Background and Future Prospects of Optical Access Network R&D

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Abstract

This article reviews how the research and development of optical media technology has evolved over the years and discusses its future prospects. As the market for optical services expands, stronger demands are being placed on technology related to optical access networks, not only for increased reliability and economy, but also for increased ease of use.

1. Background of optical access network technology

At the end of June 2006, the number of broadband users in Japan had reached 24.21 million, of which 6.3 million were FTTH (fiber to the home) users [1]. Judging from the recent slowdown of DSL (digital subscriber line) and the increasing number of users with greater bandwidth than that provided by DSL, there is no doubt that FTTH will soon take over as the main broadband service. The rapid advance of FTTH is the result of many years of research and development effort at NTT. To achieve our medium-term business strategy of gaining 30 million optical access subscribers by 2010, NTT Access Service System Laboratories is continuing to press ahead in the R&D of optical access network technology [2].

Optical fibers were first introduced into communication systems in the form of trunk systems connecting between central offices, where investment costs could easily be recovered by utilizing the characteristics of optical fibers. Consequently, our R&D was initially targeted at implementing high-quality, reliable transmission media and schemes suitable for achieving increased speed and capacity. Optical fibers were then applied to access networks connecting users to central offices on a one-to-one basis. For these applications, optical fibers have to be more economical than metallic wires, and it must be possible to connect large numbers of optical fibers efficiently and with low loss so that a large number of users can be accommodated. With the rapid growth of the B-FLET'S service recently, we have had to develop technology that is simpler and smarter so that optical fibers can be made more user-friendly and more convenient to customers and installation engineers.

During the evolution of optical fiber technology into today's access networks, NTT devised and promoted various corporate strategies and concepts, including the VI&P (visual, intelligent, and personal communications) concept (1990), the Basic Concept for the Coming Multimedia Age (1994), the Global Information Sharing Concept (1998), the Vision for a New Optical Generation (2002), and the NTT Group's Medium-Term Management Strategy (2004). Against this background, our R&D of optical access networks has brought about many technologies ranging from key technologies that form global standards to highly useful application technology adapted to the rapid expansion of optical services in recent years (**Fig. 1**). The main changes in optical access network technology are outlined below.

2. Main changes

2.1 Optical fiber cable technology

Optical fiber cables were first introduced into access networks in 1984 in the form of multimode

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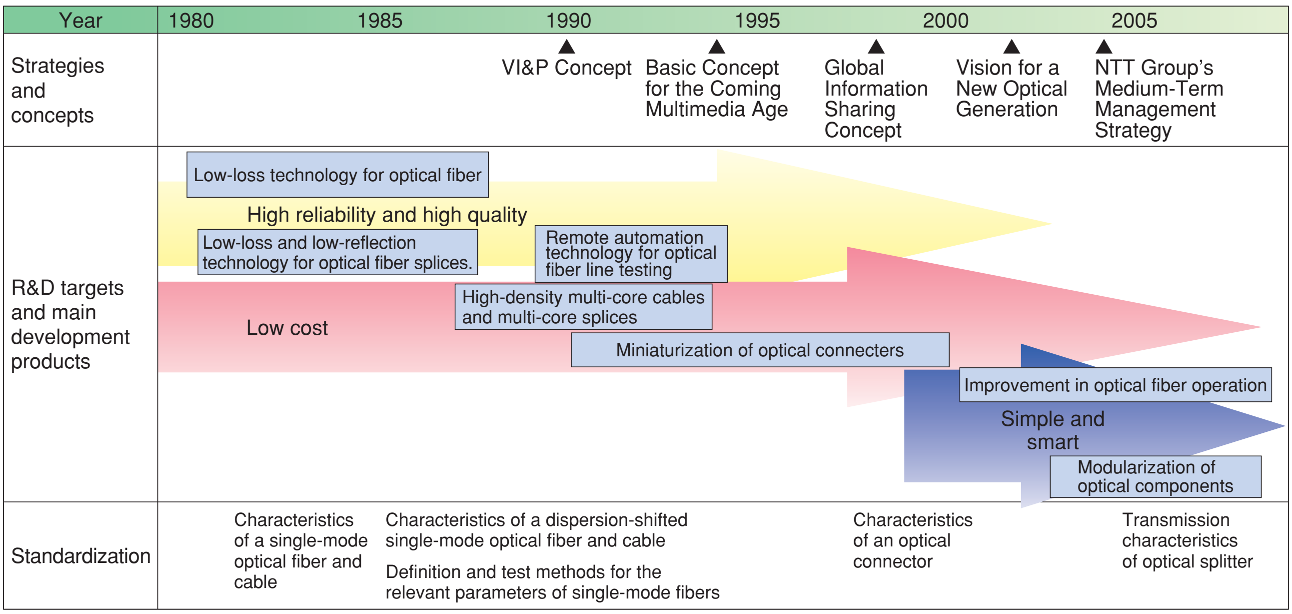

Fig. 1. Targets and background of optical access network technology in each age.

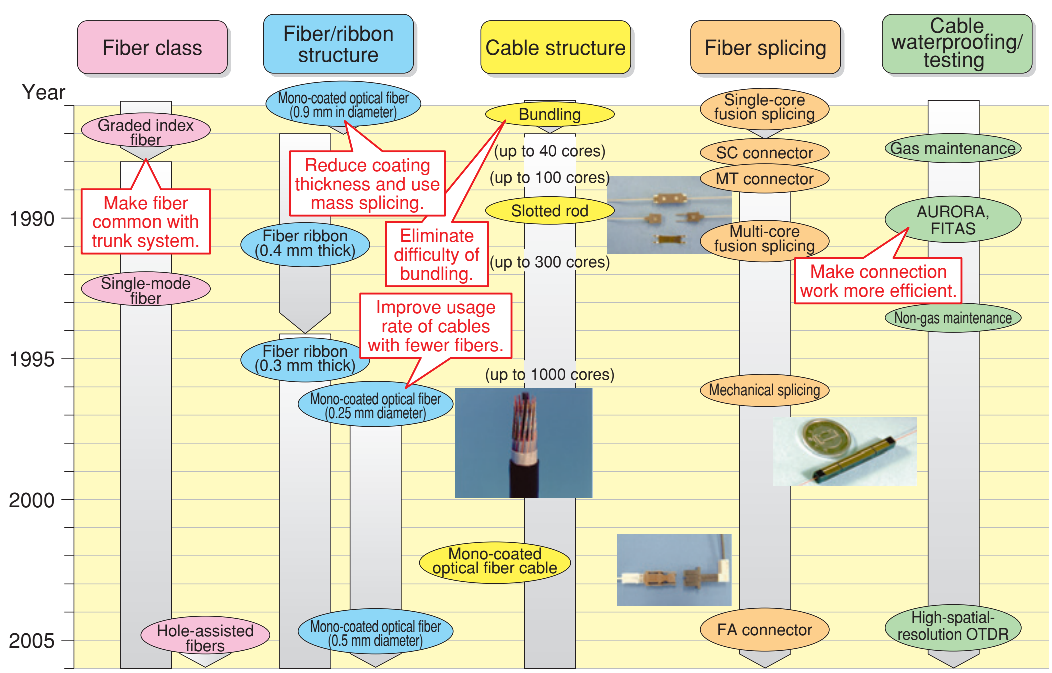

Fig. 2. Evolution of optical fiber technology.

fibers applied to the trunk system. Single-mode fibers were applied to access networks in 1988. The development of techniques for making it easy to connect several single-mode fibers at the same time with low losses enabled further cost reductions to be achieved by sharing trunk systems and optical fibers. In anticipation of future growth in the demand for optical services, we produced 1000-core high-density cables by reducing the thickness of optical fiber ribbon coatings and using slotted rod optical fiber cables. This made it possible to adapt economically and flexibly to the demand for large-scale optical services. As shown in **Fig. 2**, we have continued to make innovations in optical fiber cable technology, such as cable waterblocking technology for improved maintainability. In 2005, we developed a free-bending optical fiber cord capable of working even when bent, folded, or knotted, just like metallic cables [2].

2.2 Optical fiber splicing techniques

Optical fiber splicing techniques can be broadly divided into permanent connections involving fusion or mechanical splicing and temporary connections involving the use of connectors that can easily be disconnected and reconnected. Research into fusion splicing has been targeted at developing compact lightweight equipment for use inside manholes where there is little likelihood of reconnection, while the main focus of research on temporary connectors has been the reduction of losses and reflection. Various types of optical connectors have been developed to match the requirements and applications of each era such as SC connectors, which are mainly used in communication equipment and indoor fiber routing, and MT connectors, which are used to connect ribbon-type cables. We have recently been developing an FA (field assembly) connector [3], which has an additional outer layer gripping function that combines the ease of assembly of mechanical splicing and ease of reconnection of optical connectors with the inherent ease of use of optical fibers, resulting in optical fiber technology that is more user-friendly and convenient for making connections (Fig. 2).

2.3 Optical fiber testing/monitoring technology

After optical fiber cables have been installed, they require constant testing and periodic monitoring in order to provide stable high-quality optical services. Tests such as optical pulse and optical loss tests used to be performed manually, but with the number of optical fiber cables growing, it is becoming necessary to implement automatic and remotely controlled in-service testing functions and preventive and planned maintenance through periodic testing. In 1990, we developed an automatic optical fiber operation support system called AURORA to address these needs. This system includes functions for automatic testing and core line management of optical access networks and allows work to be performed remotely and automatically. We also developed and introduced a fiber transfer and test system (FITAS), which has testing functions and functions for switching between central offices in trunk systems (Fig. 2).

3. Strategy of R&D in optical access networks

Once the planning of an optical access network has been finalized, the actual network facilities are put in place, and maintenance/operation work is performed to provide a stable service. For our optical access network R&D, we use a scheme in which the three elements of planning, installation, and maintenance/operation are first optimized separately and then treated as a single entity so they can be connected together to achieve the best mix in terms of cost, construction work, and reliability (**Fig. 3**).

One of our main R&D targets is to help NTT Group to achieve its target of 30 million optical access subscribers by 2010 (**Fig. 4**). To achieve this, we are dividing our efforts into two phases: (1) reduce NTT's construction time and cost for optical services and (2) develop technology for maintaining and operating high-capacity optical facilities. Looking further into the future, we will be focusing not only on current issues but also on the issues involved in implementing all-optical networks once the target of 30 million optical subscribers has been reached. To resolve these issues, we will not only improve the existing technology but also create innovative new solutions. The following sections summarize our efforts in each of these areas.

3.1 Short-term efforts up to 2010

3.1.1 Reduction of NTT's construction time and cost (phase 1)

Our policies for the development of phase 1 can be described by the key phrases "DIY" (do it yourself) and "plug & play" (Fig. 4). If optical network technology can be made simple enough for users to install by themselves in their own homes, then network installation will be more flexible, the workload on installation engineers will be reduced, and the efficiency of network installations will be increased. The

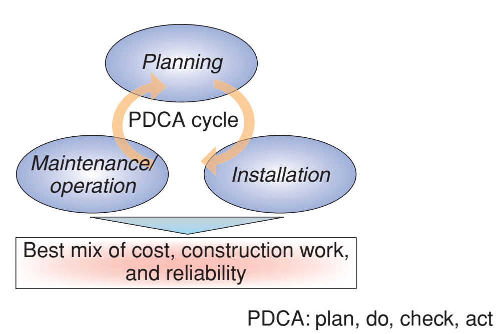

Fig. 3. R&D structure.

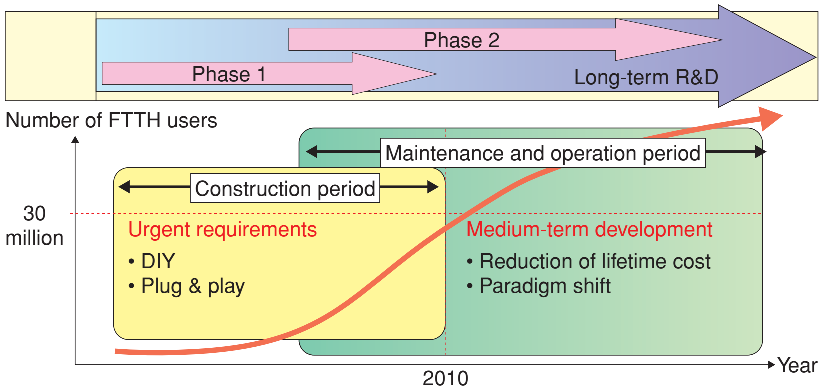

Fig. 4. R&D targets for optical access network.

plug & play style makes products into modular units that can be connected together to facilitate work in environments such as at the top of telephone poles. This will enable us to support a larger number of optical users. The fruits of our efforts in this direction include a free-bending optical fiber cord and a new aerial optical fiber closure, which are reviewed in a later article in this Special Feature.

3.1.2 Maintaining and operating high-capacity optical facilities (phase 2)

One problem foreseen for phase 2 is that the number of skilled people employed in maintenance and operations is expected to be significantly smaller than at present as large numbers of experienced workers retire and fewer people become available to take their places. To cope with this labor shortfall, we will need to create revolutionary technology for the efficient maintenance and operation of our expanding optical facilities. We plan to make these developments through reduced lifetime costs for equipment and a paradigm shift in attitudes toward information technology (IT) (Fig. 4). To reduce lifetime costs, we are studying the service order (SO) procedure, fault repairs without dispatching workers, methods of remote and automatic testing of optical access network and the like in order to achieve total optimization of not only capital expenses but also operating expenses. To achieve a paradigm shift, we are studying how IT technology can be used to improve all aspects of work (including the utilization of QR Codes*, which are two-dimensional bar codes, and mobile phones, which are described in later articles).

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

3.2 Medium- to long-term strategy

Our future strategy for optical access networks involves promoting research and development in the following areas.

3.2.1 Cable installation methods for all-optical networks

We are researching methods of installing cables to support the implementation of all-optical networks in order to provide flexible optical IP (Internet protocol) services to all customers who are using the existing telephone network. The biggest issue in the introduction of all-optical networks is how to efficiently resolve the regional digital divide. We are therefore implementing cable installation methods that increase the efficiency of installations even in sparsely populated and remote areas that currently do not have optical access [4], [5]. Depending on the installation method, there are also differences in the methods used for maintenance, operation, and management. We are therefore conducting this research in close cooperation with the operations department.

3.2.2 Optical fibers that can be handled as easily as metallic cables

To develop optical fibers that can be handled as easily as metallic cables, we are working to develop simpler specialist installation tools and, where possible, to establish installation technology that does not require special tools. First, by focusing on the connection process, we are working to integrate multiple special tools to complete the connection by one process [6]. By reducing the number of special tools and implementing a one-touch process, we should be able to reduce the need for skilled installation engineers and also reduce the time needed for installation. Furthermore, although it is still only at the stage of basic research, we are also working on a fused connection technique that requires no special tools at all.

As further promotion of our plug & play concept, we are comprehensively reviewing the structure of optical fiber cords and optical fiber cables and studying optical fiber curl cords that can expand and contract so they do not have to be cut to length [7], [8].

3.2.3 Technology for making effective use of existing facilities

If we are to meet our target of achieving 30 million optical access subscribers, we need to make more effective use of existing facilities. In particular, underground ducts have limited space available to accommodate additional cables of the existing types. We are therefore comprehensively reviewing the structure of existing optical fibers and studying new types of optical fiber cables with smaller diameters and a higher packing density [8]. For aerial installations, we are studying low-wind-pressure cables that suppress the effects of wind loading and telegraph poles strengthened with materials such as aramid fibers.

3.2.4 Testing, monitoring, and reliability technology for optical access networks

We are studying testing and monitoring technology to facilitate a rapid response to breakdowns and preventive maintenance technology that provides advance warning of potential breakdowns so their occurrence can be prevented. This preventive maintenance involves establishing testing/monitoring technology to detect any degradation of the optical equipment composing the optical access networks and technology for evaluating the reliability of the equipment based on this information. We are also making further enhancements to fault location identification test technology and improving its precision so that faults can be treated promptly.

3.2.5 Technology for supporting future large-capacity networks

Various different applications are currently being developed in network environments and some of them, such as video content delivery, will have higher data capacity requirements. In the future, networks will almost certainly have to provide greater capacity than they do at present. We are therefore conducting research aimed at increasing network capacity by maximizing the performance of optical fibers and creating technology for monitoring the transmission quality of large-capacity communications. For increased capacity, we are studying multiplexed transmission methods using photonic crystal fibers and optical fibers with new structures unlike those of conventional single-mode fibers, together with a broader range of transmission wavelengths for increased bandwidth [9]. To monitor transmission quality, we have proposed a technique called dual-channel waveform optical sampling, which we aim to put into practice [10].

Conclusion

This article gave an overview how the research and development of optical media technology has evolved over the years and indicated the future prospects of this R&D to achieve a target of 30 million FTTH customers by 2010 and all-optical networks. The other articles in this Special Feature give more details of specific technologies.

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