

Optical Fiber Network Operation Technologies for Expanding Optical Access Network Services

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Abstract

This article introduces NTT's R&D trends in optical distribution management and identification technologies and in optical fiber line testing technologies designed to reduce operating costs. Reducing optical fiber network operating costs related to service demand, cable removal, and maintenance work is essential if we are to achieve NTT's target of 30 million optical fiber access customers by 2010.

1. Background

In addition to reducing optical fiber network construction costs, we must also reduce operating costs, especially those related to service demand, cable removal, and maintenance work (Fig. 1), if we are to achieve 30 million customers by 2010.

Service demand work, which involves deploying optical services to customers' houses, can be divided into operations performed in the central office and those performed outside. In the central office, workers connect transmission equipment to a distribution

frame that terminates outside optical cables. Outside work involves connecting a drop fiber from an aerial closure to the customer's house and installing optical network units (ONUs). Once this work has been completed, tests must be performed to ensure that it has been done correctly.

The cable removal work needed to change a cable's route, as a result of road construction for example, also involves various operations. First, the new cable is installed. Then, workers identify the active route fiber and the new route fiber. Next, they cut the active route fiber and reconnect it to the new route fiber to

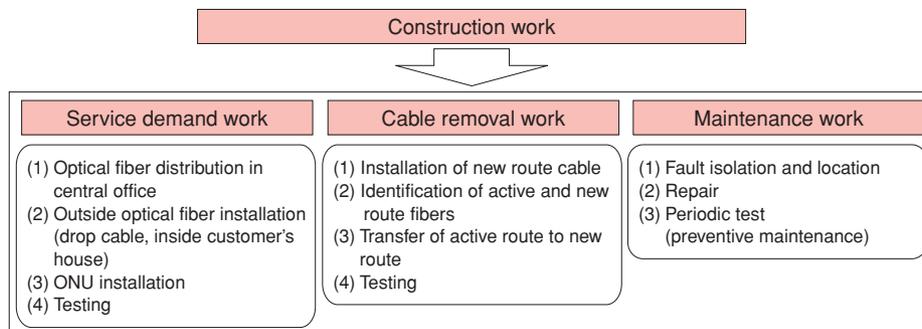


Fig. 1. Optical fiber network operation work.

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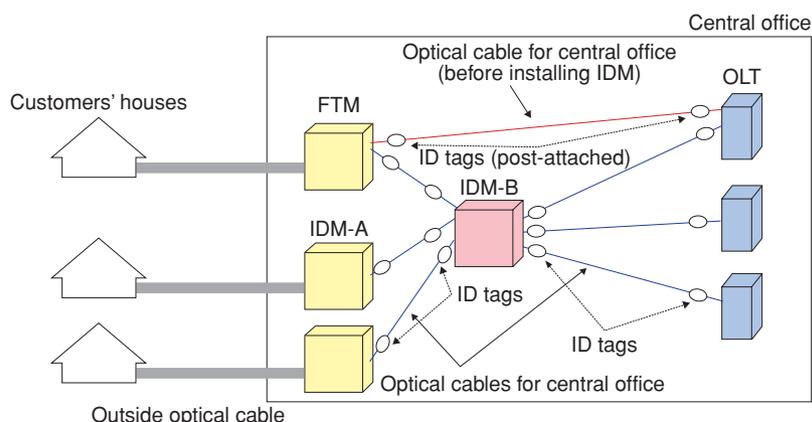


Fig. 2. Configuration of optical fiber distribution in a central office.

transfer the active route to the new route. Then, they perform tests to determine whether or not the connection has been completed successfully.

Maintenance work involves performing routine maintenance and responding to breakdowns and complaints. When a customer reports a fault, it must be isolated quickly. The fault's location must be determined and the fault must be promptly repaired and the repairs must be tested. Periodic testing as preventive maintenance allows repairs to be made before a fault occurs.

To reduce the cost of all the operations needed in an optical fiber network, we must make components easier to use and must improve the efficiency of the management and identification of the central office and outside optical distribution facilities and optical fiber line testing. In this article, we introduce the trends of NTT's research and development related to optical distribution management and identification technologies and optical fiber line testing technologies.

2. Optical distribution management and identification technologies

2.1 Optical fiber distribution technologies in a central office

The configuration used for optical fiber distribution in a central office is shown in Fig. 2. Optical fiber distribution facilities include transmission equipment such as optical line terminals (OLTs) that provide IP (Internet protocol) services, distribution frames that terminate outside optical cables, and optical cables for connecting OLTs to distribution frames. At present, the distribution frames are being changed over from fiber termination modules (FTMs) to integrated

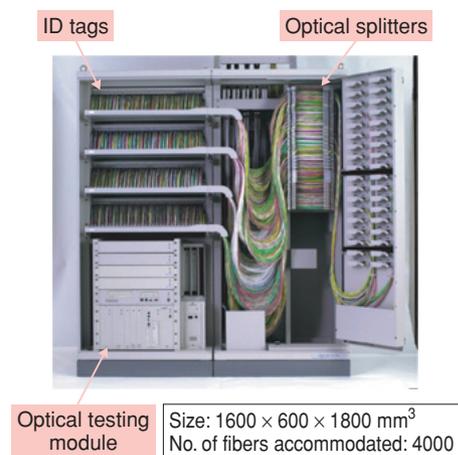


Fig. 3. Integrated distribution module.

distribution modules (IDMs). A single IDM (Fig. 3) can accommodate 4000 optical fibers because we developed compact connectors and thinner optical cables. It can also contain optical splitters for passive optical network (PON) systems and optical testing equipment (described later).

Distribution management is based on the use of ID tags, as shown in Fig. 4. An ID tag is attached to the each end of each optical cable connected to the IDMs and information about the fibers in the cable is stored in a database. This information can be accessed when the tag is read using an ID code scanner. NTT has chosen to use QR Codes*, which are a two-dimensional bar codes, for these ID tags. We have also developed ID tags that can be attached to older opti-

* QR Code is a registered trademark of Denso Wave Incorporated.

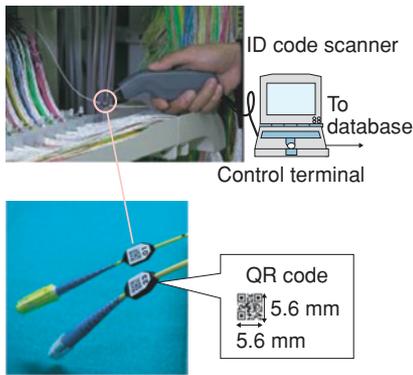
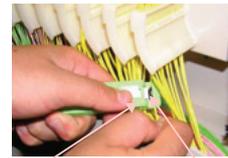


Fig. 4. Distribution management using ID tags.



(a) Post-attached ID tag



(b) Tag attachment process in an FTM

Fig. 5. Post-attached ID tag.

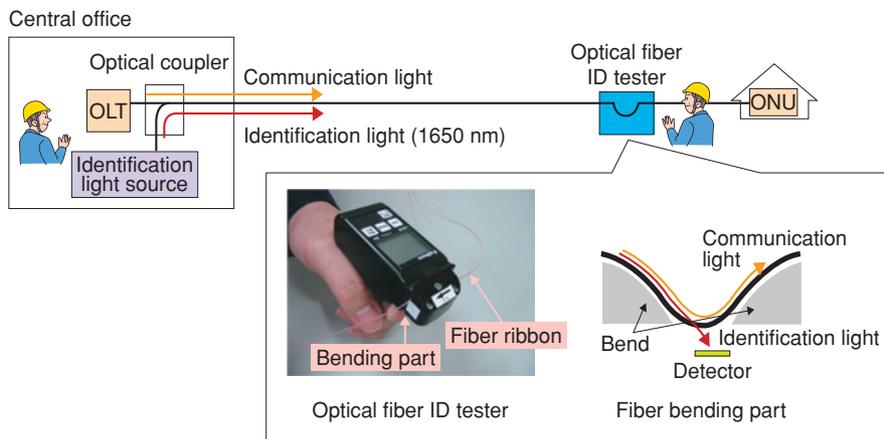


Fig. 6. Optical fiber identification technologies using an optical fiber ID tester.

cal cables connected to an FTM that were deployed before the installation of the IDMs [1]. This post-attached ID tag and the tag attachment process are shown in Fig. 5. This retrofitting makes it possible to store information about every optical cable in the database, which makes it easy to manage all the central office distribution facilities.

2.2 Optical fiber identification techniques

To reduce the risk of cutting or disconnecting the wrong optical fiber during optical fiber operations inside and outside the central office, a worker can identify optical fibers non-destructively using an optical fiber ID tester (Fig. 6). He or she selects a likely optical fiber and places it in the optical fiber ID tester. An identification light, which has a longer wavelength than the communication light, is launched into the target optical fiber from the central office. The tester bends the optical fiber and detects

the light that consequently leaks from it. If the tester detects the identification light, then the worker knows that the target fiber has been correctly selected. Otherwise, he or she can repeat the process to find the target fiber. This process does not interfere with the communication light, so in-service testing without affecting data transmission is possible. By optimizing the shape of the fiber bending structure and increasing the sensitivity of the detector, we have enabled identification to be performed even for long-wavelength-band optical communications and for optical fiber cords whose thick cover makes it difficult to detect leaking light [2].

3. Optical fiber line testing technology

3.1 Optical fiber line testing system

Optical fiber lines must be tested to assess whether service demand, cable removal, and maintenance

work has been performed correctly. Our optical fiber line testing system performs various types of optical test remotely, so it can reduce the operation time and cost. Its functions are shown in **Table 1**. In addition to testing for construction work, this system can perform various tests for service demand, cable removal, and maintenance work such as fault isolation, fault location, and periodic tests. The system configuration is shown in **Fig. 7**. An operator in a maintenance center sends orders via a data network to the optical testing module (OTM) telling it to perform various tests. The OTM retrieves optical fiber information from a database server, measures the target optical fiber, and returns the test results to the control terminal.

The OTM, which is installed in an IDM, contains various types of optical measurement equipment such as an optical time domain reflectometer (OTDR), a light source to provide the identification light, and a power meter. An optical switch called a fiber selector selects the target fiber and an optical coupler intro-

duces the test light into the target fiber. An optical filter installed in front of the ONU at a customer's house cuts and reflects the test light from the OTM while allowing the communication light from the OLT to pass. Therefore, this system can carry out automatic measurements, obtain fiber characteristics, and determine the nature and location of faults without affecting the transmission quality.

3.2 Water penetration detection technology

If water penetrates into an underground closure over time, it can increase the optical loss and degrade the mechanical strength. For this reason, water sensor modules are attached to an optical fiber for maintenance use in each underground closure. The water sensor module and the detection mechanism are shown in **Fig. 8**. If water penetrates the underground closure, an absorbent material in the sensor module expands and applies a bending force to the optical fiber. This induces bending loss, which can be detected by an OTDR. Moreover, the OTDR can determine the distance at which the bending loss is occurring, so it is possible to identify which closure has the problem. Therefore, water penetration in each underground closure can be monitored by periodic tests with the optical fiber line testing system.

3.3 Standardization of wavelengths for maintenance use

The wavelength bands defined by ITU-T (International Telecommunication Union, Telecommunication Standardization Sector) are shown in **Fig. 9**.

Table 1. Functions of the optical fiber line testing system.

Construction (service demand and cable removal work)	OTDR test	Connection loss and reflection value
	Loss test	Optical cable span loss
Maintenance	Fault test	Fault isolation and location
	Periodic test	Detection of water penetration into closure
Fiber identification	Insertion of identification light	

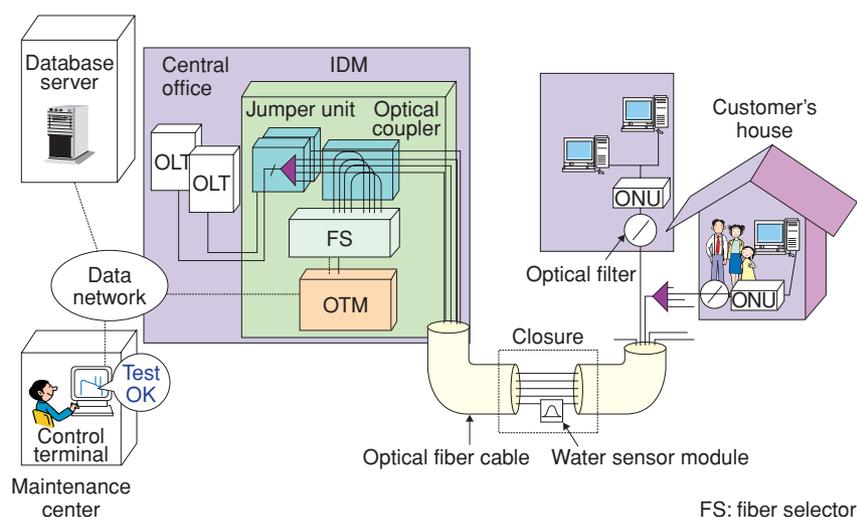


Fig. 7. Configuration of the optical fiber line testing system.

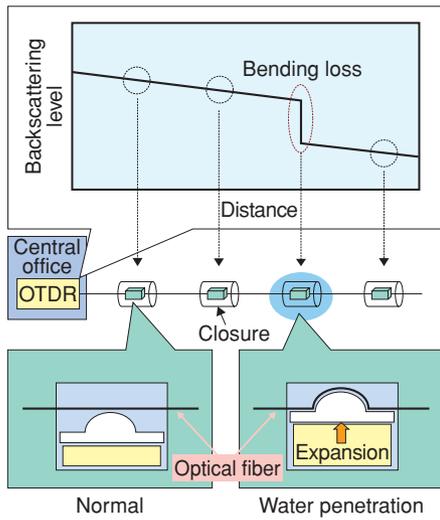


Fig. 8. Water sensor module.

ITU-T Recommendation L.41 calls for the 1650-nm window to be either vacant or used for maintenance rather than to be actively used. NTT has chosen to use the 1650-nm window for maintenance purposes in accordance with this recommendation.

3.4 Advanced measurement technique

When optical splitters are installed in optical closures and cabinets near a customer’s house, it is difficult to isolate a fiber fault in a branched optical fiber using an OTDR because the reflection from one optical filter hides the reflection from another optical filter. We have developed a fiber fault isolation technique using a high-resolution OTDR (H-OTDR), as shown in Fig. 10. For this technique, we narrowed the pulse width of the OTDR and broadened the bandwidth of the OTDR receiver circuit. As a result, the

O-band 1260–1360 nm	E-band 1360–1460 nm	S-band 1460–1530 nm	C-band 1530–1565 nm	L-band 1565–1625 nm	U-band 1625–1675 nm
1300	1400	1500	1550	1600	1650 (nm)

(a) Definition of wavelength bands in ITU-T G. Supplement 39

	1310-nm window	1550-nm window	1625-nm window	1650-nm window
Case 1	Active	Vacant or maintenance	Vacant or maintenance	Vacant or maintenance
Case 2	Vacant or maintenance	Active	Vacant or maintenance	Vacant or maintenance
Case 3	Active	Active	Vacant or maintenance	Vacant or maintenance
Case 4	Active or vacant	Active	Active	Vacant or maintenance

(b) Assignment of wavelengths for maintenances in ITU-T Recommendation L.41

Fig. 9. Standardization of wavelength bands.

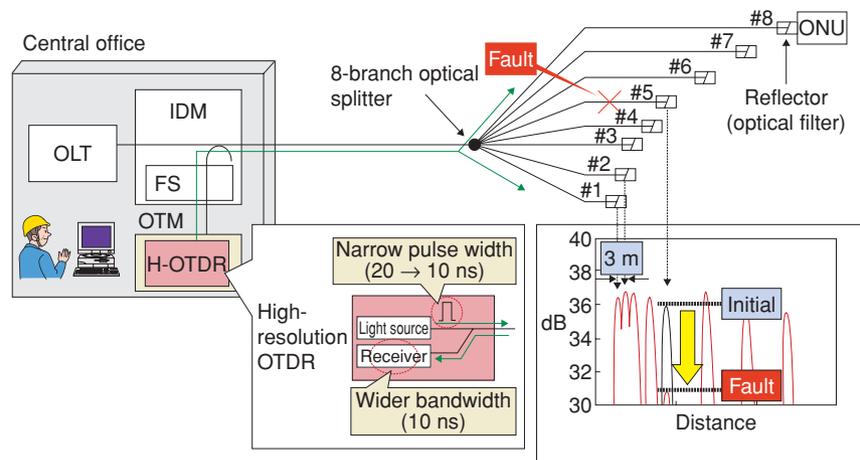


Fig. 10. Fault isolation technique using a high-resolution OTDR.

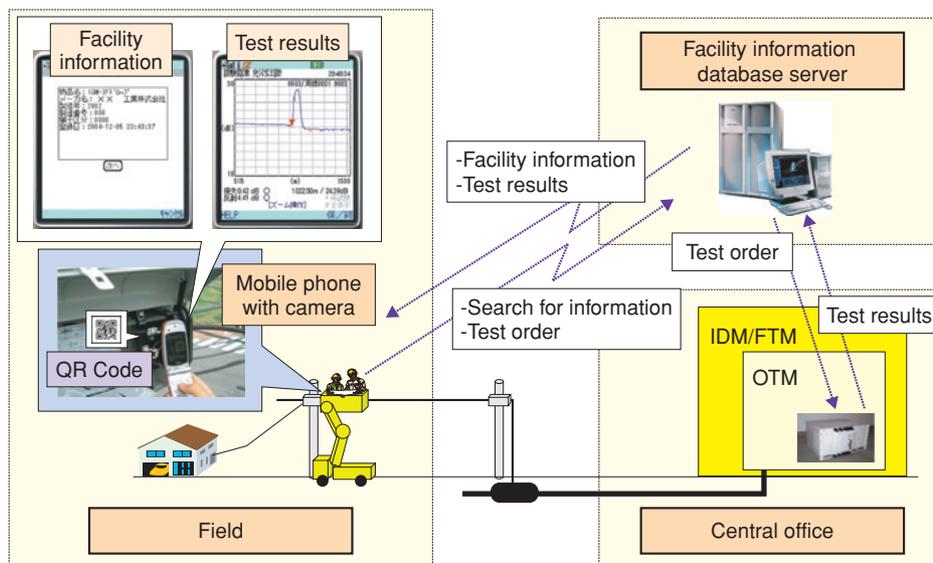


Fig. 11. Facility management and testing system using mobile phones.

reflection from each optical filter can be isolated when the difference in path lengths is more than 3 m. Using the H-OTDR, we can isolate a fiber fault by comparing the initial reflection level with measured reflection levels. This technique is also applicable to service demand and cable removal work.

4. Future plans

We are developing a facility management and testing system based on the use of mobile phones (Fig. 11) with the aim of simplifying the management and testing of outside optical facilities. With this system, a worker in the field can capture the QR Code of an ID tag attached to an outside facility using a mobile

phone containing a camera and forward that code to a database. This makes it easy to store and retrieve optical facility information in the field and perform tests. We are also investigating facility management and testing technologies that combine RFID tags and advanced optical measurement techniques.

References

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