High-Density Multi-Fiber Connectors for Optical Interconnection

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ABSTRACT As the performance limits of electrical transmission become apparent in such equipment as servers and routers, optical interconnection technology is drawing attention. Furukawa Electric has been developing, in anticipation of application to optical interconnection, optical high-density multi-fiber connectors. In this paper, compact multi-fiber ferrule μ-Joint is presented, along with MU-type plug and backplane connector, both based on μ-Joint. The μ-Joint has a cross section about one quarter that of conventional MT ferrule, so that it allows for high-density mounting with a low insertion loss of 0.5 dB or lower. Tests in conformity to Telcordia GR-1435-CORE have been carried out to confirm that the ferrule has high long-term reliability.

1. INTRODUCTION

Data traffic on the Internet continues to increase due to the growth of moving picture delivery and the like, resulting in a requirement for high-speed, large-capacity signal transmission functionality for servers and routers. Thus, the issue of inadequate transmission performance of electrical wiring is gradually emerging due to the increased number in signal transmission lines. Accordingly, optical interconnection technology is recently drawing attention as a promising means to solve this problem. Moreover, in terms of space reduction, optical interconnection is expected to enhance heat dissipation efficiency in high-end systems such as servers and super computers, so that application of optical interconnection technology to signal transmission between boards and racks is becoming a real possibility.

We have been developing the optical interconnection technology assumed to be applied to equipment wiring, in which optical fibers, optical connectors, and high-speed optical modules are downsized than conventional counterparts to constitute the product family of OptoUnity[1)].

In this paper, small-sized multi-fiber optical connectors capable of high-density mounting will be reported for their structures and evaluation results, including μ-Joint connector plug and adapter, which have, using ultra-compact multi-fiber ferrule μ-Joint, the same outer dimensions as for the MU connector[2)].

2. DEVELOPMENT CONCEPT

Figure 1 shows a schematic illustration of application of the connectors developed here. Development was advanced based on the concept mentioned below, assuming that the connectors are mainly used on board ends for signal transmission between boards and racks.

1) Should be smaller than the conventional MT ferrule and MPO connector, enabling high-density mounting.
2) Should be compatible with ThreadWave[1)], the bend-insensitive fiber for optical interconnection of Furukawa Electric.
3) Should allow for low insertion-loss connection.
4) Should be provided with high long-term reliability.

With respect to insertion loss, the target was set at 0.5 dB or lower even in case single-mode (SM) fiber is used, in consideration of total loss budget for ultra-fast transmission in the future. In terms of long-term reliability, the development target for loss variation after the tests in conformity to Telcordia GR-1435-CORE was set at 0.3 dB or lower.

3. ULTRA-COMPACT MULTI-FIBER FERRULE μ-JOINT

An ultra-compact multi-fiber ferrule μ-Joint capable of high-density mounting has been developed. Figure 2 compares μ-Joint with MT ferrule conventionally used.

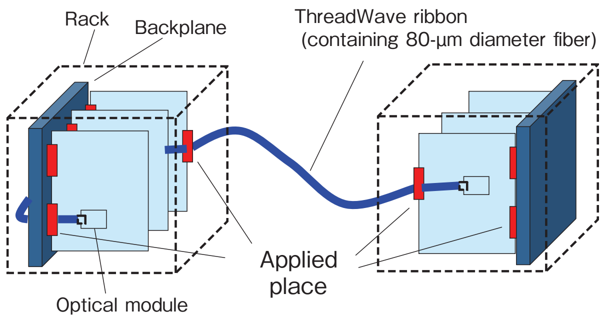

Figure 1 Schematic illustration of application of the developed connectors.

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The dimensions of μ-Joint is about half that of MT ferrule, and about 25% in cross section. It uses 0.4-mm diameter stainless steel guide pins, and is adapted to ThreadWave optical fiber having a cladding diameter of 80 μm, and core diameters of about 50 μm and about 5 μm for multimode (MM) fiber and SM fiber, respectively. ThreadWave MM fiber has a relative reflective index difference Δn of about 2%, so that it is less susceptible to bending loss increase, permitting an allowable bending radius R of 5 mm. Moreover, whereas a fiber ribbon generally has a fiber pitch of 250 μm, that of ThreadWave fiber ribbon is 125 μm, making it suitable for compact optical wiring on printed circuit boards, etc.

Improving the accuracy of ferrule is essential to realize low insertion loss. In order to achieve the target insertion loss of 0.5 dB, the target fiber-hole position error was designed to be not more than 0.5 μm. Figure 3 shows the measurement results of the misalignment of fabricated μ-Joint ferrules, in which the fiber-hole position error of 0.5 μm or lower is achieved by improving the dimensional accuracy of the mold.

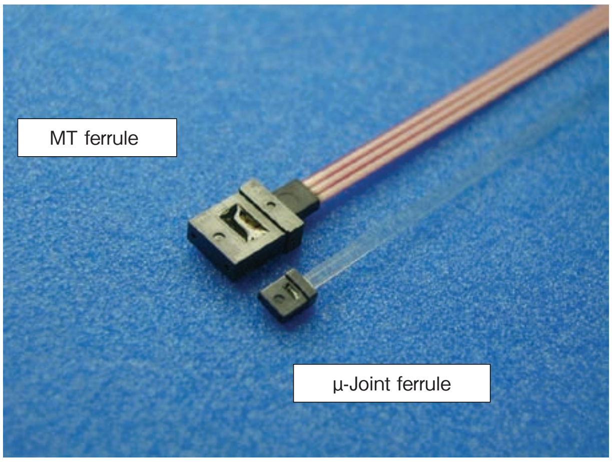

Figure 2 Comparison of MT ferrule and μ-Joint ferrule.

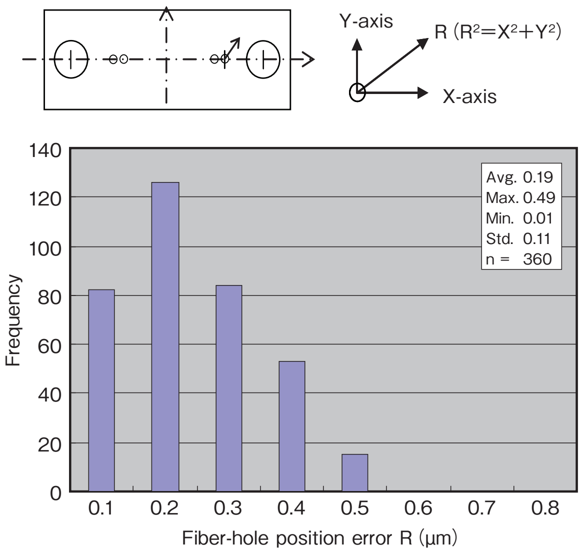

Figure 3 Fiber-hole position error of μ-Joint ferrules.

4. MU-TYPE HOUSING

Whereas MPO connector is commonly used for multi-fiber optical connection, MU connector housing is adopted here aimed at higher mounting density. The MU connector is standardized, and is practically used in transmission equipment installed in telephone stations.

Figure 4 shows μ-Joint-MU connector plugs and a duplex adapter, where the μ-Joint ferrule is applied to the MU housing. The plugs come in two types --male with guide pins, and female without guide pins-- and they are used in opposition to each other. A push-pull coupling mechanism is provided for ease of connection and disconnection. The adapter has a pitch of 4.5 mm between connectors, making possible higher mounting density than the MPO connector. In order to reduce costs, we have adopted the design such that the plug shares several off-the-shelf parts with the MU connector that is commercially available, and that two identically shaped parts are assembled back-to-back to constitute the adapter.

The ferrule compression force at the time of connector engagement is an important parameter to achieve physical contact (PC). In consideration of its application to backplane, the μ-Joint-MU connector plug was designed to provide a compression force equivalent to that of MU connectors. But, since this raised some fears of insufficient compression force when the ferrule was applied to a multi-fiber connector, the method of polishing the ferrule endface was optimized to ensure PC connection. Figure 5 shows the results of PC connection verification tests on fabricated connectors, in which the insertion loss was measured before using an index matching material on the mating portion and after applying the matching material in drops. It can be seen that the difference between the two measurements are extremely small, and hence PC connection has been achieved with respect to all the fibers studied.

5. BACKPLANE HOUSING

In anticipation of application to optical backplanes, μ-Joint-BP connector has been developed, in which the

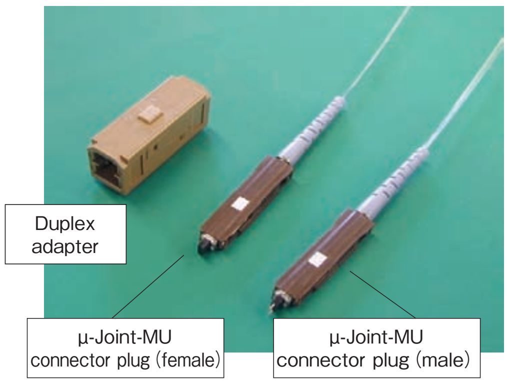

Figure 4 μ-Joint-MU connector plug and duplex adapter.

μ-Joint-MU connector plug is adapted to a backplane connector. Figure 6 shows the connector developed here.

The μ-Joint-BP connector has a structure such that the printed circuit board housing engages with the backplane housing, allowing for connection and disconnection en bloc of multiple connectors together with the board. Moreover, simultaneous use of electrical connectors on the board is possible. Since the μ-Joint-BP connector is designed to have a compression force equivalent to that of the MU connector --a single-fiber connector, excessive loads on the latch portion made of plastics can be avoided while the mounting density is significantly improved. Inheriting the mating mechanism of the single-fiber MU connector, the accuracy in the positioning mechanism of the μ-Joint-BP connector has been improved along with the mounting density enhancement.

6. EVALUATION RESULTS

Figures 7 and 8 show the insertion loss of μ-Joint connector plugs developed here engaged with an adapter. The insertion loss for MM fiber is 0.14 dB maximum at the measurement wavelength of 850 nm, and is 0.41 dB maximum for SM fiber at 1310 nm --satisfactory insertion loss characteristics in each case.

Figure 9 shows the insertion loss of μ-Joint-BP connector. The loss is 0.30 dB maximum at the measurement wavelength of 1310 nm.

Reliability evaluation tests in conformity to Telcordia GR-1435-CORE were carried out to confirm that the connectors have good environmental and mechanical characteristics. The results are shown in Table 1. Specifically, Figures 10 and 11 show the results of thermal cycling tests and durability tests, respectively, of μ-Joint-MU plug connected with an adapter. Test conditions for thermal cycling tests are: −40℃~75℃, 8 hours/cycle, 336 hours; and those for durability tests are: 200 times in total, either endface of connector is cleaned every 25 times, both endfaces of connector are cleaned every 50 times. The insertion loss variations for thermal cycling tests and durability tests are 0.1 dB or lower and less than 0.2 dB, respectively --satisfactory results.

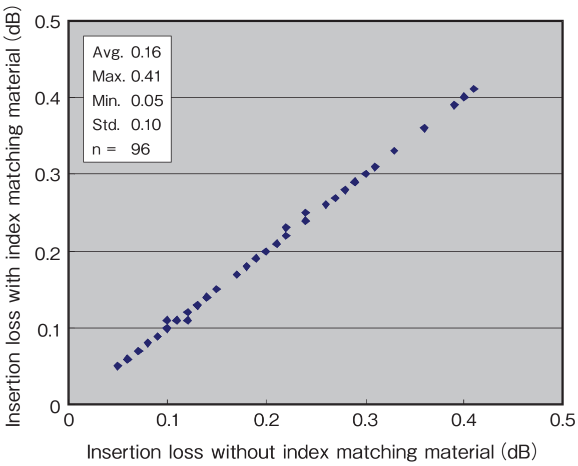

Figure 5 Results of physical contact verification tests of μ-Joint-MU.

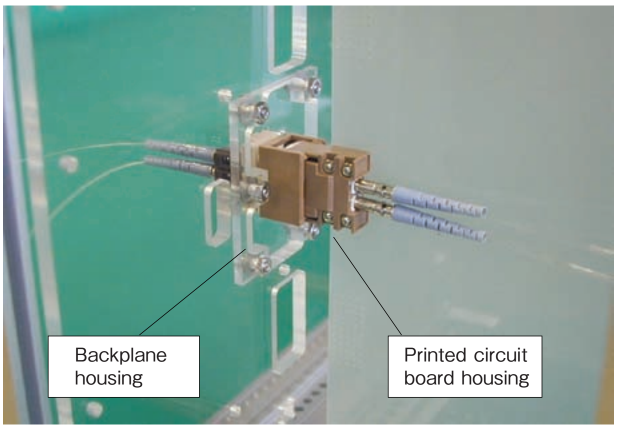

Figure 6 μ-Joint-BP connector.

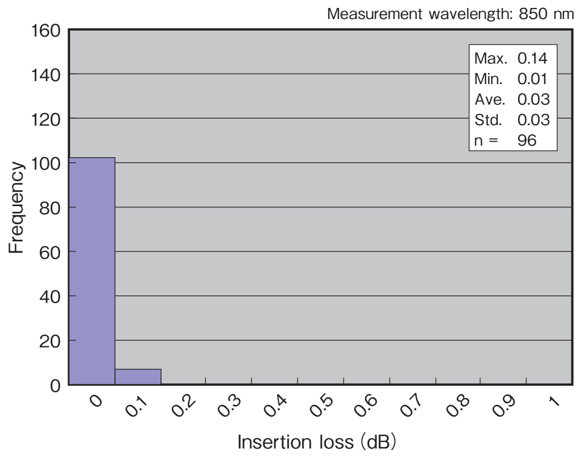

Figure 7 Insertion loss of μ-Joint-MU connector for multi-mode fiber.

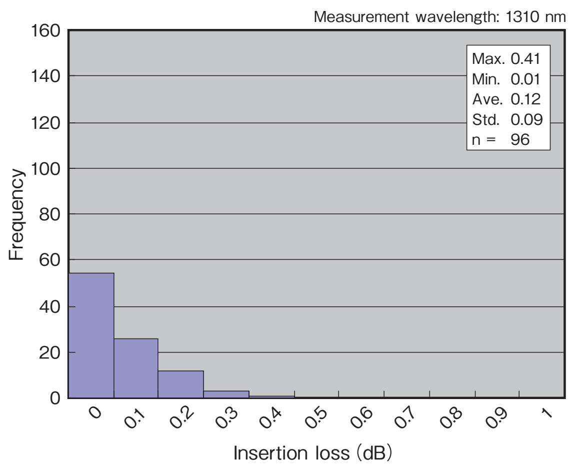

Figure 8 Insertion loss of μ-Joint-MU connector for single-mode fiber.

7. CONCLUSION

Ultra-compact multi-fiber optical connectors comprising μ-Joint-MU connector plug, adapter, and backplane connector have been developed, in anticipation of application to optical interconnection. The evaluation results have shown that the connectors have good initial performance as well as long-term reliability.

REFERENCES

1) M. Iwase et al.: Furukawa Review, No. 32, pp. 26 (2007)
2) R. Nagase et al.: NTT Gijutsu Journal, Vol. 15, No. 10, pp. 8 (2003) (in Japanese)

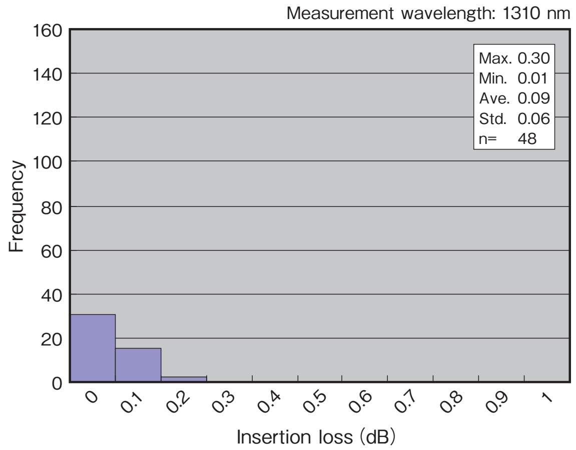

Figure 9 Insertion loss of μ-Joint-BP connector for single-mode fiber.

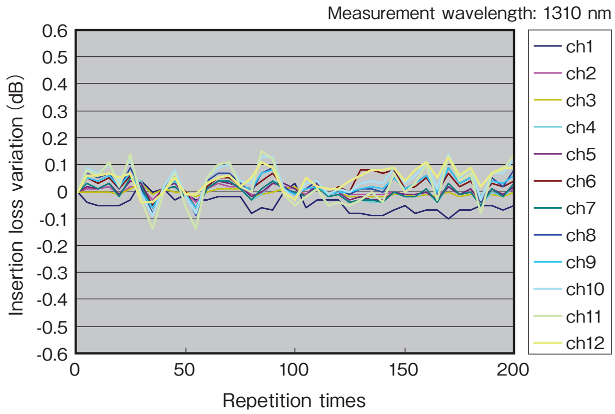

Figure 11 Durability test results of μ-Joint-MU connector for single-mode fiber.

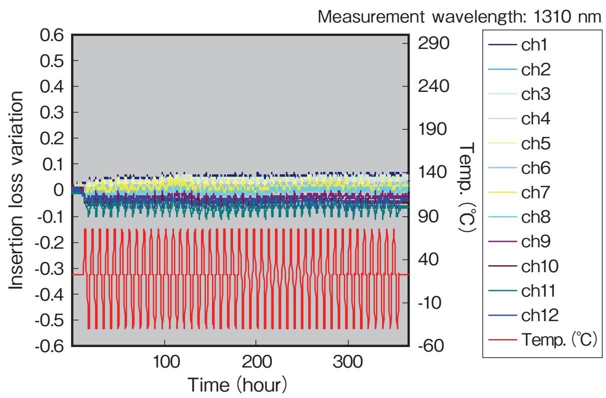

Figure 10 Thermal cycling test results of μ-Joint-MU connector for single-mode fiber.

Table 1 Results of reliability test.

Test item	Test conditions (GR-1435-CORE)	Test results	
		μ-Joint-MU (SM)	μ-Joint-BP (SM)
Thermal aging test	85℃, 336 hr	0.1 dB or lower	0.1 dB or lower
Humidity test	65℃, RH 95%, 336 hr	0.15 dB or lower	0.1 dB or lower
Thermal cycling test	-40℃~75℃, 8 hr/cycle, 42 cycle	0.1 dB or lower	0.1 dB or lower
Vibration test	1.5 mm in amplitude, 3 directions, each 2 hrs	0.1 dB or lower	0.1 dB or lower
Tension test	Media 1 (fiber ribbon), Level 1, Load: 2.2 N	0.15 dB or lower	0.1 dB or lower
Impact test	Impacting on concrete block 9 times from 1.5-m height	0.1 dB or lower	0.1 dB or lower
Durability test	Repeated connection and disconnection, 200 times in total	0.2 dB or lower	0.2 dB or lower