparable to those of current MPO connector and have been evaluated in various performance tests which has been confirmed and maintain excellent optical performance.

1. Introduction

Due to the rapid development of optical interconnection and data transmission technologies, there is an increasing demand for multi-fiber optical connectors that can support high-speed and high-density transmission. In 400G+ next-generation link architectures that adopt pluggable optical transceivers and Co-Packaging Optics, a higher density optical cable installation solution is required, which cannot be achieved with existing MPO, LC, and SC optical connector technologies. Specifically, according to recent milestones, it is necessary to accommodate 1024 or more single-mode fibers in a 1RU space.

However, when applying the current MPO technology to meet this requirement, it is anticipated that interference with utility areas (such as power lines) would make implementation difficult (Fig. 1). Additionally, there is a technological requirement to achieve low-loss connections equivalent to MPO and LC connectors. Therefore, we have developed the MMC connector, which combines an implementation density approximately three times that of MPO and comparable low connection loss to conventional connectors. As shown in Fig. 2, the developed MMC connector is expected to be deployed in various applications such as multi-fiber cables connecting buildings and trunk cables connecting server islands. Furthermore, by applying MMC and reducing the size and weight of the product compared to conventional ones, it is also expected to contribute to reducing CO_2 emissions during transportation and construction, aligning with the important social goal of SDGs.

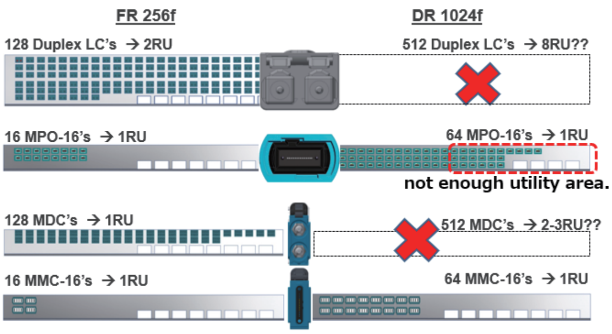

Fig. 1. Fiber core count requirements and the superiority of the MMC connector.

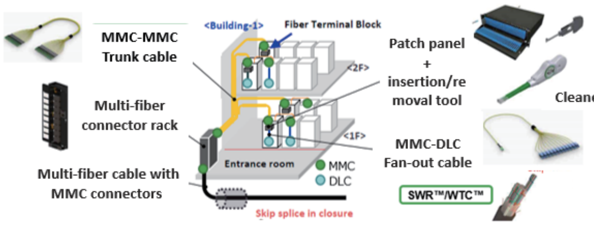

Fig. 2. Application of MMC connector products.

2. Structure

2.1 MMC connector

Figure 3 shows the appearance of MMC Connector [1)], which is a compact connector responsible for multi-core bulk connections in the next-generation connector solution, Very Small Form Factor (VSFF). The acronym MMC stands for "Mini-Multi-Connector," highlighting its small size and enabling its application in various scenarios.

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1 : Fujikura Ltd.,

2 : US Conec Ltd.,

Abbreviations, Acronyms, and Terms.

MT ferrule—Mechanichally Transferable Ferrule
A component that is precisely molded with high positional accuracy of fiber insertion holes to enable the simultaneous connection of multiple optical fibers.

MPO connector—Multifiber Push-On Connector
A multi-core push-pull type optical connector designed to enable the connection of multiple optical fibers using a single connector.

TMT ferrule—Tiny Mechanichally Transferable Ferrule
A compact MT ferrule that enables high-density implementation.

MMC connector—Mini-Multi-Connector
A compact MPO connector that enables high-density implementation.

SC connector—SC connector
The most common single-core optical connector. Easily detachable with a push-pull mechanism. The world standard connector for LAN. Plastic housing.

LC connector—LC connector
A push-pull type optical connector. It is compact and suitable for high-density arrangements due to its ferrule diameter being half of SC connectors. It features a plastic housing.

RU—Rack unit
The size and shape of one unit in a server rack are referred to as "U" (Unit). It is also known as "RU" (Rack Unit). Each unit has a width of 19 inches (approximately 482.6mm) and a height of 1.75 inches (approximately 44.5mm)

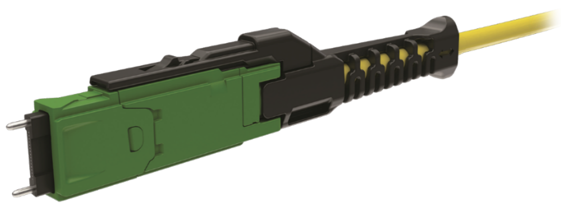

Fig. 3. Appearance of MMC connector.

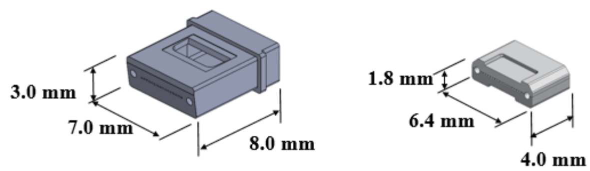

Fig.4. MT ferrule and 16F TMT ferrule dimensions.

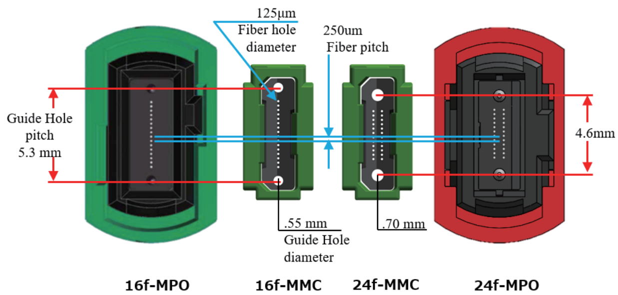

Fig. 5. Dimensional of MMC and MPO Connectors.

2.2 TMT Ferrule

In conventional MPO connectors, the MT ferrule is integrated into the housing tip for connection and disconnection. These connectors comply with industry standards such as IEC 61753-1[2] and Telcordia GR-1435[3], making them the de facto standard. In order to achieve high-density implementation for MMC connectors, we have developed a dedicated TMT ferrule ("Tiny-MT" abbreviation) that miniaturizes the MT ferrule (Fig. 4). The design of the TMT ferrule ensures compatibility with the alignment dimensions of the MT ferrule, such as guide hole pitch, guide hole diameter, and fiber aperture size [4] (Fig. 5). This design enables compatibility with conventional MPO connectors, as well as the sharing of fiber attachment-to-endface polishing dimensional measurement devices and fiber aperture eccentricity measurement devices with MT ferrules, resulting in versatility. The MMC connector aims to become the de facto standard for next-generation connectors, replacing MPO connectors, and the aforementioned versatility aligns with this goal.

2.3 MMC cleaner

To ensure the connection quality of optical connectors, cleanliness of the connector endface is crucial. For conventional MPO connectors, there are cleaners available that use non-woven fabric to remove contaminants from each connector's endface, ensuring the connection quality. However, with the high-density implementation of MMC connectors, the spacing between connectors becomes tighter, posing a challenge as existing cleaners cannot clean each connector individually (Fig. 6). Additionally, the cleaner needs to apply optimal pressure to remove contaminants without damaging the exposed fiber. As the TMT ferrule has a smaller mating area compared to the MT ferrule, optimization of the applied pressure becomes necessary. Therefore, we have developed an MMC cleaner by optimizing the dimensions of the nozzle and the tip of the cleaner (Fig. 7).

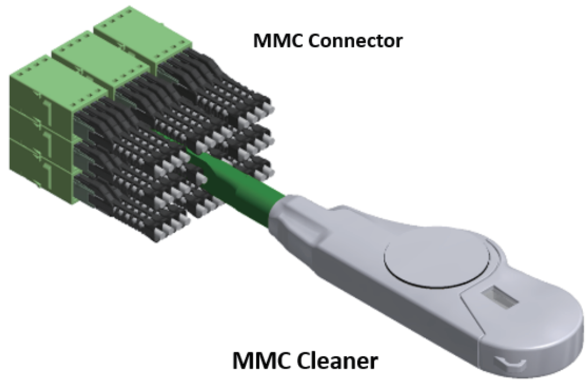

Fig. 6. Cleaning for high-density patch panels.

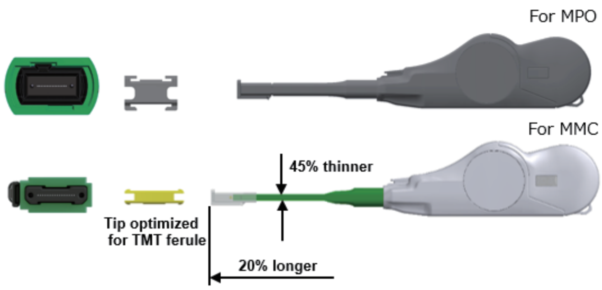

Fig. 7. Comparison of new MMC cleaner design to MPO cleaner design.

3. Performance

3.1 Optical performance

The most critical characteristic of an optical connector is the insertion loss (IL) during mating. IL represents the attenuation of the incident light as it passes through the connector interface and is expressed as a ratio, typically in dB. For multi-fiber connectors, the International Electrotechnical Commission (IEC) has defined different grades based on the acceptable level of insertion loss. The widely used MPO connector currently conforms to IEC 61753-1[2] Grade B, which specifies that the average IL should be ≤0.12 dB and the 97% value should be ≤0.25 dB for random mating. The development goal for the MMC connector is also to achieve Grade B compliance.

The value of IL is theoretically described by formula (1). As indicated by formula (1), to reduce IL, it is necessary to minimize the fiber core misalignment. The fiber core misalignment refers to the axial displacement that remains between the fiber cores of the male and female connectors within the same channel when they are mated. This core misalignment is determined by two factors on the ferrule: the core eccentricity, which represents the positional error of the fiber core with respect to the design (Fig. 8), and the shift generated by the mating spring force (Fig. 9) during connection.

By minimizing both the core eccentricity and the shift caused by the mating spring force, we can effectively reduce the fiber core misalignment and achieve lower IL values.

$$IL[dB] = 10 \times \log \left(exp \frac{d^2}{w^2} \right) \cdots (1)$$

d = fiber core misalignment [μm]
w = M.F.D.[μm]/2

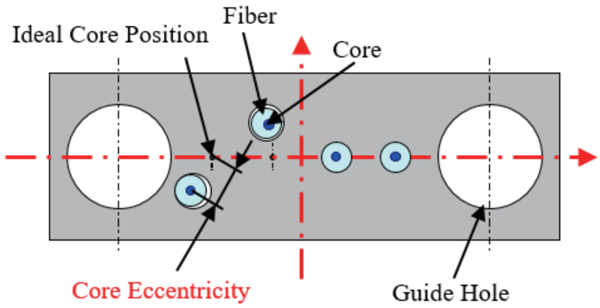

Fig.8, Illustration of fiber core ecencricity of MT ferrule.

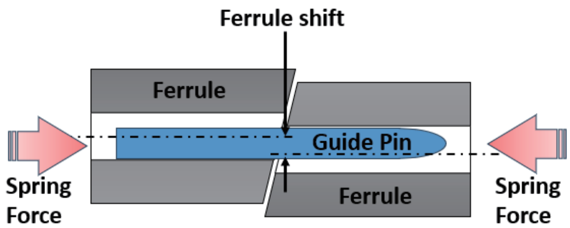

Fig.9. Ferrule shift by mating.

By controlling and optimizing these factors, we aimed to achieve the desired IL performance. Next, an important optical characteristic is the return loss (RL). RL indicates the ability to maintain stable optical communication, and it signifies that the endface shape is highly polished with excellent mating quality, including the housing. The fundamental technology for multi-fiber connectors is endface polishing, which involves physically contacting the optical fibers and applying an 8-degree angle to the ferrule endfaces to reduce Fresnel reflection. In this case, we developed a new polishing technique specifically for TMT ferrules.

Figure 10 shows the results of IL and RL measurements for randomly mated 16-core MMC connectors using a 1310 nm wavelength light source. This test complies with the requirements of IEC 61300-3-4[5] and IEC 61300-3-6[6]. The average IL was 0.06 dB, the 97% value was 0.22 dB, and the RL was 60.0 dB or higher. Additionally, Fig. 11 presents the test evaluation results for 24-core MMC connectors, also achieving compliance with Grade-B as defined in IEC 61753-1, with an average IL of 0.10 dB and a 97% value of 0.25 dB. These results confirm that we have achieved our development goals.

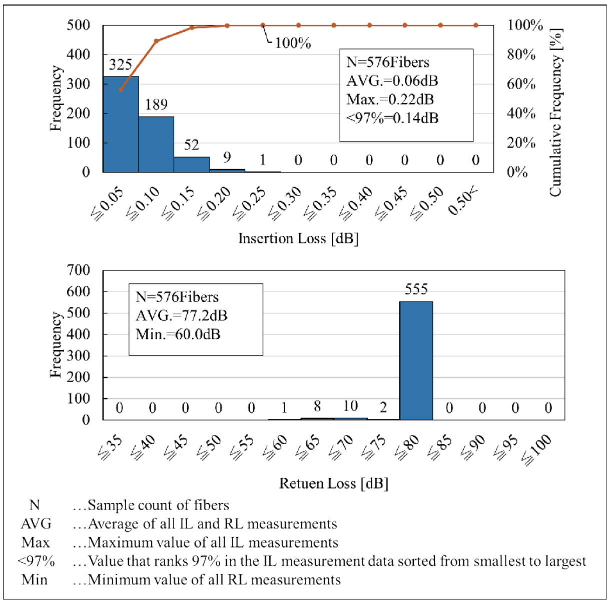

Fig. 10. Random mating test results for 16F MMC connectors.

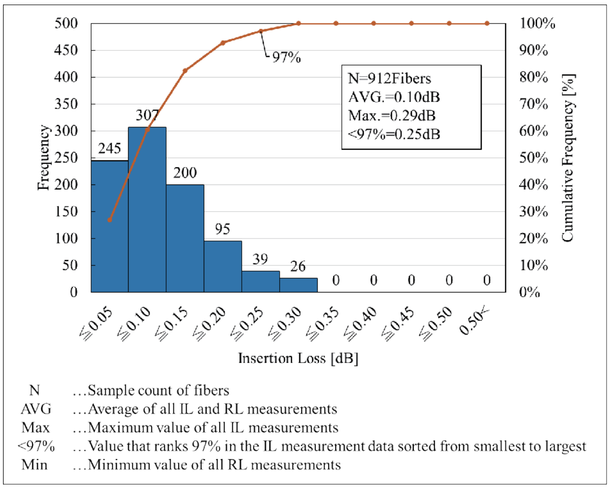

Fig. 11. Random mating test results for 24F MMC connectors.

3.2 Intermatability

Users generally procure components from multiple suppliers for operational and maintenance purposes. This applies even to multi-fiber optical connectors, as it allows for network flexibility. Therefore, evaluating compatibility among different manufacturers is an important factor.

In the development of MMC connectors, we collaborated with US Conec to ensure compatibility. The testing procedure involved receiving prototype TMT ferrules from US Conec and conducting IL and RL measurements through our evaluation process. The results, as shown in Fig. 12, achieved an average IL of 0.04 dB, a 97% value of 0.17 dB, and an RL of 63.4 dB or higher. These results also meet Grade-B standards, successfully meeting our development goals.

3.3 Environmental Testing

We conducted environmental testing of the developed MMC connector. Table 1 presents the test items, conditions, and test results. It should be noted that These tests are an accelerated test that simultaneously imposes

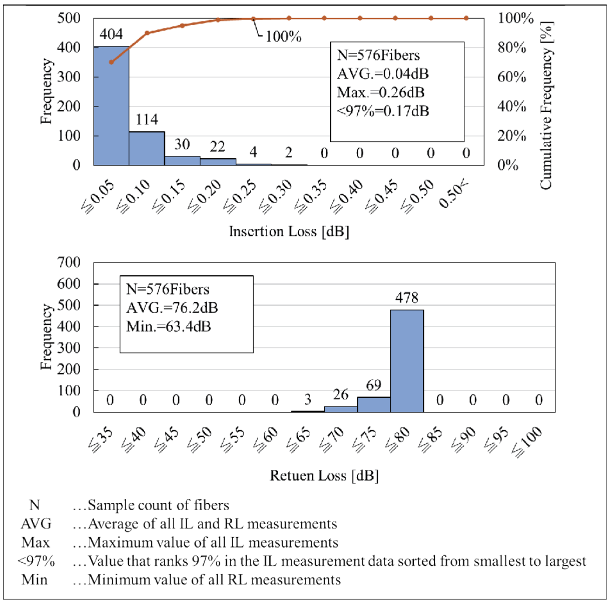

Fig. 12. Mating test results with Fujikura's 16F MMC connectors and US Conec's 16F MMC connectors.

the conditions specified in Telcordia GR-1435. Figure 13 illustrates the variation in IL and RL during the test period. As a result, it was confirmed that the developed MMC connector has enough environmental performance.

Table 1. Environmental test conditions, criteria and results.

Telcordia GR-1435			Accelerated Test			Result
Test	**Test Condition**	**Criteria**	**Duration**	**Test Condition**	**Criteria**	**Novel 16F MMC Connector**
Thermal Aging	**85°C**	Maximum Insertion Loss Change **≦0.30dB** Return loss ≧50dB	7days (21 Cycles)	**-40°C** to **85°C** Humidity **:95%**	Maximum Insertion Loss Change **≦0.30dB** Return loss ≧50dB	Maximum Insertion Loss Change =0.21dB Return loss =51.82dB
Humidity Aging	95% at 75°C					
Thermal Cycling	**-40°C** to 75°C					
Humidity/ Condensation Cycling	-10 °C to 65°C **90-100%**					
Dry-Out	75°C					

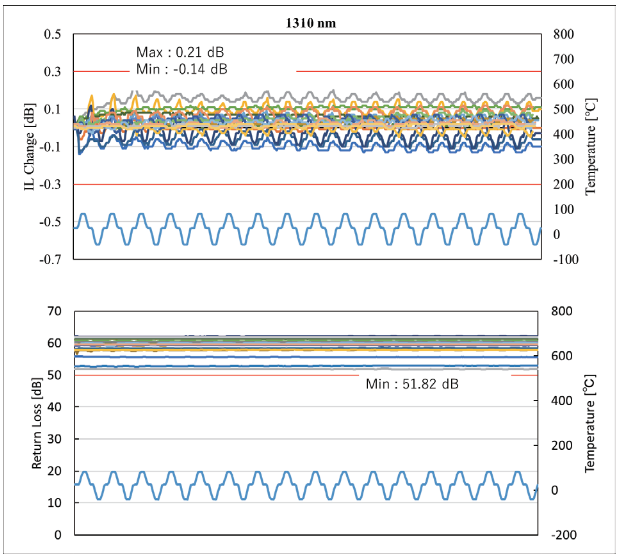

Fig. 13. IL change results during environmental testing of developed 16F MMCs.

3.4 Mechanical Testing

Table 2 presents the conditions and test results of the mechanical testing in accordance with the Telcordia GR-1435 standard. The developed MMC connector successfully passed all specified requirements, demonstrating excellent robustness.

Table 2. Mechanical test condition, criteria, and results.

Test		Condition	Criteria	Results
Vibration		10-55 Hz, 3-axis 2 h	IL ≦ 0.8 dB, IL change ≦ 0.3dB RL ≧ 50dB	IL ≦ 0.35 dB IL change ≦ 0.25 dB RL ≧ 55.3 dB
Flex		2.2 N, 100 cycles	IL ≦ 0.8 dB IL change ≦ 0.3dB RL ≧ 50dB	IL ≦ 0.51 dB IL change ≦ 0.16 dB RL ≧ 56.4 dB
Twist		2.2 N, 10 cycles	IL ≦ 0.8 dB IL change ≦ 0.3dB RL ≧ 50dB	IL ≦ 0.50 dB IL change ≦ 0.01 dB RL ≧ 56.3 dB
Transmission with Applied Load	Measure w/Load (0deg)	2.2 N	• After test IL ≦ 0.8 dB IL change ≦ 0.3dB RL ≧ 50dB • During Applied Load IL change ≦ 0.5dB RL ≧ 50dB	• After test IL ≦ 0.50 dB IL change ≦ 0.08 dB RL ≧ 66.3 dB • During Applied Load IL change ≦ 0.09 dB RL ≧ 66.4 dB
	Measure w/Load (90deg)	2.2 N	• After test IL ≦ 0.8 dB IL change ≦ 0.3dB RL ≧ 50dB • During Applied Load IL change ≦ 0.5dB RL ≧ 50dB	• After test IL ≦ 0.59 dB IL change ≦ 0.09 dB RL ≧ 66.6 dB • During Applied Load IL change ≦ 0.04 dB RL ≧ 66.2 dB
Impact		1.5 m, 8 times	IL ≦ 0.8 dB IL change ≦ 0.3dB RL ≧ 50dB	IL ≦ 0.58 dB IL change ≦ 0.16 dB RL ≧ 62.1
Durability		50 times	IL ≦ 0.8 dB IL change ≦ 0.3dB RL ≧ 50dB	IL ≦ 0.18 dB IL change ≦ 0.07 dB RL ≧ 68.1

For the "Durability" test in Table 2, the cleaning process was performed using the developed MMC cleaner. The test results shown in Fig. 14 display the increase in IL measured at each mating compared to the IL measured at the beginning of the test. The maximum increase in IL was 0.07 dB, indicating the stability of the MMC connector's mating performance and confirming the excellent cleaning capability of the developed MMC cleaner. Additionally, Fig. 15 presents optical microscope images of the connector end-face before and after cleaning. It is evident that the contamination observed before cleaning was effectively removed after cleaning.

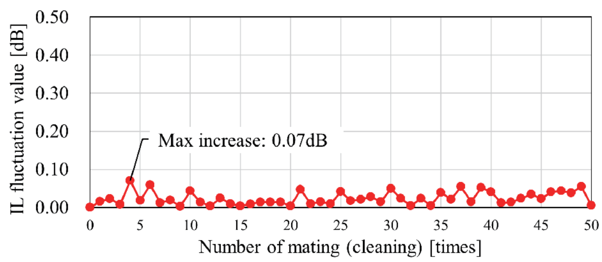

Fig. 14. IL increase as a function of mating cycles.

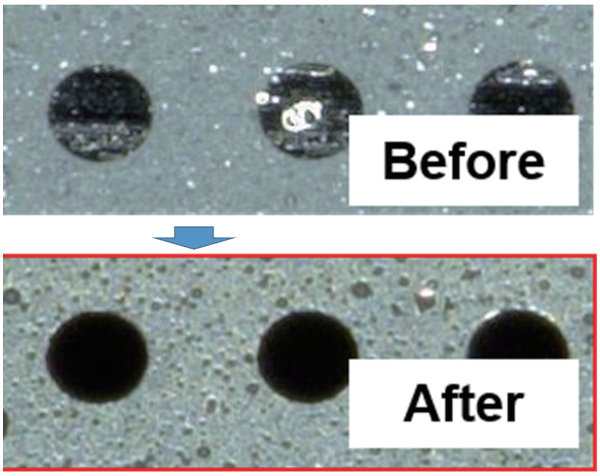

Fig. 15. Connector end face before and after cleaning with MMC cleaner.

4. Conclusion

In conclusion, this report presents that the developed MMC connector meets the optical performance requirements of IEC Grade B specification and demonstrates performance compatibility between two manufacturing companies. Furthermore, its environmental and mechanical stability has been verified. The MMC cleaner enhances maintenance operability in line with the increasing wiring density. These performance levels satisfy industry needs and we will continue to strive for product development that can keep up with the Data center market.

Reference

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