# Influence of High-Optical Power Light Launched Into Optical Fibers in MT Connector

Kazuo Hogari, *Member, IEEE*, Kenji Kurokawa, and Izumi Sankawa

***Abstract*—This paper describes the influence of a high-optical power light launched into optical fibers in an mechanically transferable (MT) connector. The features of the MT connector are the use of index matching material to suppress Fresnel reflection and the accommodation of several optical fibers to allow the connection of optical fiber ribbons. First, we experimentally investigated the relationship between connection loss, launched light power, temperature increase, and optical loss increase using an MT connector sample without contamination. Based on the results, we clarified the relationship between the allowed connection loss and the launched optical power in the optical fibers needed to maintain MT connector reliability. In addition, we examined the influence of the contamination of the connector endface and confirmed that it is necessary to clean the endface appropriately in an optical transmission system that uses high-optical power light to prevent any fatal damage to the MT connector.**

***Index Terms*—Optical fiber connecting, optical fibers, optical fiber amplifiers, optical losses, wavelength-division multiplexing (WDM).**

## I. Introduction

THE demand for greater transmission capacity is growing rapidly as a result of the increase in the number of broadband multimedia services provided by the Internet. Wavelength-division multiplexing (WDM) technology is a promising way of meeting this demand and is now being actively developed.

Distributed Raman amplification (DRA) has been applied to WDM systems as one approach to extending the WDM channel wavelength range [1]–[3]. DRA gain is available at any wavelength by changing the pump wavelength, and a broad bandwidth can be obtained by combining multiple pump wavelengths [4], [5]. When DRA is used, a high-optical power light must be launched into the optical fibers and/or the connectors. Therefore, it is necessary to maintain the characteristics under such conditions.

By contrast, an optical fiber connector is important for the construction of flexible optical networks. A mechanically transferable (MT) connector for optical fiber ribbons has been researched and developed [6]–[8]. This connector has a low connection loss and stable mechanical characteristics. The features of the MT connector are the use of index matching material to suppress Fresnel reflection and the accommodation of several optical fibers in a connector to allow connection with optical fiber ribbons. Although some papers have reported on the characteristics of single fiber connectors, such as the SC or MU connector, under high-optical power light input conditions [9], [10], the MT connector performance under these conditions remains unclear.

This paper describes the effect of launching high-optical power light into the optical fibers in an MT connector. First, we investigated experimentally the relationship between the connection loss, launched light power, temperature increase, and optical loss increase using an MT connector sample without contamination. Based on the results, we investigated the relationship between the allowed connection losses and launched optical power in optical fibers needed to maintain MT connector reliability under high-optical power light input conditions. In addition, we examined the influence of contamination on the connector endface.

## II. MT Connector Structure

The MT connector structure is shown in Fig. 1. The connector consists of a pair of plastic ferrules, optical fiber ribbon, two guide-pins, and a clamp spring. At the ferrule end, four or eight optical fibers are positioned accurately between two guide-holes. The ferrule is made by a precision plastic molding technique. The optical fibers to be connected can be easily aligned with two guide-holes and the two guide-pins using matching index material.

This connector has the advantages of ease of handling, small size, low connection loss, and stable mechanical characteristics.

## III. Experiments and Results

### A. Experimental Setup

Fig. 2 shows our experimental setup. In order to maintain MT connector reliability, we must investigate the temperature increase at the connection point that is induced by the heat generated by the light that radiates through the connection point. Therefore, we measured the temperature increase at the connection point using four-fiber MT connectors with various connection losses when we launched a high-optical power light into the optical fibers. We intentionally fabricated MT connectors with a high connection loss by increasing the imperfect alignment of the optical fiber. We used 1.3-$\mu$m zero-dispersion single-mode (SM) optical fiber defined by ITU-T Recommendation G.652 [11]. We used four Raman lasers operating in the 1.4-$\mu$m region as a high-power laser, and the optical power launched into the optical fibers was 0.5, 1, or 2 W. We measured the surface temperature at the connection point of the connector with a thermometer. At the same time, we measured the optical loss change. The tests were performed on the MT connector under different connector endface conditions, namely, no contamina-

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The authors are with NTT Access Network Service Systems Laboratories, Tsukuba-shi, 305-0805 Ibaraki-ken, Japan (e-mail: hogari@ansl.ntt.co.jp).

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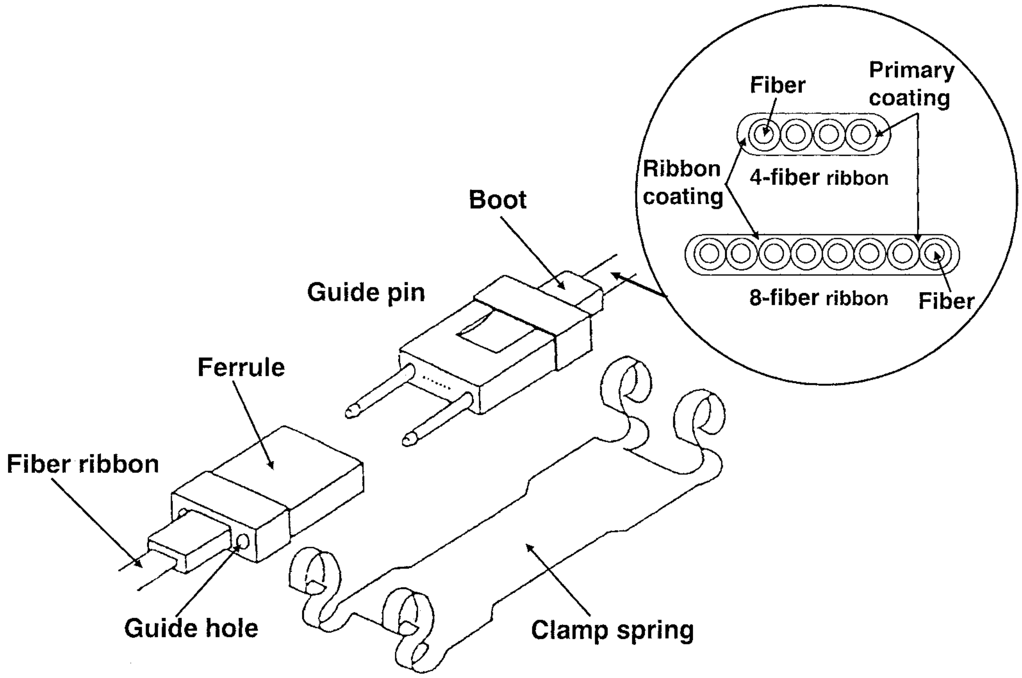


Fig. 1. MT connector structure.

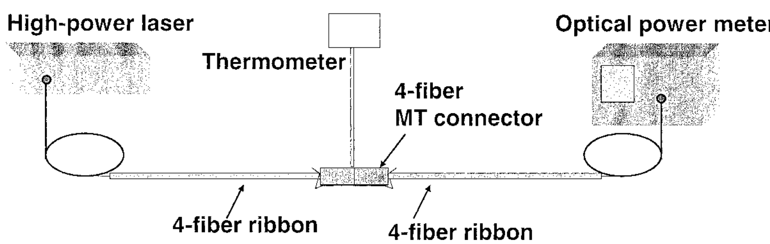


Fig. 2. Measurement configuration.

tion, contamination with shin grease, contamination with dust from an air-conditioner filter, and contamination with metal filings. The connector endface was examined using a microscope, and the connection loss was measured before the tests.

### *B. Influence of Connection Loss, Launched Light Power, Temperature Increase*

Fig. 3 shows an example of the test results without contamination when a high-optical power light was launched into one fiber in a four-fiber MT connector. It can be seen that the temperature increase saturates about 150 s. from the start of testing. We also found that the temperature increase depends on the connection loss. Moreover, some test samples with no contamination were measured under 2 W of optical light power for 72 h (3 d). The temperature increase $\Delta T$ was little different from the results obtained 600 s from the start of the test.

Fig. 4 shows a connection point model. The light launched into the optical fiber is divided into three components (transmitted light, radiated light, and reflected light) through the connection point. The temperature increase depends on the radiated light power. Thus, the radiated optical power $P_3$ is given by

$$P_3 = P_1 - P_2 - P_4 \tag{1}$$

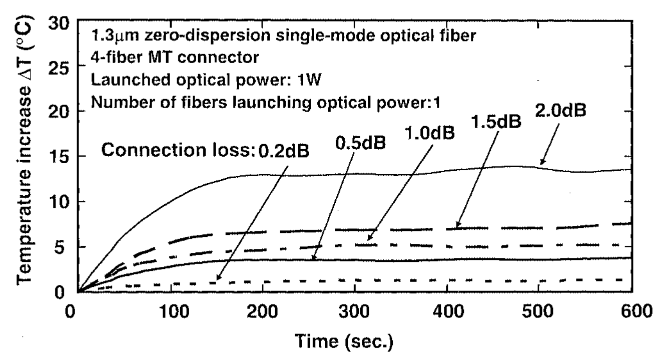


Fig. 3. Example of measured result for temperature increase $\Delta T$ during test.

where $P_1$ is the launched light power, $P_2$ is the transmitted light power, and $P_4$ is the reflected light power. Equation (1) is approximated by (2) because, when the index matching material is used to suppress the Fresnel reflection, the reflected light power $P_4$ is very small compared with $P_1$, $P_2$, and $P_3$

$$P_3 \approx P_1 - P_2 = \left(1 - 10^{-\frac{\alpha}{10}}\right) P_1 \tag{2}$$

where $\alpha$ is the connection loss. Fig. 5 shows the measured results of the relationship between temperature increase $\Delta T$ and

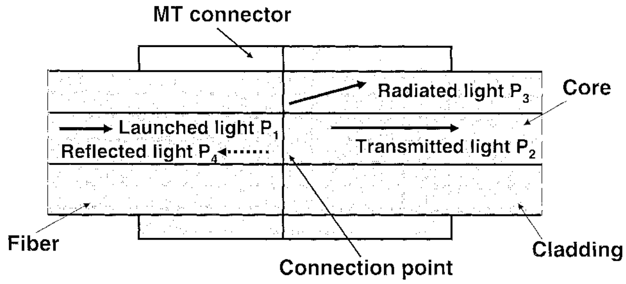


Fig. 4. Connection point model.

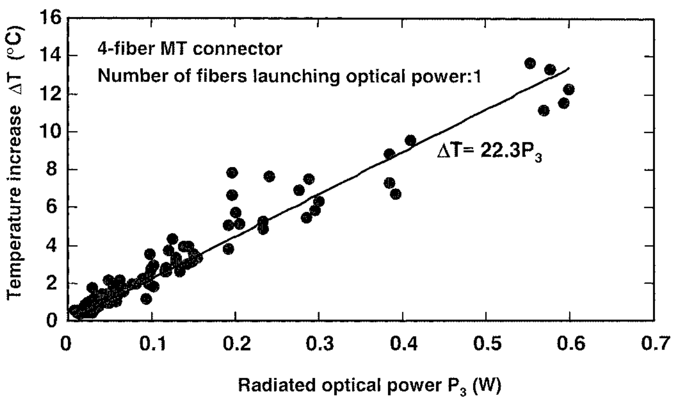


Fig. 5. Relationship between temperature increase and radiated optical power. (For high-optical power light launched into one fiber in MT connector).

radiated optical power $P_3$ when a high-optical power light is launched into one fiber in the MT connector. The maximum value obtained during the test was taken as the temperature increase $\Delta T$. We found that the temperature increase $\Delta T$ is almost proportional to the radiated optical power $P_3$. Thus, the data from Fig. 5 can be fitted to obtain a formula that approximates the relationship between the radiated optical power $P_3$ and temperature increase $\Delta T$. This formula is given by

$$\Delta T = 22.3P_3. \quad (3)$$

Based on (3), the relationship between the radiated optical power $P_3$ and the temperature increase $\Delta T$, when a high-optical power light is launched into several optical fibers in a MT connector, is given by

$$\begin{aligned}\Delta T &= \Sigma 22.3P_3 \\ &= 22.3P_3'. \end{aligned} \quad (4)$$

We also measured the temperature increase $\Delta T$ when a high-optical power light was launched into four fibers in a four-fiber MT connector. Measured results and results calculated using (2) and (4) are also shown in Fig. 6 and are almost in agreement. We can therefore use these equations to predict the temperature increase in an MT connector with no contamination.

### C. Allowed Connection Loss and Launched Optical Power in MT Connector

It is important to obtain the allowed launched optical power $P_1$ and connection loss $\alpha$ needed to maintain MT connector reliability. When the temperature increase $\Delta T$ is determined, the relationship between $P_1$ and $\alpha$ can be calculated using (2) and (4). Calculated results are shown in Fig. 7. The temperature increase $\Delta T$ must be 10 °C [10] to maintain MT connector reliability. The allowed range for $P_1$ and $\alpha$ is found on the hatched side of the curve for high-optical power light launched into one, two, three, or four optical fibers in the MT connector.

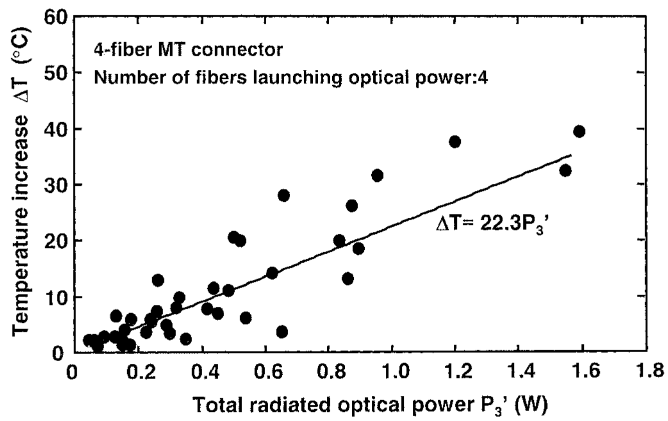


Fig. 6. Relationship between temperature increase and total radiated optical power (for high-optical power light launched into four fibers in MT connector).

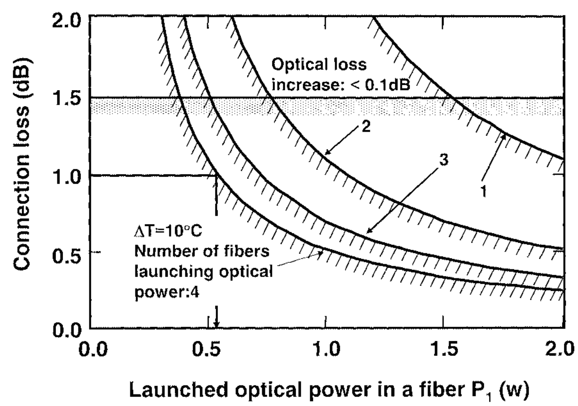


Fig. 7. Relationship between launched optical power $P_1$ and connection loss $\alpha$ for temperature increase $\Delta T$ of less than 10 °C.

The measured connection loss distribution of the MT connector is shown in Fig. 8. The connection loss was less than 1 dB with 95% probability. Thus, Fig. 7 reveals that the MT connector can maintain a high reliability with a $P_1$ value of less than 0.5 W, which is launched into four fibers in the MT connector.

We also measured the optical loss increase during the test. The measured results are shown in Fig. 9. When the connection loss was less than 1.5 dB, the optical loss increase was less than 0.1 dB. Thus, we confirmed that the MT connector has stable loss characteristics with a connection loss of less than 1.5 dB. Therefore, the allowed range is seen on the hatched side of the curve in Fig. 7. In addition, we found that the use of index matching material when high-optical power light was launched into the optical fibers had very little effect.

On the basis of the above discussion, the launched light power should be selected from the hatched regions in Fig. 7 if we are to use the MT connector without any damage under high-optical power conditions when there is no contamination.

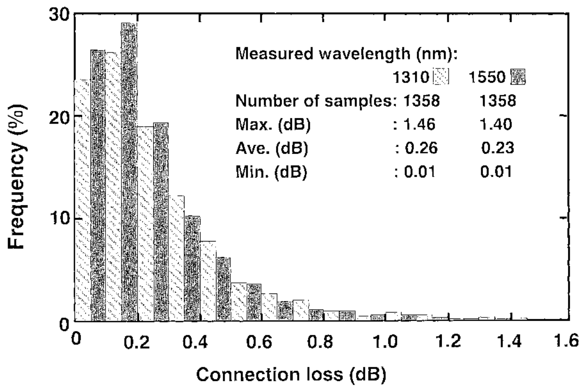


Fig. 8. Measured connection loss distribution of MT connector.

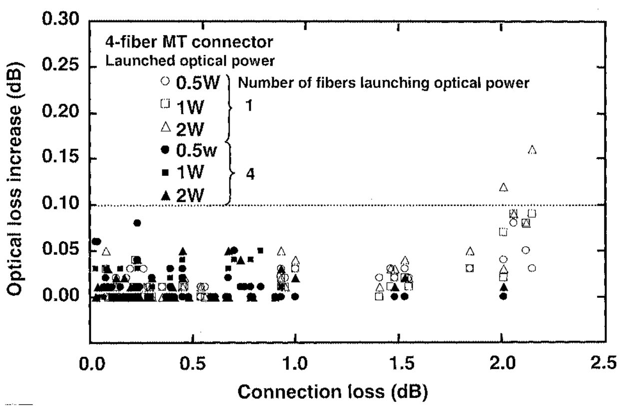


Fig. 9. Relationship between connection loss and optical loss increase during the test without contamination.

## D. Influence of Contamination on Connector Endface

It is important to clean the connector endface during the connector joining operation. This is because the connector performance deteriorates when the endface is contaminated with dust. When a high-optical power light is launched into a contaminated connector endface, there may be fatal damage rather than performance degradation. We therefore prepared connector samples contaminated with shin grease, dust from an air-conditioner filter, or metal filings and investigated them in the same way as the uncontaminated connector. For the measurement, we launched a high-optical power light into one fiber in the MT connector.

When the connector endface was contaminated with shin grease (total sample number: 36), the connector remained undamaged and the temperature and loss increases were almost the same as those obtained when there was no contamination.

By contrast, when the connector endface was contaminated with dust from an air-conditioner filter (total sample number: 36) or metal filings (total sample number: 36), some samples (four samples with dust from an air-conditioner filter and one sample with metal filings) suffered optical fiber surface damage and a large loss increase with a low connection loss connector and a launched optical power of 0.5 W. Fig. 10 shows a photograph of a fiber endface before and after testing. We observed damage to the fiber core when the endface was contaminated. Moreover, when the launched optical power was increased to 2 W, the number of optical fiber samples with surface damage increased. Thus, if the connector endface is not cleaned, there is the possibility of fatal damage occurring when an optical transmission system is operated with high-optical power light. Therefore, we found that it is necessary to undertake appropriate connector endface cleaning in an optical transmission system that uses high-optical power light.

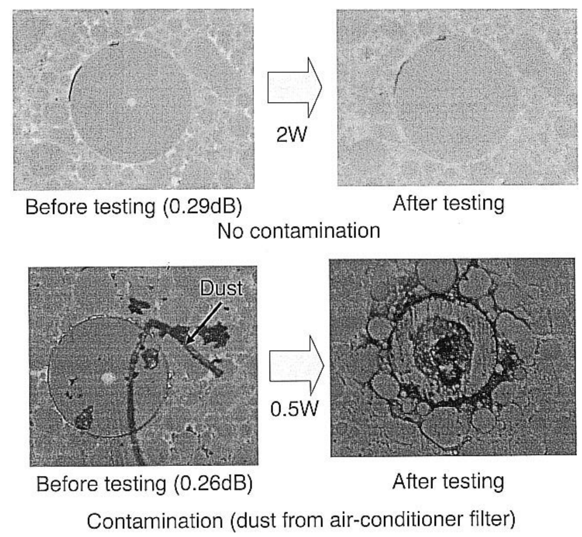


Fig. 10. Condition of connector endface contaminated with air-conditioner filter dust after test.

## IV. Conclusion

This paper described the effect of launching a high-optical power light into optical fibers in an MT connector. The features of the MT connector are the use of index matching material to suppress Fresnel reflection and the accommodation of several optical fibers to allow optical fiber ribbons to be connected. This connector has the advantages of ease of handling, small size, low connection loss, and stable mechanical characteristics. First, we experimentally investigated the relationship between the connection loss, launched light power, temperature increase, and optical loss increase using an uncontaminated MT connector sample, and we found that the use of index matching material when a high-optical power light was launched into the optical fibers had very little effect. Based on these results, we clarified the relationship between the allowed connection losses and the optical power launched into an optical fiber in terms of maintaining MT connector reliability. In addition, we examined the influence of connector endface contamination and confirmed that it is necessary to clean the connector endface appropriately in an optical transmission system using high-optical power light to prevent fatal damage to the MT connector.

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**Kazuo Hogari** (M'90) was born in Ibaraki Prefecture, Japan, on February 28, 1959. He received the B.E. degree in electrical engineering from Ibaraki University, Ibaraki, Japan, in 1981 and the Dr. Eng. degree in electrical engineering from Waseda University, Tokyo, Japan, in 1994.

He joined the NTT Electrical Communications Laboratories, Ibaraki, Japan, in 1981, where he has been engaged in research and development of optical fiber cables and optical components. He is presently a Senior Research Engineer, Supervisor, of NTT Access Network Service Systems Laboratories.

Dr. Hogari is a Member of the Institute of Electronics, Information and Communication Engineers (IEICE) of Japan. He received the most outstanding technical paper of the 43rd IWCS in 1994.

**Kenji Kurokawa** was born in Japan in April 1962. He received the B.S. and M.S. degrees in physics and the Ph.D. degree from the University of Tokyo, Tokyo, Japan, in 1985, 1987, and 1997, respectively.

He joined the Ibaraki Electrical Communication Laboratory, Nippon Telegraph and Telephone Corporation, Ibaraki, Japan, in 1987, where he has been engaged in research on ultrashort optical pulse generation and nonlinear effects in optical fibers.

Dr. Kurokawa is a Member of the physical society of Japan, the Japan Society of Applied Physics, and the Institute of Electronics, Information and Communication Engineers (IEICE) of Japan.

**Izumi Sankawa** received the B.E. and Dr. Eng. degrees in electrical engineering from Waseda University, Tokyo, Japan, in 1979 and 1991, respectively.

He joined the Ibaraki Electrical Communication Laboratories, NTT, Ibaraki, Japan, in 1979, where he has been engaged in research on optical fiber splicing, testing technologies, and optical fiber measurement and surveillance systems. He is presently Senior Research Engineer, Supervisor, of NTT Access Network Service Systems Laboratories, Tsukuba, Japan.

Dr. Sankawa is a Member of the Institute of Electronic, Information and Communication Engineers (IEICE) of Japan, the Japan Society of Applied Physics, and the Japan Society of Physics.