

# Latest Topics in Optical Fiber Technology Research

*Yuji Azuma*

## Abstract

This article introduces some of the latest research topics related to new optical fiber technologies. These technologies enable functional and efficient operation and maintenance of networks while maintaining high reliability, and will support future high-speed, high-capacity networks. The Feature Articles in this month's issue are based on lectures given at the NTT Tsukuba Forum 2012 workshop held on October 19, 2012.



## 1. Forty years of optical fiber technology research

It has been 40 years since the NTT Research and Development Center was opened in 1972 in Tsukuba. The research and development of optical fiber technology also has a history of roughly 40 years. The current optical broadband service infrastructure, which connects 17 million customers, is the result of developing technologies such as single-mode fiber, optical cables, optical interconnects, and operation and maintenance systems. Initially, optical fiber equipment was intended to create an optical fiber network that was as easy to handle as wired networks. However, to obtain high speed and a wide bandwidth, sophisticated skill or knowledge was often needed to build, maintain, and operate the equipment, and, depending on the amount of information being transmitted, the additional care resulted in time-consuming work. The situation was gradually improved through technical innovations, but several issues remained. By resolving these issues and achieving ease of use comparable to or better than that of metal cable, we will be able to provide services of even better quality and at lower cost compared with the efficiency benchmark of working with wire.

## 2. Rapid fault handling

Optical access equipment extending outward from communications buildings is designed to be highly

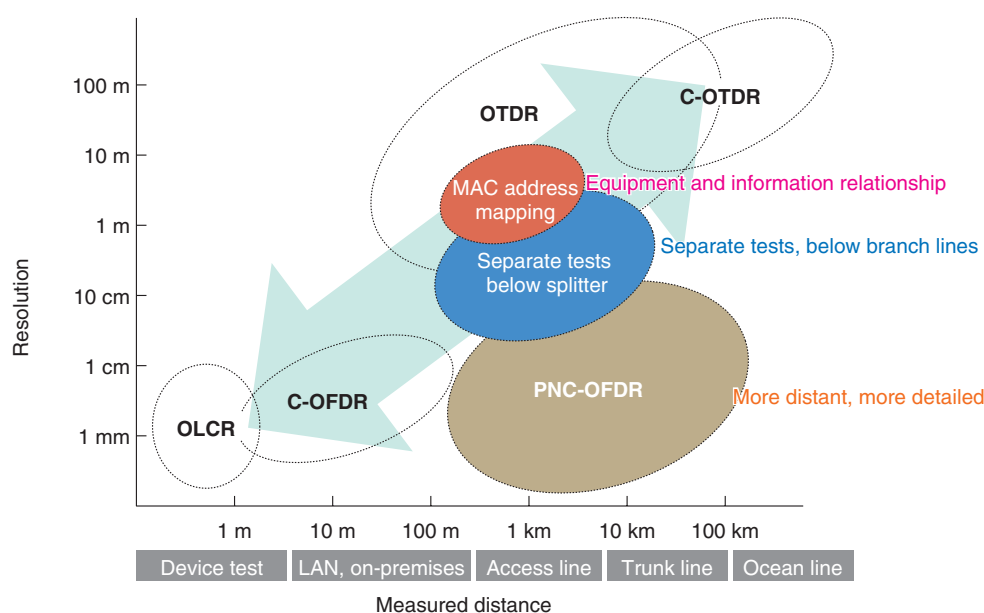
reliable and to withstand harsh environments. However, in extremely rare cases, faults can occur that interrupt service. To repair such faults and quickly restore service, the location and cause of the fault must be narrowed down as much as possible before sending maintenance staff to the site. To achieve this, we are working on three new approaches that will allow us to categorize such faults remotely (**Fig. 1**).

### 2.1 Accurate measurement of remote fault points

The optical time domain reflectometry (OTDR) technique currently used in the field to measure the distances to fault points is not highly accurate, so it is therefore difficult to determine the precise location and cause of a fault. The phase-noise-compensated optical frequency domain reflectometry (PNC-OFDR) technique that we are researching overcomes these problems. In addition to locating faults, we can also detect tiny identification (ID) patterns embedded in remote connectors, creating the potential for entirely new facility operation scenarios.

### 2.2 Measurement to distinguish fault points below a splitter

In passive optical networks (PONs), optical splitters are placed at locations close to the customers to increase the efficiency of equipment sharing. However, if a fault occurs between a splitter and the customer's residence, the location of the fault cannot be determined correctly using conventional OTDR. We



C-OFDR: coherent optical frequency domain reflectometry  
 C-OTDR: coherent optical time domain reflectometry  
 LAN: local area network

MAC: media access control  
 OLCR: optical low coherence reflectometry  
 PNC-OFDR: phase-noise-compensated optical frequency domain reflectometry

Fig. 1. Three approaches to categorize remote fault locations.

have devised a principle that enables us to obtain measurements below individual splitters using a physical phenomenon called Brillouin scattering\*, which occurs within the optical fiber, and have demonstrated this principle for the first time. If this approach can be implemented practically, it will overcome one of the major difficulties with PONs.

### 2.3 Information linkage between an optical fiber and transmission systems

When a fault occurs, we use different instruments and systems to diagnose the fault in each transmission path (optical fiber) and transmission system. We have focused on measuring the round-trip times between an optical line terminal (OLT) and each optical network unit (ONU). This approach is often employed with PON systems, and we have shown that we can convert the measurement data to an optical fiber length and map ONU MAC (media access control) addresses to the location of reflections at the end of an optical fiber. By establishing this technology, we will be able to use it both to locate faults and

to detect potential faults, thus providing preventative maintenance.

### 3. Building an equipment database, and safe and secure work navigation

Communication services are provided through various types of equipment. This equipment is complex, and there is a large amount of it, so a lot of work is involved in carefully managing and maintaining a database for each type of equipment. If we are to increase the efficiency of this administration work, we must construct an inexpensive mechanism that can build and update the database autonomously without requiring manual intervention. The mechanism must assign a unique ID to each element of the equipment. We are conducting applied research on an equipment management system using image processing and augmented reality (AR) technologies as an effective means of achieving this. An example of the use of AR technology on optical patch panels in a communications building is shown in **Fig. 2**. The optical patch panel has connector terminals densely arranged with  $4 \times 7$  mm spacing. The positions of markers attached to the patch panel beforehand are

\* Brillouin scattering: Optical scattering that occurs within a medium due to phonons (sound waves) and that involves changes in frequency.

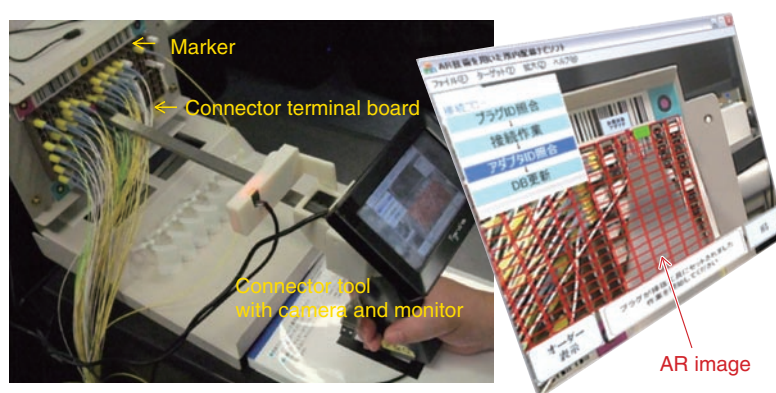


Fig. 2. Navigating on-premises terminal panels using AR technology.

captured with a camera. Then an AR image of the terminal matrix is drawn on the monitor based on a unique ID, and this can be used to direct the work. Also, because the state of the work is being monitored, the database can be built and updated autonomously. Moreover, failsafe functions can be implemented to prevent errors. Thus, we are progressing with research and development (R&D) of a navigation system that can maintain a database that is always up to date and that facilitates safe and secure maintenance work.

#### 4. Flexible branching of an optical fiber

With metal cables, current flows as long as there is contact, so branches can be established anywhere. If optical fibers could be similarly branched, it would expand the range of operations and maintenance scenarios in which they could be used. Local light injection technology involves placing a probe fiber near a bent section of optical fiber and injecting light through the probe fiber (Fig. 3(a)). Light radiating from the optical fiber passes through the insulation, so some corresponding losses are unavoidable. However, the system should be practically usable if a stable level of coupling efficiency that is suitable for the operational application can be ensured by optimizing the refractive-index-matched materials, optical lenses, and probe position. For example, until now, it was necessary to have a person in the communications building who would inject optical test signals into fibers. However, this line illumination work would change significantly if such test signals could be injected at arbitrary locations. We are also studying applications for tasks such as checking the link status

of a line, and for short-interruption optical media switching, which is described below.

### 5. Switching optical media in the broadband era

Twenty years ago, when telephone services were dominant, if work was undertaken only when lines were not being used, there was little effect on customers. Now, however, in the optical broadband era, information flows nonstop, 24 hours a day, 365 days a year, via Internet, cloud computing, video distribution, and other services. Therefore, the old approach cannot be used without affecting customers. We are conducting R&D to find ways of switching optical media that are appropriate for the modern era.

#### 5.1 Uninterruptible optical access line switching system

Approximately four years ago, we conceived principles that enable media to be switched without the disconnection or suspension of services and were able to demonstrate the practical implementation of this approach. Our technique involves (1) connecting an optical fiber (the detour path) of approximately the same length as the current optical fiber (the main path) in parallel with it, (2) disconnecting the main path and transmitting the optical signal over the detour path, (3) performing the switch work while the main path is offline, (4) adjusting the length of the detour path while it is transmitting the signal so that it is approximately the same as that of the main path after switching, (5) reconnecting the main path as the new line in parallel with the detour path, and (6) disconnecting the detour path. All of the steps in this procedure can be performed without interrupting the

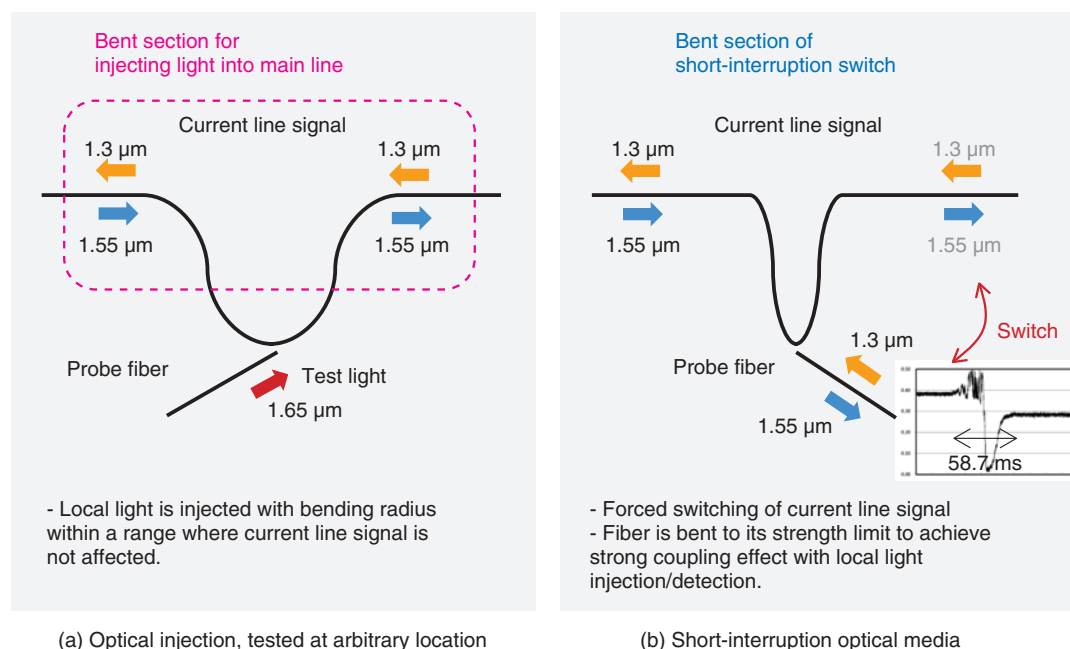


Fig. 3. Local optical injection/detection technology.

signal. The system is complex and requires precise control of path lengths, measurements, loss compensation, and the cancellation of interference. We are therefore undertaking R&D to build a system that is compact, smart, and compatible with a variety of scenarios in the field. If this system can be realized, we will be able to change an optical access line at any time.

## 5.2 Momentarily interrupted optical access line switching system

We are also conducting R&D on another approach to switching media. We can mechanically switch the transmission path in an instant by using a local light injection technique that involves bending the optical fiber close to its breaking limit to maximize the efficiency of the optical link. This approach does not require us to cut the optical fiber (Fig. 3(b)), but it causes a momentary interruption. We have already confirmed the ability to switch within approximately 60 ms. This can only be applied to certain types of optical fiber, but if this simple system is realized, it will be applicable to many work scenarios including cable switching or replacing an OLT.

## 6. Expanding applications of bending-loss-resistant fiber

Our free-bending optical cord has overturned the common belief that optical fiber cannot be bent. In the past, great care had to be taken not to bend optical fiber, but we have expanded the range of application scenarios with the implementation of hole-assisted fiber (HAF), which produces almost no losses even when bent. Recently, these optical fibers have even been passed through narrow gaps such as those around doors and window sashes. There is a maintenance and operability trade-off with these technologies, but by applying HAF where it is needed, interruptions due to bending can be eliminated, and it may be possible to simplify the optical cable structure.

## 7. Next-generation optical fiber research for the ultrahigh-speed, high-capacity era

Internet traffic is increasing exponentially with the accelerating spread of services such as social networking and video content services. The bandwidth of optical fiber communications systems that form the backbone for this communication is also being increased yearly. However, there are limits to the increase in bandwidth and speed that can be achieved

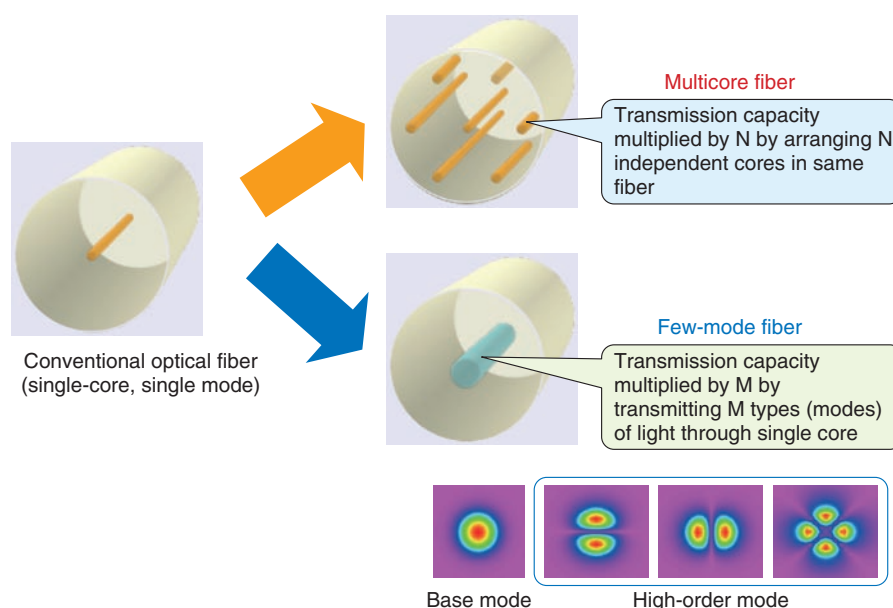


Fig. 4. Next-generation fiber for space-division multiplexing.

with the single-mode optical fiber currently in use, and it is estimated that these limits will be reached in ten years. Therefore, a new transmission medium that overcomes these limitations will need to be created. We are focusing on ways to spatially extend the transmission area of optical fiber, which is one way to overcome these limitations (**Fig. 4**). Current optical fibers transmit optical signals using a single mode, through a single core (transmission path) within a strand of quartz glass. However, optical fiber design and production technology is advancing because of the employment of complex cross sections such as hole structures, and digital transmission processing technology. Fiber with multiple cores in a single strand of quartz glass, and multi-mode fiber capable of transmitting stable signals with multiple modes in a single core are presenting new possibilities for novel fiber structures with higher spatial multiplexing. We have continued to demonstrate the possibilities of multicore fiber with, for example, a successful 1-Pbit/s transmission over a single 12-core optical fiber of 52 km, which is a world record (ECOC (European Conference on Optical Communication) International Exhibition, Sept. 2012, and NTT News Release).

## Profile

### ■ Career highlights

Executive Manager, Senior Research Engineer, Supervisor, Access Media Project, NTT Access Network Service Systems Laboratories.

Yuji Azuma received the B.E. degree in electrical engineering from Doshisha University, Kyoto, in 1984. He joined Nippon Telegraph and Telephone Public Corporation (now NTT) and engaged in research on the characteristics of multicore optical fiber and fiber nonlinearity. From 1989, he was engaged in the troubleshooting and development of optical fiber networks and IP networks. He moved to NTT Access Network Service Systems Laboratories in 2006 and has been engaged in R&D of access media and equipment maintenance. He is a member of the Institute of Electronics, Information and Communication Engineers.