Development of Mini-MPO Connector

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ABSTRACT In recent years there has been a need for connectors that will provide high-density packaging in the connection of optical fibers for communications equipment. The existing MPO connector enables high-density batch connection of up to 12 fibers, but an even more compact structure is needed to obtain high-density connection of fewer fibers.

The Mini-MPO connector has therefore been developed based on the MPO structure. It is adapted to the connection of 1, 2 or 4 fibers, and is smaller and simpler in structure than the MPO.

In terms of optical characteristics, an angled-interface single-mode 2-fiber Mini-MPO connector has an insertion loss averaging 0.2 dB or less and a return loss of 53 dB or less--excellent performance which is equivalent to that of conventional MPO connectors.

1. INTRODUCTION

In working to achieve fiber-to-the-home implementation, attention has focused on increasing the number of optical fibers per cable and raising density, creating the need for connectors for these cables[1)~2)]. MT connector (mechanically transferable connector) now in use can handle 2- to 12-fiber ribbons[3)~4)]. These MT connectors are generally used in outdoor applications.

There is a need, however, for a connector structure for indoor and device-to-device use that is easily reconnectable. The MPO connector (multifiber push-on connector), a push-pull, reconnectable connector that adopts the MT connector ferrule, meets such needs[5)]. In terms of fiber density, the MPO connector is more advantageous the more fibers there are, and in recent years, with progress in high-speed computers, demand for 8- and 12-fiber MPO connectors has increased.

There has also been a need in recent years for connection in 2- and 4-fiber units for data communications, requiring optical connectors having a more compact, denser structure than the MPO connector. This led to focusing on a design having no more than four fibers, and the development of the Mini-MPO connector, based on the MPO connector[6)~7)].

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2. DESIGN CONCEPT

2.1 MPO Connector Structure

Connectors for fibers used in indoor equipment for optical transmission are subject to a number of requirements, including:

- High-density connection
- Easy connection and disconnection
- No need for refractive index matching material

The MT connector is designed for the high-density connection of multiple optical fibers. Figure 1 shows its structure. The MT connector has two alignment pins to align the ferrule, and a clamp spring. When closed, the MT connector is extremely compact and is thus well suited for high-density fiber connection within closures or cabinets. At points where frequent connection and disconnection is necessary, a design that has easier reconnectability is needed.

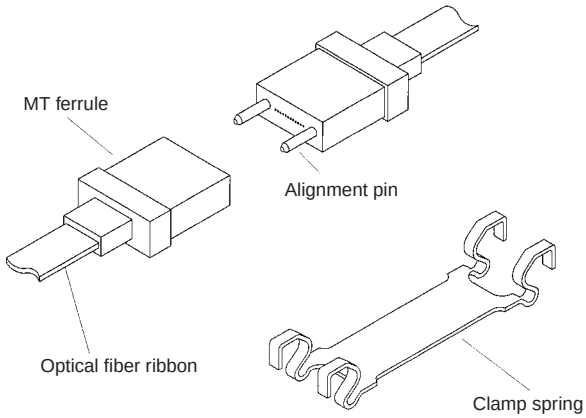


Figure 1 MT connector structure

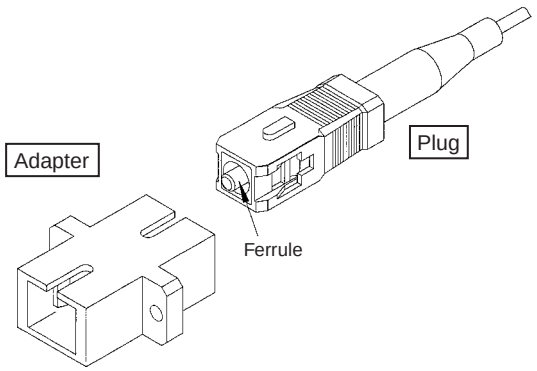


Figure 2 SC connector structure

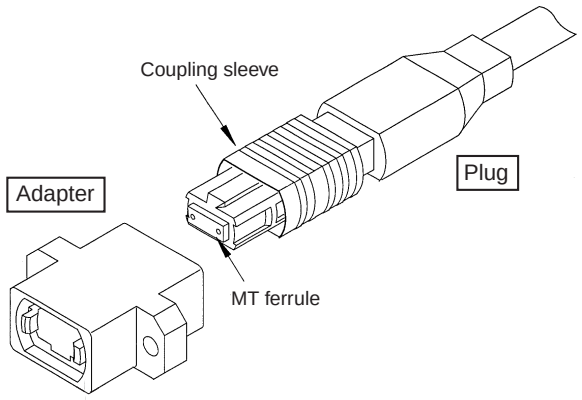


Figure 3 MPO connector structure

A typical single-fiber connector, on the other hand, is the SC connector (subscriber loop system optical fiber connector)[8]. Figure 2 shows its structure. It connects two plugs by means of an adapter, which can be connected and disconnected with a single action.

The MPO connector combines high-density connection with convenient disconnecting action. Figure 3 shows its structure. The MPO is ideal in satisfying the need for high-density packaging in equipment.

2.2 Optical Characteristics

If there is a gap between the optical fibers in a connector, Fresnel reflection occurs at the interface between the fiber endface and air, causing degradation of both insertion loss and return loss characteristics. It is thus desirable that physical contact be maintained between the opposing optical fibers, and in single-fiber SC connectors this is accomplished by forming the end face of the ferrule into a spherical configuration[9].

Since multi-fiber MT and MPO connectors have a larger connection surface than SC connectors, extremely high accuracy in fiber endface geometry is required to achieve perfect physical contact. In MT connectors Fresnel reflection is prevented by the use of a refractive index matching material at the fiber joint.

Where frequent connection and disconnection are required, however, the application and removal of the refractive index matching material becomes tedious. In MPO connectors, the fiber protrudes slightly from the surrounding ferrule, and physical contact is achieved by polishing its endface configuration.

Further, in MPO connectors the fiber endface is generally polished on an angle, which is chosen so that the light of Fresnel reflection is not returned to the core but is deflected to the clad. By this means Fresnel reflection is reduced and good reflection characteristics can be obtained at all times[10)~11)].

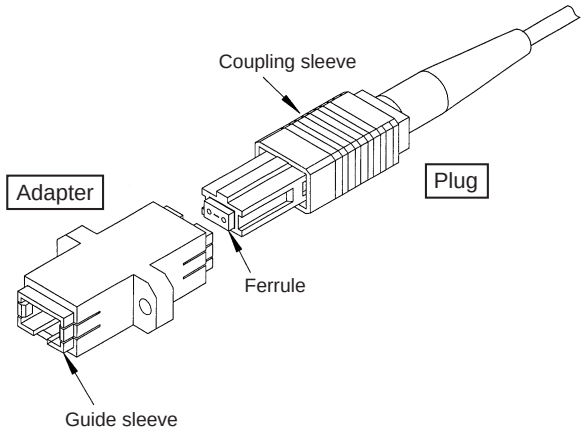


Figure 4 Mini-MPO connector structure

2.3 Development of the Mini-MPO Connector

2.3.1 Basic Structure

The Mini-MPO connector was developed with the objective of high-density connection of up to four optical fibers.

Figure 4 shows the structure of the Mini-MPO connector. The design of the Mini-MPO is based on a configuration similar to the MPO connector, and the mechanism for connection and disconnection and the method of polishing to achieve physical contact used on the MPO connector ferrule are retained.

2.3.2 Reduction in Connector Size

Table 1 compares the dimensions of the Mini-MPO and conventional MPO connectors. As can be seen, the closer pitch of the alignment pins in the ferrule makes it possible

Table 1 Dimensions of MPO and Mini-MPO Connectors

	MPO	Mini-MPO
Ferrule	6.4, 2.5, 4.6	4.4, 2.5, 2.6, Fiber pitch: 0.25 mm
Adapter	5, 9.6	4, 7.2
Plug	9.8, 15	8, 10

to reduce the height dimension and make the plug and adapter more compact.

In addition, by simplifying the structure of the Mini-MPO adapter, an even more compact configuration has been achieved. By this means it has been possible to reduce both the height and width dimensions. Instead of a reinforcing member, the Mini-MPO connector has a guide sleeve that is inserted into the coupling sleeve. The dimensions of the Mini-MPO adapter are 10 x 8 x 24 mm, which is the same as or even less than the dimensions of the SC adapter (12 x 9 x 24 mm).

Based on the design concept described above, prototype Mini-MPO connectors were manufactured and their optical characteristics evaluated.

3. OPTICAL CHARACTERISTICS

3.1 Initial Characteristics

The first prototype Mini-MPO built was for two single-mode fibers. The end face of the ferrule was polished to an angle of 8° and no index matching material was used in the evaluations.

Figure 5 shows the results of measurements of insertion loss. The light sources used for the measurements were LEDs of 1310- and 1550-nm wavelength, and the data is the insertion loss value with respect to a standard plug. For both wavelengths the average loss was satisfactory at 0.2 dB or less with a maximum of 0.4 dB--values just as good as those of the conventional MPO connector.

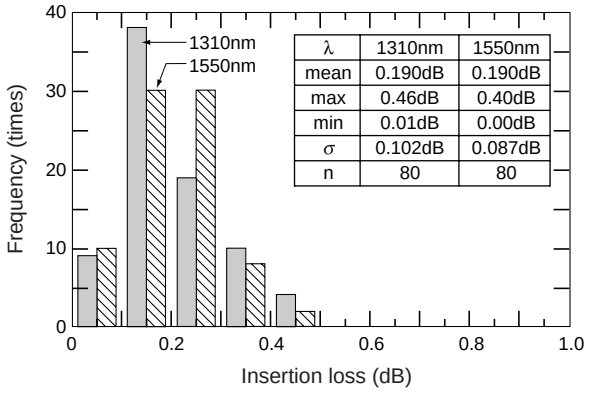
Figure 6 shows return loss characteristics. Measurements were made using LDs of 1310- and 1550-nm wavelength, and the return loss between a reference plug and the connection point was measured. The results were highly satisfactory, with an average of approximately 60 dB and a minimum of 53 dB.

3.2 Reliability Tests

Next the Mini-MPO connectors were tested for connection-disconnection performance and for temperature cycling. Table 2 shows the results.

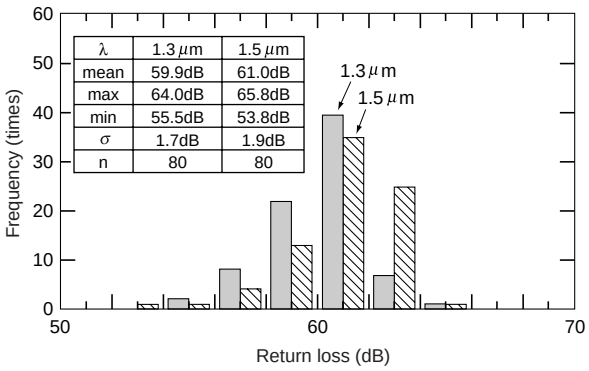
Figure 7 is representative of the results of connection-disconnection tests. A total of 500 reconnections were performed, and the insertion loss was measured. The change in insertion loss due to connection-disconnection was extremely stable within ±0.2 dB. Furthermore no particular damage to the connectors due to repeated connection-disconnection was observed. This confirmed that the structure was capable of withstanding frequent connection and disconnections.

Figures 8 and 9 show insertion loss change and return loss in an environment of -25 to 70°C. The insertion loss change was extremely stable--within +0.2 dB--over the full temperature range. Return loss also was 50 dB or more, a satisfactory result that was no different from room temperature performance.



λ	1310nm	1550nm
mean	0.190dB	0.190dB
max	0.46dB	0.40dB
min	0.01dB	0.00dB
σ	0.102dB	0.087dB
n	80	80

Figure 5 Insertion loss of single-mode 2-fiber Mini-MPO connector



λ	1.3 μm	1.5 μm
mean	59.9dB	61.0dB
max	64.0dB	65.8dB
min	55.5dB	53.8dB
σ	1.7dB	1.9dB
n	80	80

Figure 6 Return loss of single-mode 2-fiber Mini-MPO connector

Table 2 Results of Reliability Tests

Item	Conditions	Results
Connection-disconnection test	500 connection-disconnections λ = 1310 nm	Insertion loss change < 0.2 dB: (n=6)
Temperature cycling test	10 cycles -25/+70˚C λ = 1310 nm	Insertion loss change < 0.2 dB: (n=6) Return loss change < 50 dB: (n=4)

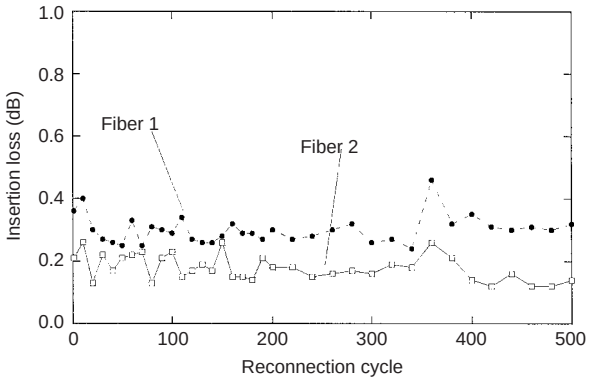


Figure 7 Insertion loss of two fibers in the same 2-fiber Mini-MPO connector during 500 reconnections

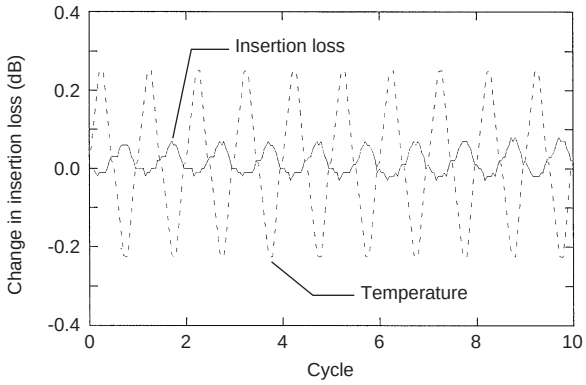


Figure 8 Change in insertion loss in Mini-MPO connector during temperature cycling test

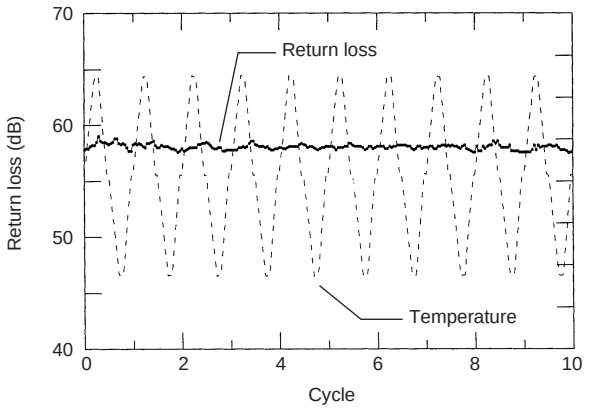


Figure 9 Return loss in Mini-MPO connector during temperature cycling test

4. STUDIES OF FLAT INTERFACES

4.1 Problems with Flat Interfaces

With recent progress in optical array device technology thought is being given to laser diode modules that can be joined by MT connectors in the hope of using optical fiber connections for high-speed computers and large-capacity exchanges. It is further expected that development will proceed not only in MT (MPO) connectors but in Mini-MPO connectors as well.

Connecting MPO and Mini-MPO connectors and optical modules will require both angled interfaces and flat interfaces. With a flat interface and no physical contact, there will be a marked degradation in return loss due to Fresnel reflection; to obtain satisfactory return loss characteristics it is essential that positive physical contact between the fibers be maintained. Accordingly attention was given to techniques of achieving physical contact with a flat interface in Mini-MPO connectors.

4.2 Evaluation of Optical Characteristics

A prototype flat-interface 2-fiber Mini-MPO connector was manufactured for single-mode and multimode fibers (core diameter 62.5μm). In evaluating optical characteristics, no refractive index matching material was used.

Table 3 Optical Properties of Flat-Interface Mini-MPO Connectors (n=16)

	Single Mode	Multi-mode (62.5 μm)
Insertion loss (dB)	mean=0.33 max=0.48	mean=0.02 max=0.10
Return loss (dB)	mean=47.9 max=41.0	mean=37.8 max=34.8

Table 3 shows data for insertion loss and return loss characteristics. Both are the values when connected to a reference plug. The results show that there is no practical problem in terms of either insertion loss or return loss. Return loss in particular is 47 dB average and 41 dB minimum for single mode and 37 dB average and 34 minimum for multimode --excellent results that are just as good as those for ordinary MT connectors using refractive index matching material.

4.3 Confirming Physical Contact

Next tests were carried out to confirm physical contact. In a flat interface, a gap between the fibers will result in a considerable degradation of both insertion loss and return loss. In connectors in which physical contact is not achieved, a refractive index matching material is applied in the gap between the fibers to improve optical characteristics. Thus to investigate the situation with physical contact, it is appropriate to compare the optical characteristics with and without refractive index matching material.

Figure 10 shows the relationship between insertion loss characteristics before and after application of refractive index matching material. In connectors in which physical contact is not achieved, application of refractive index matching material reduces insertion loss. This result, by showing that the difference in characteristics with and without the matching material is very small, suggests that physical contact was substantially achieved.

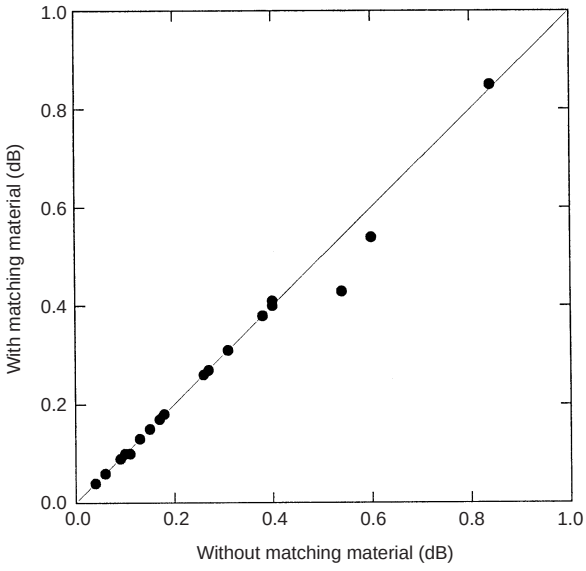


Figure 10 Relationship between insertion loss with and without index matching material for flat- interface Mini-MPO connectors

5. CONCLUSIONS

A new connector known as the Mini-MPO has been developed based on the existing MPO connector but connecting small-core fibers at higher density. It is smaller and simpler in structure, with an adapter cross-section measuring approximately one-half that of the MPO connectors.

In terms of optical characteristics it gives an average of 0.2 dB or less for insertion loss and 53 dB or more for return loss in single-mode angled-interface connectors--satisfactory characteristics that are equivalent to those obtained with conventional MPO connectors. The characteristics obtained in temperature cycling tests and connection-disconnection tests were stable, and constituted no practical problem. Good return loss characteristics were also obtained for flat-interface connectors.

Both the Mini-MPO and MPO connectors are expected to be used in an increasing range of applications as time goes on.

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