Development of Automated Optical Fiber Cross-connect Equipment

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Abstract

We have developed automatic optical fiber cross-connect equipment that provides automatic cross-connection among any of 200 pairs of input and output optical fibers using a fiber-handling robot. This equipment allows the cross-connection and management of optical fibers in networks in intelligent buildings and optical access networks to be performed by remote control. It eliminates the need for manual cross-connection and decreases the operating cost.

1. Importance of automatic optical cross-connection

With the rapid progress of broadband Internet service, optical communication networks have been extended to offices and homes. It is important to decrease the network operating cost after network equipment has been installed while offering a high-speed, high-transmission-capacity network that is highly reliable and economical. This article introduces automated optical fiber cross-connect equipment developed in NTT Microsystem Integration Laboratories. This equipment eliminates the need for manual cross-connection and decreases the operating cost.

1.1 Conventional optical cross-connection and effectiveness of automation

In intelligent buildings in a metropolitan area network (MAN) and in small-scale facilities in the optical access network, optical cross-connection is necessary for broadband service to be offered through the optical fibers. Conventionally, optical connectors are joined manually using an optical connection board and a patch panel. In this manual connection, mistakes occur due to discrepancies between the actual physical settings of the connections and their management because these processes are independent. This reduces reliability. Moreover, manual cross-connection is time-consuming and expensive because maintenance personnel must be dispatched to remote places to correct mistakes.

1.2 Application of automated optical fiber cross-connect equipment

Figure 1 shows how the automated optical fiber cross-connect equipment is used in an optical access network and a MAN. We investigated cross-connect equipment that would allow us to reduce the operating costs of cross-connection, especially for small-scale remote unmanned facilities. Introducing this equipment in the optical access network enables an optical subscriber cable to be automatically connected and disconnected to an optical cable for a central office in an instant. Therefore, interruptions to the broadband communication service can be minimized. Moreover, no one has to be dispatched to the small-scale facilities in the optical access network. In intelligent buildings on a MAN, it is possible to reconfigure the network flexibly when floor layouts are remodeled and it is easy to construct private networks between floors.

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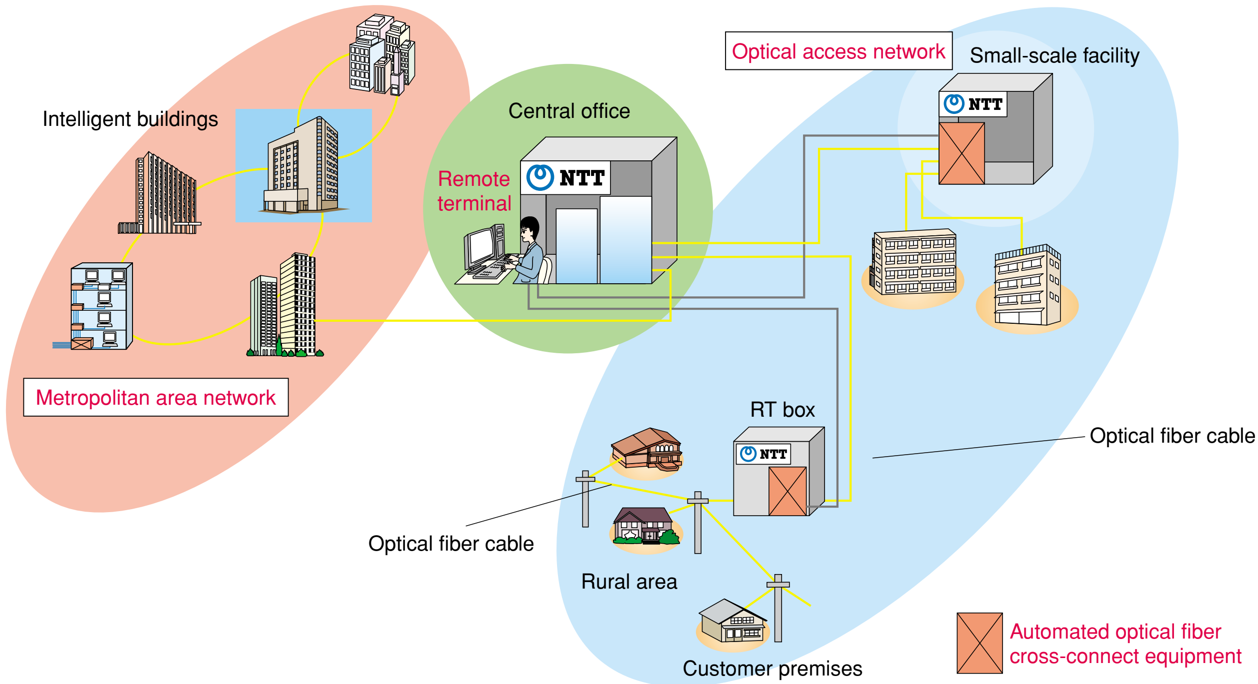

Fig. 1. Application of automated optical fiber cross-connect equipment.

2. Development

2.1 Requirements

Table 1 summarizes the requirements for optical fiber cross-connect equipment set up in an intelligent building or in a remote terminal box (RT box). The system must have several hundred ports so that it can terminate subscriber optical cables in a small-scale facility. Moreover, the equipment must fit conventional 19-inch and RT-box device racks because it must be installed efficiently with other telecommunications equipment and communications devices for the construction of various systems. It should have a switching time of no more than a few minutes, a low insertion loss, and optical wavelength transparency. The switching state must also be maintained even if the power supply fails (self-holding). In addition, the equipment must satisfy environmental specifications, electromagnetic compatibility (EMC), and earthquake-proof requirements, etc.

Several optical switches such as the laser diode optical matrix switch [1] and thermo-optical matrix switch [2] have been proposed. However, these switches do not exhibit self-holding of the optical

Table 1. Requirements for optical fiber cross-connect equipment.

Port capacity	200 × 200 non-blocking
Size	Should fit in 19-inch rack and in racks used in small-scale remote unmanned facilities
Optical characteristics	Insertion loss: less than 1 dB Return loss: more than 40 dB Wavelength independent
Self-holding	Possible (when the power supply is cut)
Switching time	1 min. (average)
Operation temperature and humidity	Temperature: 5–45°C, Humidity: 20–70%
EMC	VCCI class A
Earthquake-proof	Fully operable after a category 7 earthquake

connection and their optical performances are worse than those of an optical connector. Furthermore, it is difficult to achieve several hundred non-blocking optical cross-connections with these switches.

2.2 Configuration of automated cross-connect equipment

To meet all of the above requirements, we devised a robotics-based handling method in which a fiber-handling robot connects and disconnects optical connector plugs to and from optical adaptors to achieve the cross-connection of optical fibers (**Fig. 2**). A 100×100 automated optical fiber cross-connect system was previously developed [3], but for use in both an optical access network and a MAN, we developed a new configuration for the automated optical fiber cross-connect equipment. The equipment comprises a control-terminal PC and the optical fiber cross-connect module. In the terminal PC, operation and maintenance software controls the equipment, issues cross-connection commands, and manages the equipment. The cross-connection module consists of an optical connection part, robot mechanism, and controller. Two or more cross-connect modules can be installed in one device rack, and as many as four modules can be controlled by one controller.

To satisfy environmental requirements, the positioning error due to thermal expansion caused by temperature changes should be corrected. To ensure electromagnetic compatibility, we designed a sealed housing that prevents electromagnetic waves from escaping. As earthquake-proofing measures, we developed an earthquake-proof mechanism in the module and a restoration procedure in the operation and maintenance software.

2.3 Optical cross-connect module

Figure 3 shows the inside of the automated optical fiber cross-connect module and fiber-handling robot. The module can connect any of the 200 input optical fibers to any of the 200 output fibers by exchanging optical jumper cords. Cross-connections are made by exchanging one plug for another. First, the robot hand disconnects two target plugs, each of which has a jumper cord, and arranges them on the arrangement board. The cord is rewound into the fiber storage cartridge so that it does not become tangled with other cords. Next, the robot hand grasps one of the target plugs and connects it to the target adaptor in the connection board. It then connects the other plug in the same way.

To make the module compact, the optical connection part, optical fiber storage cartridge, and robot mechanism were newly developed. For high connection density in the optical connection part, we designed a housing to accommodate two 25-port optical adaptors in two staggered rows and stacked two housings vertically. The optical fiber storage cartridge was designed to be compact while accommodating multiple fibers.

Cross-connecting fibers on a densely packed connection board requires robot fingers that can access the whole area of the connection board. We designed a long finger using the finite element method. As a result, 200×200 port cross-connection is possible because the packaging density is twice that of con-

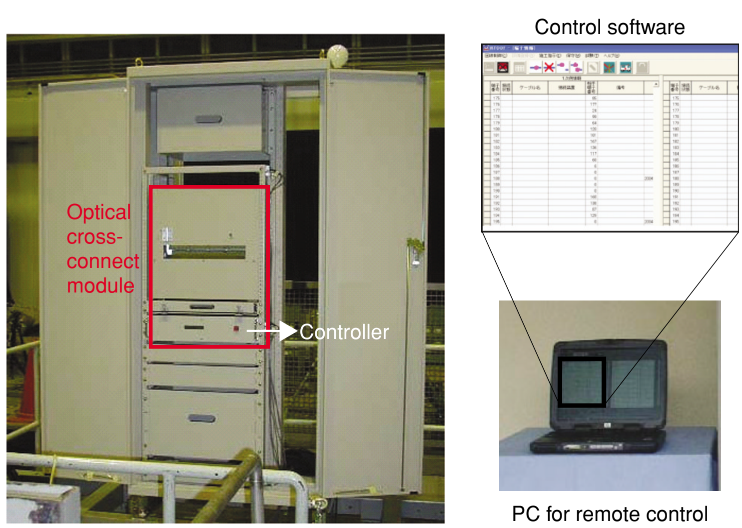

Fig. 2. Configuration of the automated optical fiber cross-connect equipment.

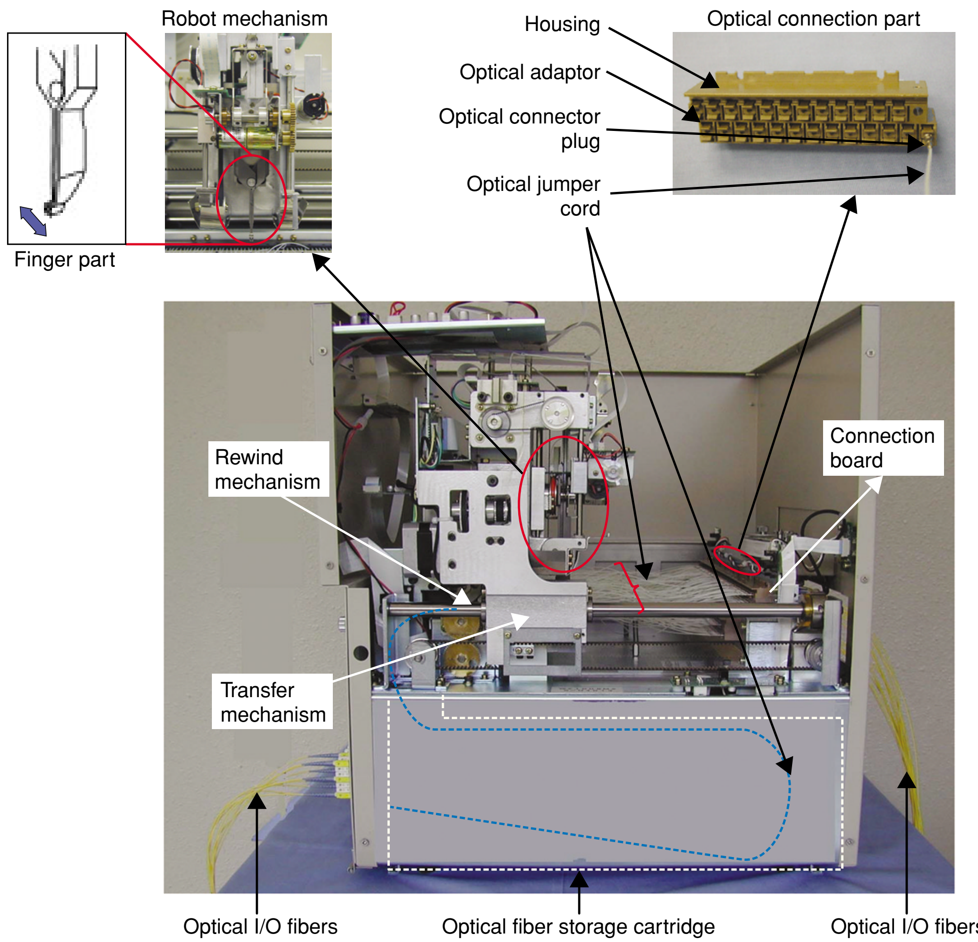

Fig. 3. Configuration of the automated optical-fiber cross-connect module.

ventional automatic equipment. We confirmed that the equipment could be installed in a 19-inch rack or in an RT-box device rack.

2.4 Operation and maintenance software

The operation and maintenance software installed in the control-terminal PC is connected with the optical cross-connect module by a local area network (LAN) or RS-232C line. This software has two modes: operating and maintenance.

In the operating mode, a telecommunication line control function connects and disconnects the control-terminal PC to and from the controller's communication line. An equipment registration function registers information about the input and output equipment to which the optical cross-connect module is connected. An earthquake-proof function performs a restoration procedure after an earthquake. An optical cross-connection function handles the connection and disconnection of specific optical fibers.

The maintenance mode has functions for i) displaying sensors installed in the module, ii) examining mechanisms, iii) initializing various mechanism elements such as the rewind and robot mechanisms, and iv) batch processing that is continuously executed in the order of the setting sequences. These functions enable an inexperienced terminal operator to operate the equipment via a simple graphical user interface.

3. Performance of the equipment

We evaluated the performance of the equipment. The main results are summarized in **Table 2**. The optical characteristics of the newly developed optical parts unit were equivalent to those of an MU-type optical connector, and it passed the long-term relia-

Table 2. Results of performance evaluation test.

	Test	Performance
Optical device	Optical characteristics	Insertion loss: less than 0.5 dB Return loss: more than 45 dB
	Reliability	Satisfied Telcordia GR-326 standard
Equipment	Optical characteristics	Insertion loss: less than 1 dB Return loss: more than 40 dB
	Switching time (average)	Less than 1 min. (to exchange one pair of fibers)
	Operating range of temperature and humidity	Temperature: 5–45°C, Humidity: 20–70%
	EMC	VCCI class A
	Earthquake-proof	Fully operable after a category 7 earthquake (simulated below the floor of the NTT test building)

bility test specified by the Telcordia GR-326 standard. The initial insertion loss of the equipment was less than 1 dB, and the return loss was more than 40 dB. A pair of optical jumper cords could be exchanged in one minute or less on average. The equipment operated perfectly under room temperature changes from 5 to 45°C. The EMC characteristics satisfied class A of the VCCI (Voluntary Control Council for Information Technology Equipment) standard. It could also be operated after a simulated category seven earthquake (on the Japanese scale) was applied below the floor (acceleration input: 10 m/s^2) on which the equipment was standing.

The evaluation results confirm that the automated optical fiber cross-connect equipment is suitable for practical use in intelligent buildings and optical access networks.

References

[1] M. Ikeda, S. Oku, Y. Suzuki, and M. Okayasu, "Lossless 4x4 Monolithic LD Optical Matrix Switches," International Topical Meeting on Photonic Switching, pp. 792, 2D1, 1992.

[2] R. Nagase, A. Himeno, M. Okubo, K. Kato, K. Yukimatsu, and M. Kawachi, "Silica-based 8x8 Optical Matrix Switch Module with Hybrid Integrated Driving Circuits and its System Application," IEEE J. Lightwave Technol. 12, No. 9, pp. 1631-1639, Sep. 1994.

[3] K. Sasakura, J. Yamaguchi, T. Yoshizawa, K. Kobayashi, and K. Kaneko, "Automated optical fiber cabling system for Intelligent buildings," Proc. 48th IWCS, pp. 364-368, 1999.

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