Lensed Connector for Single Mode Fiber

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In recent years, data traffic has been rapidly increasing because of development of information and communication technology using the internet. It has been progressed the optical wring between electronic devices to speed up data transmission, but there is concern that the communication degradation will occur due to dust in optical connection portion. In order to solve this concern, we have developed lensed connector for multi mode fiber which indicates good dust immunity and mating workability. On the other hand, data center needs to be further scaled up. It is supposed that optical wiring will be replaced to single mode fiber from multi mode fiber, in order to communicate long-distance between the building. This time, we have developed lensed connector for single mode fiber and confirmed that this connector is practically usable level.

1. Introduction

In recent years, data traffic has been increased with the development of telecommunications using the internet. As one means of realizing higher data traffic, optical wiring between electronic devices installed in a data center is positively studied. In introducing optical wiring, high density is an important factor. As means to realize this, we have developed MPO connectors [1)] and backplane connectors [2)] that can connect many optical fibers at one time, and ultra low loss MT ferrule [3)]. In the current optical interconnection in the data center, Multi-Mode Fiber(MMF) is mainly used for short-distance communication. On the other hand, in order to process with further increase in data traffic, the scale of the data center is being increased, and long distance communication within or between the buildings will be indispensable. Along with this, application of Single-Mode Fiber (SMF) capable of long-distance optical wiring is advanced, and demand for SMF components is expected to increase.

In the MPO connector and the backplane connector that can connect a large number of optical fibers at once, it is one of the problems that the optical path is blocked by the dust on the end face of the connector and the frequency of deterioration of the communication quality is high. On the contrary, we have developed a the optical connector cleaner [4)] and contributed to solving the problem. On the other hand, it is often difficult to use a cleaner for the backplane connector installed in a secluded place of the device, and the dust of the optical connection part still remains as a problem. As a means to solve this problem, attention has been drawn to lens connectors having good anti-dust characteristics by enlarging the optical path at the connector end face. We have developed an MMF lens connector [5)] and applied it to MPO connector and backplane connector and reported that its characteristics are practically usable level.

It is expected that deterioration of communication quality due to dust on the optical connector becomes serious in a system constructed with SMF where future demand expansion is expected. By applying lens connectors that are excellent in dust resistance and attach/detachability to the SMF system, it is expected to lead to solving dust problems.

2. Feature of Lensed Connector

There are two ways of fiber coupling of the optical connector, Physical Contact(PC) and Beam Coupling. The PC method is directly butting the fibers against each other, and corresponds to the conventional MT connector. Beam coupling is a method of optically connecting on air layer, and corresponds to the lens connector. Table 1 shows a comparison of characteristics of PC and beam coupling.

Sections of the connection image in Table 1 show the cross section of MT connector and lens connector. In PC connection, the fibers of each connector are physically contacted to connect by applying pressure from the rear end side of the connector. In the conventional MT connector, a pressure force matching the number of fibers is required. On the other hand, In beam coupling, a beam that is converted into collimated light by a convex lens formed on the connector optically connects to the opposing connector in a non-contact manner. Therefore, it is unnecessary to apply a large pressing force at the time of connection, and it

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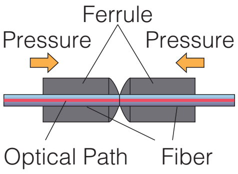
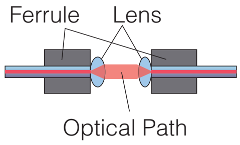
Table 1. Comparison table of charactaristics between PC coupling and expanded beam coupling.

Method of Connecting	Physical Contact (PC)	Expanded Beam Coupling
Connection Image		
Dustproof	Usual	Good
Workability of attaching and detaching	Usual	Good
Potential of Cost	Usual	Good
Insertion Loss	Very good	Difficult

is unnecessary to increase the pressing force due to the number of fibers, so that the workability of attaching and detaching the connector is good. Since it is collimated light, even if dust enters between the connectors and a gap occurs, it is possible to connect stably. Furthermore, even if dust adheres to the optical path, since the optical path is enlarged, there is no big influence on the connection loss. In addition, since the end face polishing are unnecessary in the manufacturing process of the lens connector, lens connector has lower cost potential than conventional MT connector.

Compared with the conventional MT connector, the lens connector has many factors for insertion loss, so it is generally difficult to realize lower insetion loss characteristic.

We applied the high precision molding technology cultivated at the conventional MT connector and challenged the development of a SMF lens connector with the goal of a maximum insertion loss of 1.0 dB considered to be usable on the system.

3. Designing of Fujikura's Lensed Connector

The SMF lensed MT ferrule we developed has the same outer shaple as the conventional MT ferrule.

Therefore, it is possible to replace the MT ferrule without changing the design of the housing. Generally the lensed ferrule consists of two components, lens part and fiber hole part. In the MMF lensed MT ferrlule developed until now [5], these two components can be molded integrally, and making it possible to manufacture at low cost. In case of the SMF lensed ferrule, these components (lens and fiber hole) with more higher precision is required than MMF lensed ferrule. Therefore, the structure was separated totwo parts in order to mold lens part and fiber hole part with high precision. Regarding the positioning accuracy of these two parts, an assembling method was adopted in which the two parts are precisely fixed by precision pins and glued.

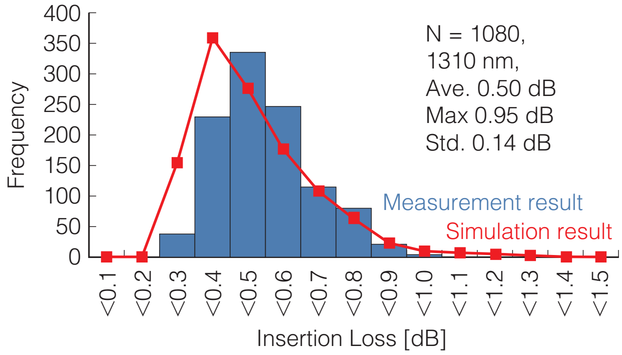


Fig. 1. Measuement and Calculation result of Insertion Loss of 12 fiber lens connector at 1310 nm.

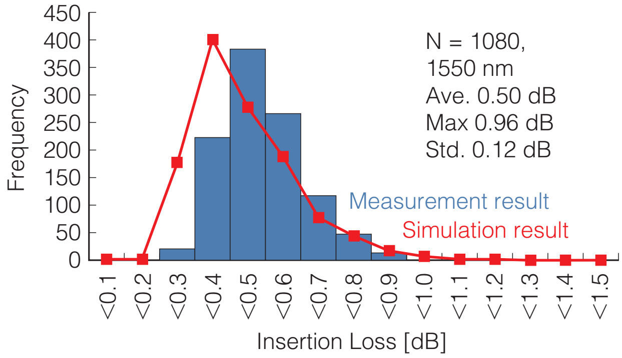


Fig. 2. Measuement and Calculation result of Insertion Loss of 12 fiber lens connector at 1550 nm.

4. Performance of SMF Lensed Connector

The optical design parameters of the lens connector were optimized that light emitted from the fiber is converted into collimated light. If the beam diameter is large, the influence of the insertion loss by inclination of connectors becomes large, whereas if it is small, the influence on the insertion loss due to the dust becomes large. Considering these balances, the mode field diameter was designed to be 100 um.

By applying AR coating on the lens surface, the occurrence of reflection loss by difference in refractive index between air and resin was suppressed.

The insertion loss distribution was predicted by the Monte Carlo method, taking into consideration the parts accuracy of the lens part and the fiber hole part, the clearance of the part, the assembly accuracy and so on. As a result, at the wavelengths 1310 nm/1550 nm, the insertion loss could be 1.0 dB with a probability of 97%. (Calculation results are shown in Fig. 1 and 2 which are results of connection loss.)

We made the SMF lensed MT ferrule by the above

Table 2. Mechanical performance test result of SMF lensed MPO connector. *Test items assuming difficult cleaning conditions.

Item	Criteria IEC 61753-1 Category U	Test Result Insertion Loss Max Change [dB]	
		1310 nm	1550 nm
Vibration	10 - 55 Hz, 15 sweeps, 3 axes, 0.75 mm amplitude	0.06 dB	0.08 dB
Tensile	5.0 N, 60 sec	0.05 dB	0.03 dB
Inpact	5 drops, 1.5 mm height	0.03 dB	0.06 dB
Twist	2.0 N, 25 cycle, ±180 °	0.06 dB	0.06 dB
Durability*	500 cycle, without cleaning, measure every 25 cycle	0.03 dB	0.03 dB

Table 3. Environmental performance test result of SMF lensed MPO connector.

Item	Criteria IEC 61753-1 Category U	Test Result Insertion Loss Max Change [dB]	
		1310 nm	1550 nm
Low Temperature	−25 ±2 °C, 96 h	0.14 dB	0.11 dB
High Temperature	70 ±2 °C, 96 h	0.19 dB	0.15 dB
Humidity Cycle	25 - 55 °C, >90%, 24 h 6 cycle, 144 h	0.19 dB	0.18 dB
Thermal Cycle	−25 - 70 °C, 12 cycle, 144 h	0.18 dB	0.14 dB

design and mounted the ferrule assembly on the MPO connector and evaluated optical, mechanical and environmental characteristics. The pressing force of the lens connector was 5 N. For the mechanical characteristics, the evaluation method of the environmental characteristics and the test conditions, the test was conducted with reference to the International Standard IEC 61753-1 Category U [7].

4.1 Initial Performance

Insertion Loss of our our developed product is shown in fig. 1 and 2. For fig. 1 and 2 the following can be seen. For measurement wavelength 1310 nm / 1550 nm, the average is 0.50 dB and 0.50 dB, the maximum is 0.95 dB and 0.96 dB.

Regarding the return loss, for measurement wavelength 1310 nm / 1550 nm, the average of 37.2 dB / 39.3 dB, the minimum result is 35.4 dB / 36.3 dB. Low reflection is an important development subject in the future works.

4.2 Mechanical Performance

The mechanical test conditions and test results are shown in Table 2. As shown in Table 2, it was confirmed that the maximum loss increase value was 0.08 dB in all tests and satisfied the IEC 61753-1 standard (variation value of 0.2 dB or less). As for the test conditions of the detachment test, it was assumed that it was applied to a place where end face cleaning is difficult (eg backplane connector etc.), we decided not to clean end face during the test. For result of durability, The maximum insertion loss increase value was 0.03 dB.

4.3 Environmental Performance

The environmental test conditions and test results are shown in Table 3. As shown in Table 3, it was confirmed that the maximum loss increase value was 0.19 dB in all tests and satisfied the IEC 61753-1 standard (variation value of 0.2 dB or less).

5. Conclusion

We have achieved insertion loss of less than 1.0 dB with the SMF lens connector. It was mounted on the MPO connector and the reliability test based on IEC 61753-1 Category U was carried out and it was confirmed that it satisfied the standard (variation amount of 0.2 dB or less).

The important issues in future works are low loss, low reflection, multi-fiber(16F, 24F, 48F, etc...). We will contribute to the development of optical fiber network by solving these problems with the SMF lens connector.

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