Development of 16F, low-loss, IEC-Grade B, MMC High-Density Optical Connector and Corresponding Cleaning tool

Kouta Yamanaka (1) , Shuhei Kanno (1) , Yuya Sakaguchi (1) , Satoshi Shida (1) , Yasuyuki Wada (1) , Takaaki Ishikawa (1) , Kansei Shindo (1) , Mike Hughes(2), Sharon Lutz (2) , Jeff Hendrick (2)

(1) Fujikura Ltd., Japan kouta.yamanaka@jp.fujikura.com ,

(2) US Conec Ltd., USA mikehughes@usconec.com

Abstract

In this study, a versatile optical multi-fiber connector, comprising a miniature ferrule (TMT) with a single row of 16 fibers and a Very Small Form Factor (VSFF) connector embodiment (MMC) was tested and qualified. The MMC connector presents a reduction in the optical connectivity footprint compared to conventional MPO connectors. The smaller connector footprint increases fiber densities with three times the port density of MPO.. Furthermore, a new cleaning tool with an optimized tip nozzle design providing efficient cleaning capability was developed and evaluated.

Keywords: MT, TMT, MPO-16, MMC, multi-fiber, connector, MPO, VSFF, cleaners, high density

1. Introduction

Due to the rapid developments in optical interconnection and data transmission technologies, the demand for high-speed, high-density transmission-capable multi-fiber optical connectors has increased. Additionally, emerging technologies are requiring higher fiber densities in equipment and hardware panels due to the number of fibers in the network, thermal airflow considerations and the need to share switch faceplate space with external laser source fibers for co-packaged architectures. The MPO format is inadequate for these emerging optical fiber networks which is driving innovation in multi-fiber connectivity. Moreover, new link designs with more connections per link are reducing the insertion loss requirements per mated connector pair to satisfy the increasing demand for single-mode fiber-based data transmission technologies [1]. Therefore, the MMC connector product line was developed to represent a new standard of compact, low-loss, multi-fiber optical connectors.

2. Structure and Design

2.1 MT Ferrule/MMC Connector

The MMC optical connector housing utilizes a similar design as the VSFF MDC two fiber optical connector. The two ceramic single fiber optical ferrules are replaced by the new TMT ferrule. [2]. The TMT ferrule is 50% shorter than the MT ferrule of the current MPO connector and 40% thinner than the MT ferrule. Figure 1 shows the external connecting parts of the novel MMC connectors. As illustrated above, depending on the fiber count, the increase in fiber density with MMC connectors can be up to three times that of an MPO connector demonstrating the appeal of MMC connector.

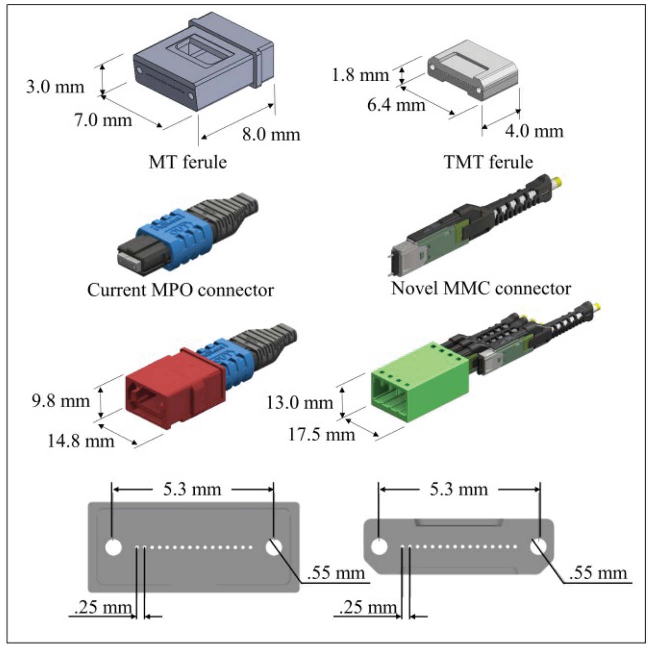


Figure 1. Architecture of the novel MMC connector and the external connecting regions.

2.2 MMC Connector Cleaner

For optimal optical communication system performance, optical fiber end faces must be clean to ensure maximum optical power throughput at the mated optical connectors. Standards, such as IEC 61300-3-35, specify size and quantity of contaminants allowed based on location of the contaminant from the fiber core [3]. There are many methods that can be used to clean optical fiber connectors to meet the standard. The most popular field method is using dry, push-actuated cleaners. Optical connectors can be cleaned directly with the cleaning tool and, most importantly, these dry, push-actuated cleaners will also clean an optical connector after installation by cleaning through the optical adapter, saving valuable installation and/or troubleshooting time.

While shrinking the optical connector format for increased fiber and connector density is a plus for end users, the smaller format creates challenges for accessories that interface the installed connectors. The current push actuated cleaners were designed for the larger existing MT ferrules and MPO optical connectors. The smaller format of the TMT ferrule and MMC connectors will not accommodate the larger nozzle and tip profiles of the current cleaners. A cleaner with a smaller tip had to be designed to physically fit into the adapter ports of the VSFF MMC adapters. Because the pitch between optical connectors in duplex or quad MMC adapters (3.9 mm) is much less than associated MPO connector adapters , the nozzle of the push activated dry cleaner also had to be lengthened and its outside diameter reduced to allow it to be inserted into an adapter and to fit between adjacent connectors during the push-actuated cleaning process. (See Figure 2.)

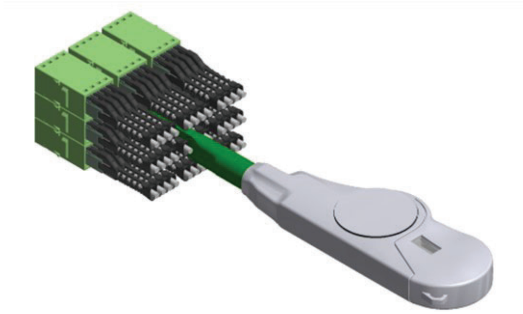


Figure 2. MMC Cleaner in Dense Field Cleaning Application

Figure 3 illustrates the design of the cleaning tool, which is optimized to match the MMC end face area. Therefore, the nozzle is 45% thinner and 20% longer than MPOs to accommodate the narrow-pitch MMC design. This modified nozzle enables the alignment and actuation of the cleaning cloth and allows for easy access of individual plugs, even on densely populated MMC front panels. Also, the MMC cleaner tip is narrower than the MPO cleaner tip.

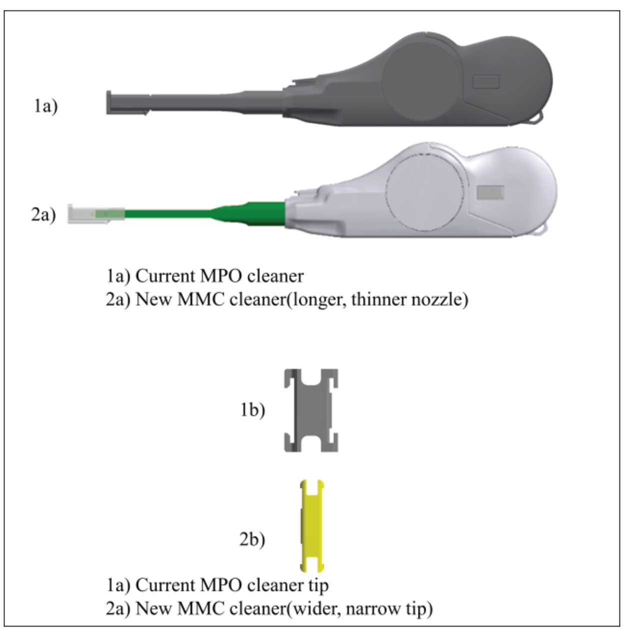


Figure 3. Comparison of new MMC cleaner design to MPO cleaner design

3. Characteristics

3.1 Optical performance

An important feature of an optical connector is its insertion loss performance (hereinafter referred to as "IL"). IL is a measurement indicating the ratio of light outgoing through the connector to light incoming, and is defined by formula (1) below [4]. Insertion loss performance is highly dependent on the fiber alignment, so insertion loss can be optimized by improved fiber hole positioning.

$$IL = [10 \times \log (P_1/P_2)] - (A \times L) \qquad (1)$$

Note:

- P_1 is reference. Optical loss value of the measurement system.
- P_2 is Optical loss values integrating the evaluation sample.
- The product $A \times L$ in Eq. (1) is ignored because the fiber of the evaluation samples are all single-mode 125um fibers and the lengths are less than 10m.

The magnitude of return loss (hereinafter referred to as RL) is also critical to the performance of the connector within the system. In the basic technology of multi-fiber optical connectors, polished end-faces provide physical contact between optical fibers, thereby minimizing losses due to Fresnel reflections in the path. Furthermore, the ferrule end face being polished at an 8 degree angle, minimizes the RL. RL is defined by the following equation (2) [5]. If the RL is maintained constant, it means that stable optical transmission is possible, which indicates that the end-face geometry is polished with extremely high precision and that the mating system, including the housing, is highly robust.

$$RL= -10 \times \log(P_r / P_i) \qquad (2)$$

Note:

- P_i is entering power to DUT.
- P_r is total power reflected by the DUT.

Figure 4 demonstrates the IL and RL of the MMC connector with 16 single-mode fibers. IL and RL were measured at a wavelength of 1310 nm with random connections without a matching gel. This test conforms to the IEC 61300-3-45 and IEC 61300-3-6 requirements [5,6]. IL and RL were measured as <0.23 dB at 97% and >57.5dB, respectively.

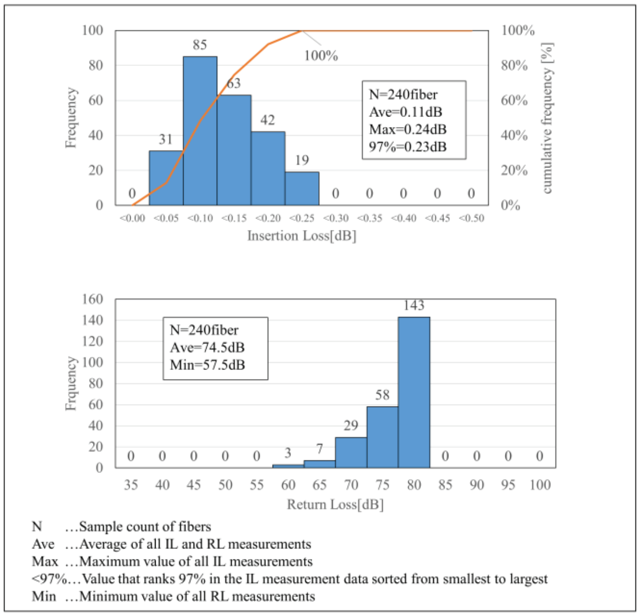


Figure 4. IL and RL of the MMC connectors with 16 single-mode fibers.

3.2 Environmental Testing

Environmental tests simulating an accelerated aging of the actual operating environment were conducted on the developed MMC. Table 1 shows the test conditions and Figure 5 shows the test results. The developed MMC connectors demonstrated robust stability adequate to pass criteria more stringent than the requirements of the Telcordia GR-1435 standard [6].

Table 1. Comparison of test conditions

Telcordia GR-1435				Accelerated Test		
Test	**Duration**	**Test Parameter**	**Criteria**	**Duration**	**Test Parameter**	**Criteria**
Thermal Aging	7 Days	**85°C**	Maximum Insertion Loss Change **≦0.30dB** Reflectance ≧50dB	7days (21 Cycles)	**-40°C** to **85°C** Humidity :**95%**	Maximum Insertion Loss Change **≦0.30dB** Reflectance ≧50dB
Humidity Aging	7 Days	95% at 75°C				
Thermal Cycling	7 Days (21 Cycles)	**-40°C** to 75°C				
Humidity/ Condensation Cycling	7 Days (14 Cycles)	-10 °C to 65°C **90-100%**				
Dry-Out	1 Day	75°C				

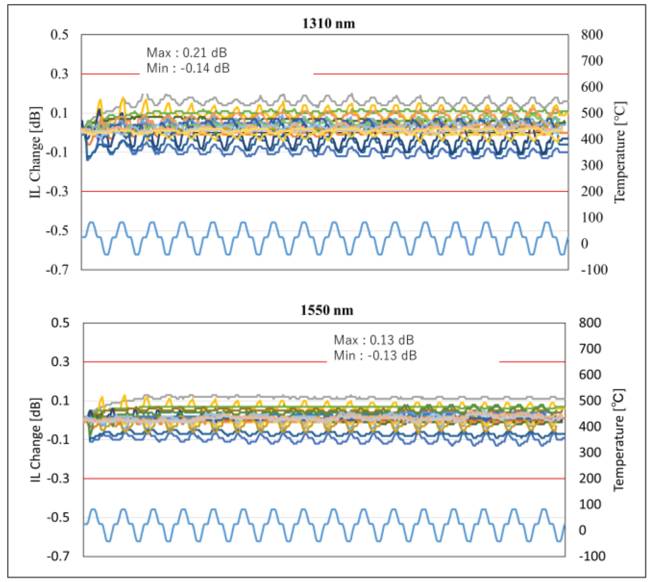


Figure 5. IL change results during environmental testing of developed MMCs

3.3 Mechanical Testing

Table 2 shows the criteria and test results for mechanical testing in accordance with the Telcordia GR-1435 standard. The developed MMCs passed all of the predefined criteria.

Table 2. Summary of Mechanical testing Criteria and Results

Test		Criteria	Results
Vibration		IL ≦ 0.8 dB, IL change ≦ 0.3dB RL ≧ 50dB	IL ≦ 0.35 dB IL change ≦ 0.25 dB RL ≧ 55.3 dB
Flex		IL ≦ 0.8 dB IL change ≦ 0.3dB RL ≧ 50dB	IL ≦ 0.51 dB IL change ≦ 0.16 dB RL ≧ 56.4 dB
Twist		IL ≦ 0.8 dB IL change ≦ 0.3dB RL ≧ 50dB	IL ≦ 0.50 dB IL change ≦ 0.01 dB RL ≧ 56.3 dB
Proof	0 deg	IL ≦ 0.8 dB IL change ≦ 0.3dB RL ≧ 50dB	IL ≦ 0.44 dB IL change ≦ 0.06 dB RL ≧ 62.5 dB
	90 deg	IL ≦ 0.8 dB IL change ≦ 0.3dB RL ≧ 50dB	IL ≦ 0.43 dB IL change ≦ 0.23 dB RL ≧ 63.1dB
Transmission with Applied Load	Measure w/Load (0deg)	• 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)	• 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		IL ≦ 0.8 dB IL change ≦ 0.3dB RL ≧ 50dB	IL ≦ 0.58 dB IL change ≦ 0.16 dB RL ≧ 62.1
Durability		IL ≦ 0.8 dB IL change ≦ 0.3dB RL ≧ 50dB	IL ≦ 0.18 dB IL change ≦ 0.13 dB RL ≧ 68.1

3.3.1 Cleaner Performance.

In Table 2, the Durability test utilized the MMC cleaner previously described. . Figure 6 shows an increase in IL after 50 consecutive mating cycles using the cleaning tool. This test was conducted following the durability test guidelines in Telcordia GR-1435. The maximum increase in IL was 0.07 dB, which indicated the cleaning tool's effectiveness. Additionally, figure 7 shows representative images before and after cleaning. As this figure shows, the contamination seen in the Before image is effectively removed in the After image.

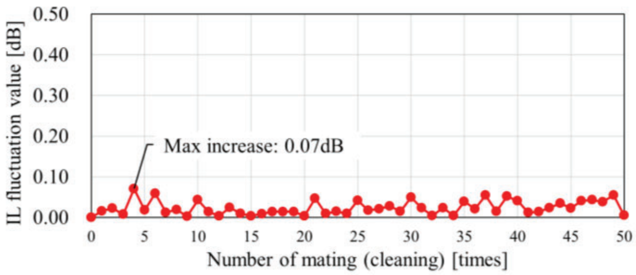


Figure 6. IL increase as a function of mating cycles.

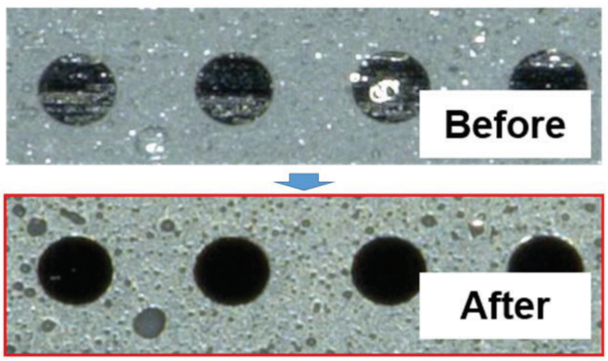


Figure 7. Representative images before and after cleaning.

3.4 Intermateability

Compatibility between different manufacturers to ensure assurance of supply is imperative for broad market adoption of any new technology. US Conec and Fujikura independently developed molding technology to produce the ferrule in different locations. As shown in Figure 8, ferrules produced at the two locations yielded low insertions losses establishing a design that is fully reproducible between multiple vendors.

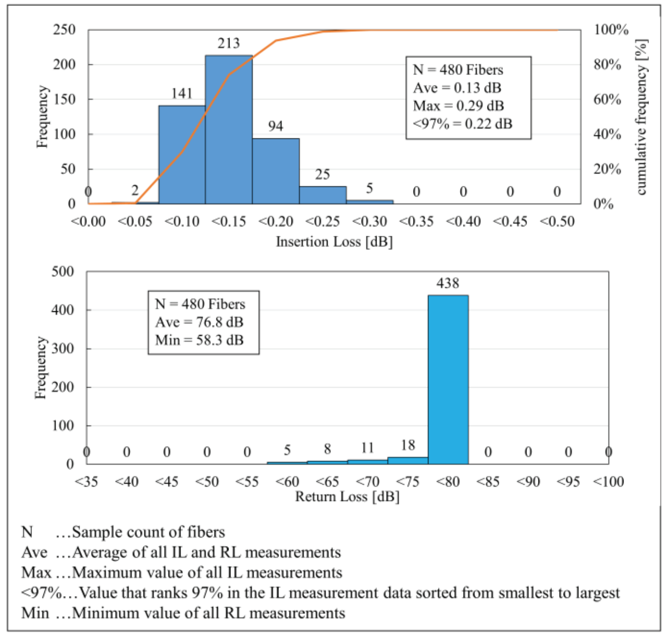


Figure 8. IL results of MMC connectors with USConec and Fujikura manufactured TMT ferrules.

4. Conclusion

With an increase of three times the panel density over MPO and improved insertion loss performance over IEC Grade B specification [7], the MMC connector meets the industry needs for density and performance. The MMC connector has demonstrated environmental and mechanical stability meeting industry expectations. Intermateability between two manufacturers has also been shown. Development of a suitable cleaning tool allows for easy installation and maintenance.

5. References

[1] Mark Zhang Baoli, et.al: Low-loss Field-installable Splice-on MPO Connector For High-Density Optical Interconnection Applications, 61th IWCS (2012)

[2] Darrell Childers, Jeff Hendrick, Jason Higley, Mike Hughes, Dan Kurtz, Sharon Lutz, Dirk Schoellner, "A Novel, Low-loss, Multi-Fiber Connector with Increased Usable Fiber Density", 70th International Cable and Connectivity Symposium, (2021).

[3] IEC. "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-35: Examinations and measurements - Visual inspection of fibre optic connectors and fibre-stub transceivers" IEC 61300-3-35:2022 (ed 3.0)

[4] IEC. "Fiber optic interconnecting devices and passive components – Basic test and measurement procedures Part 3-45: Examinations and measurements – Attenuation of random mated multi-fibre connectors" IEC 61300-3-45:2011(ed1.0).

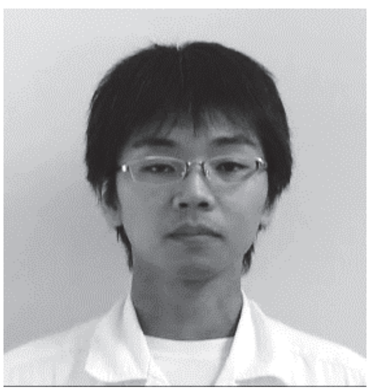
[5] IEC. "Fiber optic interconnecting devices and passive components – Basic test and measurement procedures Part 3-6: Examinations and measurements – Return loss" IEC 61300-3-6:2009(ed3.0).

[6] Telcordia GR-1435, Issue 2, Generic Requirements for Multi-Fiber Optical Connectors, 2008

[7] IEC. "Fibre optic connector optical interfaces – Part 2-1: Optical interface standard single mode non-angled physically contacting fibres" IEC 61755-2-1:2006 (ed1.0).

6. Pictures of Authors

Kouta Yamanaka received the B.E. in Mechanical Systems Engineering from Shinshu University in 2012. He joined Fujikura Ltd, in the same year and has been engaged in research and development of MT ferrules in the Optical Network Product R&D Department.



Shuhei Kanno received his B.E. and M.E. in Chemical Engineering from Chiba University in 2010. He joined Fujikura Ltd, in 2010, and has been engaged in research and development in the Optical Network Product R&D Department.

Yuya Sakaguchi holds a M.E. in Mechanical Engineering from Tokyo University of Agriculture and Technology. He joined Fujikura Ltd. in 2014, where he is currently a Assistant Manager in Fiber Optics Network Product R&D Department.

Satoshi Shida holds a B.E. in Mechanical Engineering from Doshisha University. He joined Fujikura Ltd. in 1994, where he is currently a Senior Manager in Fiber Optics Network Product R&D Department.

Yasuyuki Wada is a Development Manager of MT ferrule at Fujikura. He has 25 years of experience in mold design and fabrication for the semiconductor, automotive, and electronics industries. Currently at Fujikura, he is in charge of developing molding technology for MT ferrules, for which high-precision molding is the key. He holds a bachelor's degree in mechanical engineering from Osaka Institute of Technology.

Takaaki Ishikawa received the M.E. degrees in physics from the Tokyo University of Science in 1999. He joined Fujikura Ltd in 2000. He has been engaged in the research and development of optical connectivity solutions in the Optical Network Product R&D Department. He has also been engaged in the research and development of freespace optics for wavelength selective switch products.

Kansei Shindo received his B.E. in Mechanical Engineering from Tokyo University of Agriculture and Technology in 1992. He joined Fujikura Ltd, in 1992, where he is currently a department Manager in the Optical Network Product R&D Department.

Jeff Hendrick is a Product Manager at US Conec, Ltd. He has over 22 years of technical and commercial experience in the fiber optic industry. He is a co-inventor on two patents. He received a B.S. of Electrical Engineering from North Carolina State University.

Mike Hughes is the Vice President of Product Management at US Conec Ltd. He has over 29 years of experience in copper and fiber optic connectors and cabling products. Mike has held engineering and commercial positions in high density optical interconnect technology for 20 years. Mike holds a Bachelor of Science in Mechanical Engineering from North Carolina State University and Master of Business Administration from Wake Forest University.

Sharon has over 20 years of experience in fiber optic interconnects with US Conec and is currently the Product Manager with responsibility over precision optical components. Sharon received her Bachelors of Science degree in Mechanical Engineering from the University of North Carolina at Charlotte in 2004 and her Master of Business Administration from Wake Forest University in 2019. She has been an active member in IEC since 2008 and currently serves as SC86B WG6 convenor.