Optical Fiber Cable Technologies for Making Effective Use of the Existing Infrastructure

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Abstract

We introduce technologies related to ultrahigh-density optical fiber cables with a small diameter that will enable us to install cables in the small space available in ducts and aerial facilities of the existing infrastructure, enabling effective and economical construction of optical access networks.

1. Introduction

The rapid increase in the number of FTTH (fiber-to-the-home) subscribers has led to a shortage of ducts and space in which optical fiber cables can be installed. Many metallic cables have already been installed in existing ducts and aerial facilities, but we need to install many new optical fiber cables in them as well. Therefore, if we wish to construct efficient and economical access networks, we need high-density optical fiber cables with a smaller cable diameter that can be easily installed in the small spaces between existing cables in ducts and in aerial facilities. The following section introduces technologies related to small-diameter ultrahigh-density optical fiber cables, which will enable us to utilize the existing infrastructure efficiently and thus support the further spread of FTTH.

2. Current optical fiber cable technologies in optical access networks

The configuration of an optical access network is illustrated in **Fig. 1**. An access network is divided into four areas—the central office area, feeder area, distribution area, and user area—covering the distance from the central office to the user's home. Various types of optical fiber cable have been deployed in each of these areas. Now, new optical fiber cables are being developed to meet the specific requirements of each of these areas. For example, in the user area, indoor and drop cables containing one fiber are designed to provide efficient and economical fiber distribution to residences [1]. On the other hand, in the feeder and distribution areas, it is important that optical fiber cables containing many fibers should be able to utilize existing infrastructures such as ducts and aerial facilities. In addition, in the feeder areas, many metallic cables have been installed in ducts to provide telephone and digital subscriber line (DSL) services. This has led to a shortage of ducts and space in which optical fiber cables can be installed. Currently, the usual construction method is to install multiple optical fiber cables in a duct using inner pipes, as shown in **Fig. 2**. However, it is predicted that there will be an infrastructure shortfall during the expansion period, as shown in **Fig. 3** because of the growing demand for optical fiber in the future [2]. Therefore, the optical fiber cables to be used in these areas must have a smaller diameter than conventional optical fiber cables to allow the existing infrastructure to be used effectively.

3. Current optical fiber technologies

Various types of optical fiber with a low bending loss have recently been proposed with a view to achieving easy fiber handling and wiring on residential and business premises, and they are now being used in optical drop and indoor cables in Japan [3], [4]. These fibers can be bent with a smaller diameter than conventional single-mode fiber, so they offer improved fiber handling characteristics. Optical fiber cables using conventional single-mode optical fiber

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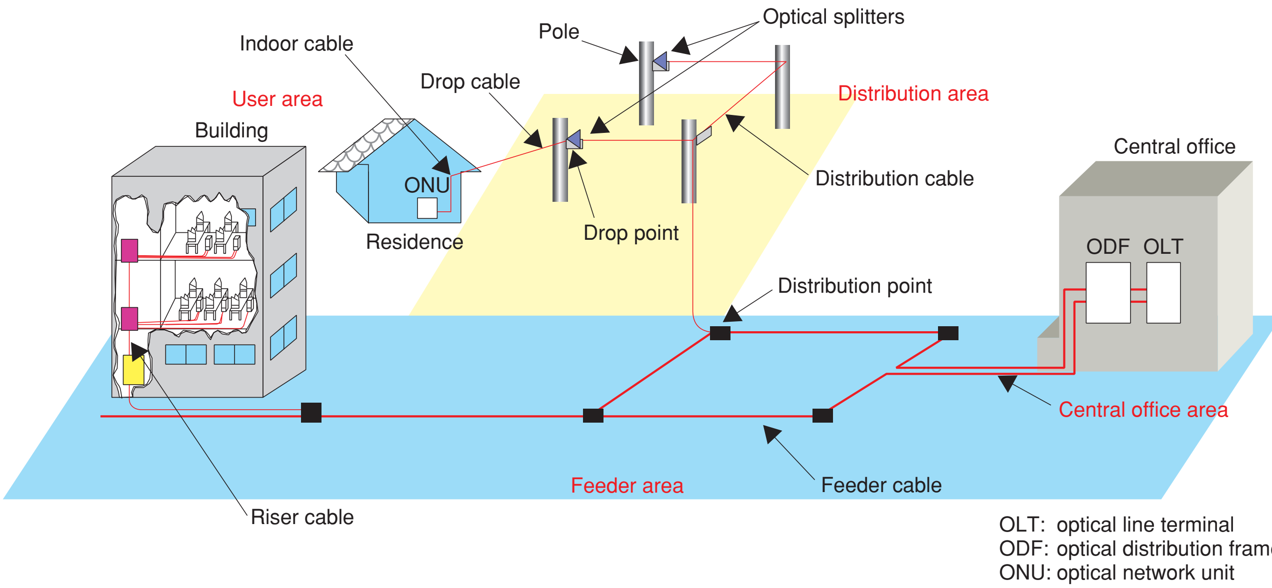

Fig. 1. Configuration of optical access network.

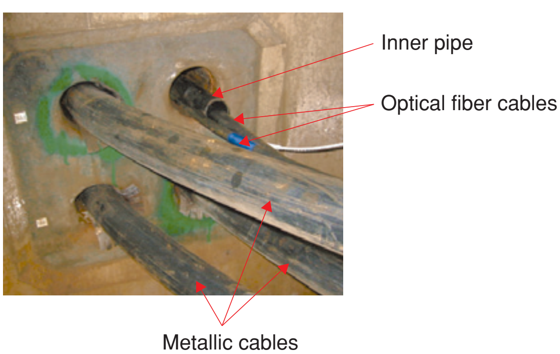

Fig. 2. Example of optical and metallic cable installations.

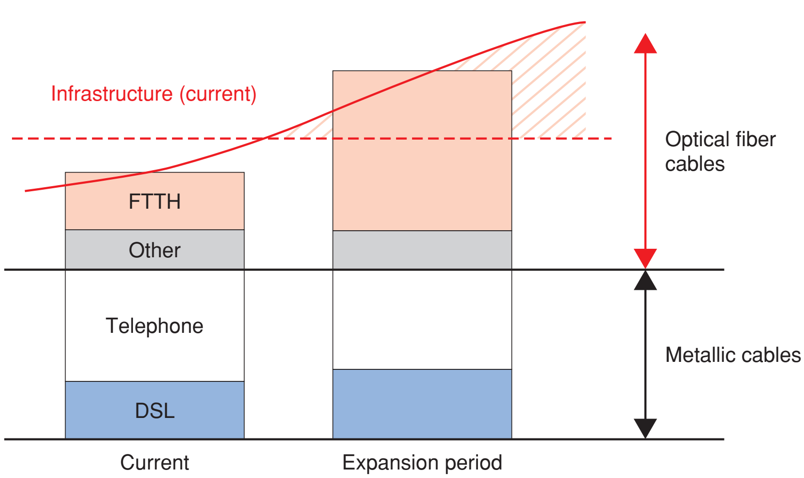

Fig. 3. Infrastructure in FTTH expansion period [3].

have been designed to maintain stable loss characteristics under the influence of external conditions such as bending, lateral force, tension, twisting, and temperature change. Such conditions would also affect the characteristics of small-diameter ultrahigh-density cable if conventional single-mode fibers were used. On the other hand, we should be able to make ultrahigh-density cables with stable characteristics if we use optical fibers that have a low bending loss to suppress the increase in loss caused by fiber bending.

4. Ultrahigh-density optical fiber cable technologies

The relationship between the cable diameter and the number of optical fibers is shown in **Fig. 4**. The line indicates the diameter of an optical fiber cable core containing tightly bundled 0.25-mm-diameter monocoated optical fibers. Our goal is to make an ultrahigh-density optical fiber cable that comes as close to this diameter as possible. Optical fiber cables should have stable optical characteristics, sufficient mechanical strength, high reliability, excellent mass-producibility, and sufficient workability for optical fiber handling and identification, as shown in **Fig. 5**. Therefore, as the first step, we are targeting 100-fiber cable with an outer diameter of about 6 mm, which is about half that of a conventional cable, and 1000-fiber cable with an outer diameter of about 20 mm, which is about two-thirds that of conventional cable to meet the above requirements.

A prototype of an ultrahigh-density 100-fiber cable is shown in **Fig. 6**. This cable is composed of 0.25-mm diameter mono-coated optical fibers with a low

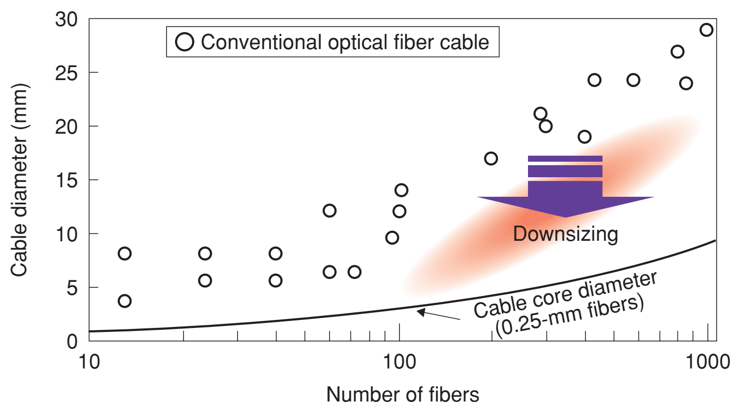

Fig. 4. Relationship between cable diameter and number of fibers.

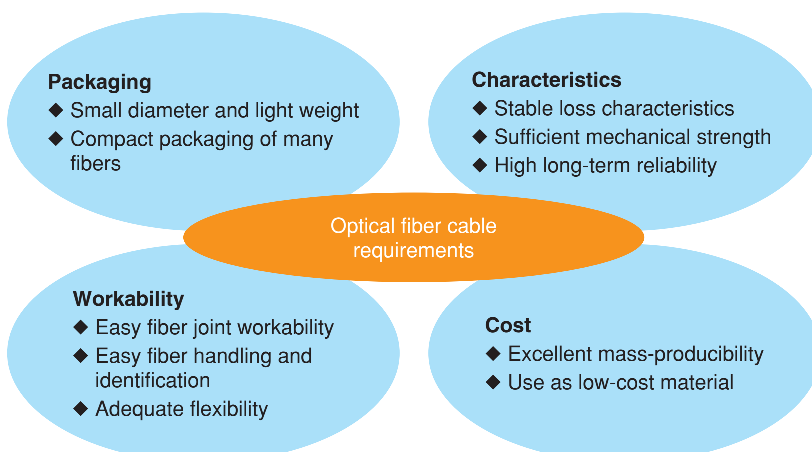

Fig. 5. Optical fiber cable requirements.

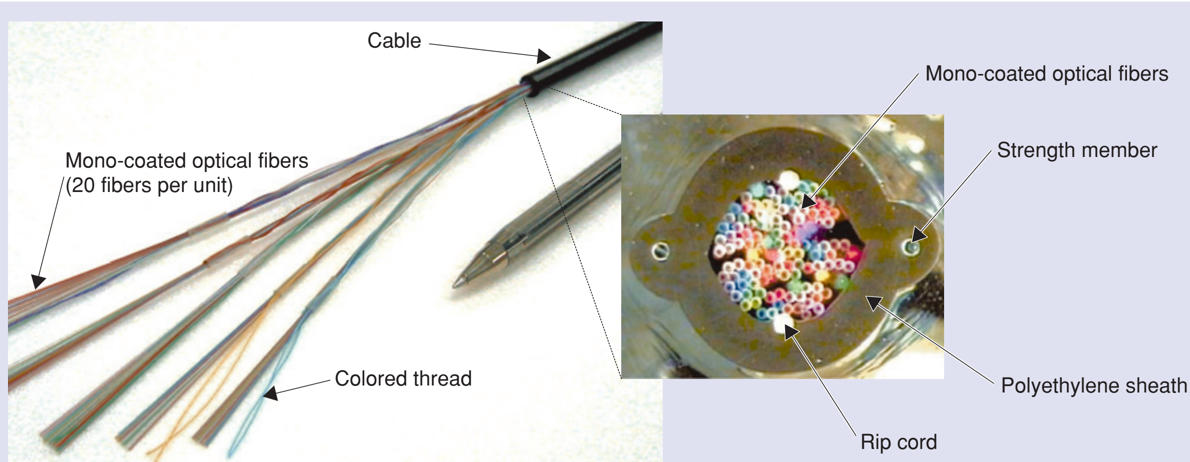

Fig. 6. Ultrahigh-density optical fiber cable.

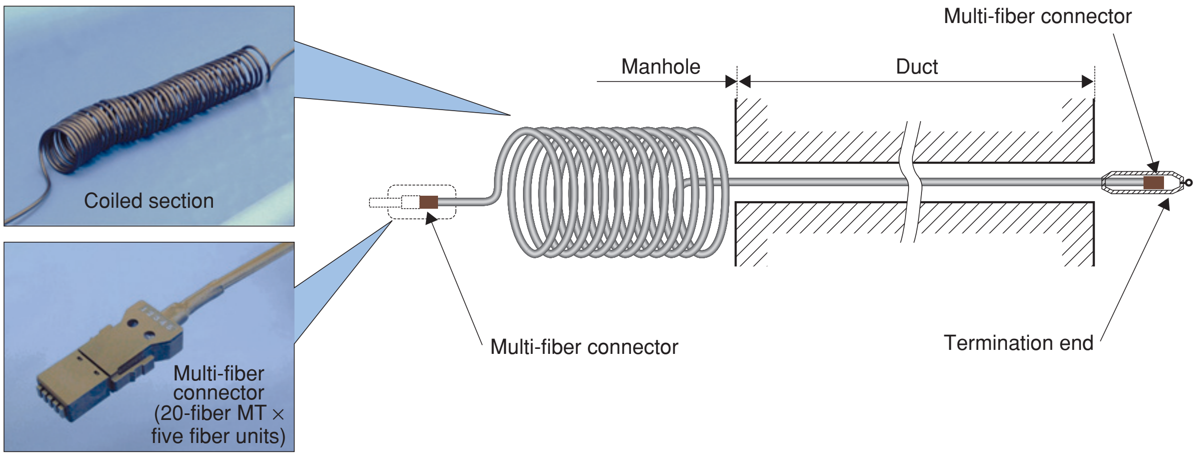

Fig. 7. Preconnectorized 100-fiber optical fiber cable with coiled cable section.

bending loss, strength members, rip cords, and a polyethylene sheath. The cable has five 20-fiber units and each 20-fiber unit is SZ stranded* with a colored thread for easy identification. This cable has a diameter of about 6 mm and weight of 0.03 kg per meter, which are half the diameter and a quarter the weight of conventional 100-fiber optical fiber cables. It has a fiber density of more than 3.0 fiber/mm^2. Our experimental results indicated stable optical characteristics under bending, twisting, and temperature variations that were as good as those of conventional optical fiber cables. We plan to investigate ultrahigh-density optical fiber cable with water-blocking and flame retardant properties.

5. Preconnectorized optical fiber cable with a coiled section

When mono-coated optical fibers are used, a large number of fibers must be joined, and fiber joint workability is unsatisfactory. Thus, the fiber joint workability must be improved if we are to construct optical fiber access networks effectively. One method of improving the workability involves the use of optical fiber cables that are equipped with a connector at each end. When these cables are used and access networks are designed, the optical cable length is generally overestimated to allow for errors in information about facilities and other such factors. Thus, space is also required to accommodate the excess cable length. Such space is usually hard to find in manholes, so the use of preconnectorized optical fiber cables has been restricted solely to facilities with more available space. The ultrahigh-density optical fiber cables described in the previous section have the attractive features of a small diameter and stable characteristics for small radius bending. Thus, they can be formed into cables with a coiled section that can be expanded and contracted. This can accommodate the estimation errors in cable length, so optical fiber cable with both ends preconnectorized and having a coiled section can be used in small spaces.

An example of a preconnectorized 100-fiber cable with a coiled section is shown in **Fig. 7**. Both connectors are pre-assembled MT connectors that can connect 100 fibers simultaneously. The coiled section can accommodate an estimation error in the required cable length of several tens of meters. The diameter of the coil depends on the bending characteristics of the cable and is chosen to suppress the increase in loss that occurs when the cable is coiled and when the coiled section is expanded and contracted. Moreover, we can also downsize the termination end with the connectors, which are designed to be pulled during installation, because the cable is lightweight and can be installed with low tensile force, and the connector is small. We also plan to investigate a smaller termination end.

6. Conclusion

This paper introduced ultrahigh-density optical fiber cables having a small diameter with a view to making effective use of the existing infrastructure. In the future, we plan to investigate ultrahigh-density optical fiber cables based on an optical fiber ribbon

* SZ stranding: The fiber units are stranded and reversed at certain intervals to enable the fiber units to be easily branched when the cable sheath is removed.

that contains from several hundreds to 1000 fibers. We will also investigate related technologies such as closures and cabinets.

References

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