ITU-T Standardization Activities for Spatial Division Multiplexing Optical Fibers and Maintenance of Outdoor Optical Facilities

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Abstract

International standards related to optical fiber cables and the maintenance of outdoor optical facilities have been developed as ITU-T (International Telecommunication Union - Telecommunication Standardization Sector) Recommendations, the content of which has been discussed in Study Group 15 and revised in accordance with the progress of optical communication systems. We introduce space division multiplexing optical fibers that are expected to become an ultra-high-capacity transmission medium that breaks the communication capacity limit of existing single-mode optical fibers, as well as the standardization trend in the maintenance and operation of outdoor optical facilities, which must be more efficient due to the spread of optical communication services.

Keywords: optical fiber, space division multiplexing, outdoor optical facilities

1. Introduction

The International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) has developed international standard documents (Recommendations) that stipulate the system requirements and functions of communication networks, methods for testing transmission characteristics, and operating methods of network infrastructure, which greatly contribute to ensuring the interoperability and quality of service for telecommunication carriers. In September 2022, a technical report on space division multiplexing (SDM) optical fibers was agreed at Question 5 of ITU-T Study Group (SG) 15 [1] Working Party (WP) 2, which is responsible for establishing new Recommendations and revising existing Recommendations on optical fibers. This technical report is a major step in that it comprehensively describes the maturity and challenges of SDM fiber technology and provides a roadmap for future international standardization activities and practical deployment. Against the backdrop of the demand for proper operation of outdoor optical facilities in line with the spread of optical communication services worldwide, standardization work on maintenance and operation methods of outdoor optical facilities is also being conducted in Question 7 of the SG15 WP2.

The following chapters outline the content of the SDM fiber technical report and trends in the Recommendations for the maintenance and operation of outdoor optical facilities.

2. Technical report on SDM optical fiber cables

The transmission capacity per fiber has already exceeded 10 Tbit/s in a commercial optical communication system. It is expected that significantly larger transmission capacity, more than 100 Tbit/s, will be needed by the late 2020s. However, the maximum transmission capacity of an existing single-mode optical fiber (SMF) will also become apparent at 100 Tbit/s, making SDM optical fiber cables more

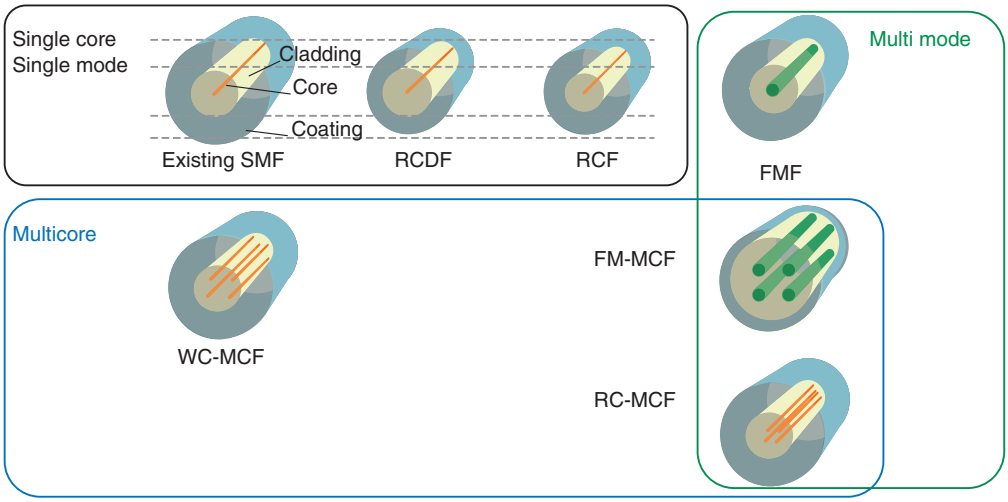

Fig. 1. Classification of SDM optical fibers considered in TR.sdm.

attractive as a new optical transmission medium. Therefore, ITU-T has prepared and published a new technical report, i.e., TR.sdm, during the last SG15 meeting held in September 2022. TR.sdm covers the current technical status of SDM optical fiber cable technology, its applicability to various network areas, and future standardization objectives.

Figure 1 shows the classification of SDM optical fibers considered in TR.sdm. TR.sdm considers novel optical fibers, such as a multicore fiber (MCF) and few-mode fiber (FMF), as well as single-core fibers that have a thinner coating or smaller cladding diameter than existing SMF, namely, a reduced coating diameter fiber (RCDF) or reduced cladding fiber (RCF), respectively. RCDF and RCF are beneficial in maximizing the number of fibers accommodated in existing cables while using the current cabling technology. A weakly coupled multicore fiber (WC-MCF), in which multiple cores are multiplexed so that they operate independently in the same cladding, is expected to expand capacity as much as multiple cores. However, WC-MCF requires a relatively large core pitch to reduce optical signal interference between cores, i.e., crosstalk. A larger core pitch and/or larger number of cores intrinsically requires an enlarged cladding diameter. However, the larger cladding diameter directly degrades the mass-productivity of optical fibers. Thus, a standard 125-μm-cladding-diameter WC-MCF, which has optical properties comparable to those of the conventional SMF, is expected to be useful as a future optical transmission medium. An FMF, which multiplexes multiple types of propagation light (modes) in the same core, can maximize the number of optical signals per unit cross-sectional area. Moreover, a few-mode MCF (FM-MCF) significantly increases the number of spatial channels as the multiple of the number of modes and cores. A randomly coupled MCF (RC-MCF) has a similar cross-sectional structure with a WC-MCF. However, an RC-MCF can propagate the number of modes equivalent to the number of cores by setting the adequate core pitch so that the optical signals are actively mixed between cores. Thus, RC-MCF can achieve higher core multiplicity than WC-MCF. However, these multimode fibers, i.e., FMF, FM-MCF, and RC-MCF, require complex signal processing at the receiver end to demodulate the mixed optical signals. Therefore, the availability of the corresponding transmission technology should be considered carefully for practical deployment. TR.sdm considers that an RCDF or standard cladding diameter WC-MCF would be the first candidate for early SDM transmission systems. RCDF can maximize the number of accommodated fibers in an existing cable and support user multiplexing, which is particularly needed in hyper-scale datacenter interconnections. WC-MCF would be useful for long-haul submarine and terrestrial backbone networks since they set strict limits on cable diameter, number of accommodated fibers, and/or duct size, and these networks intrinsically require continuous upgradability. However, total cost merit should be considered carefully since the deployment of these new SDM optical fibers also requires new installation, connection,

optical amplification technologies, and sub-systems.

3. Standardization activities for maintenance and operation of outdoor facilities

While the annual growth rate of FTTH (fiber-to-the-home) subscribers in the Organization for Economic Co-operation and Development (OECD) countries reached 18.6% over the year to December 2021, the global broadband penetration rate has been increasing due to the increasing number of hours at home and the spread of remote work in the wake of the pandemic [2]. In the near future, the spread of fifth-generation mobile communication systems is expected to lead to a significant worldwide increase in the use of optical broadband for wireless services. Therefore, there is an urgent international need for efficient maintenance and operation of the huge number of outdoor optical facilities expected to support communication services.

In 2020, ITU-T Recommendation L.330 (Telecommunication infrastructure facilities management) was established to define general matters related to management for the proper operation of outdoor facilities. To ensure the safe operation of outdoor facilities over long periods, which cannot avoid aging-based deterioration, it is essential to conduct inspections on appropriate periods, check items, and work flow. ITU-T Recommendation L.330 defines the basic inspection requirements and flow as well as 17 outdoor facilities that should be inspected. It provides an exhaustive list of inspection periods and items to be checked for each type of facility as well as the measurement accuracy of deterioration events required during detailed inspections. The establishment of this Recommendation L.330 will encourage telecom carriers to increase their awareness of inspections as well as accelerate the development of products that meet inspection requirements. Recommendation L.330 has also triggered work to establish maintenance-related ITU-T Recommendations that describe detailed inspection measures, related technologies, and work safety issues that differ for each type of outdoor facility. Specifically, we are in the process of revising the current ITU-T Recommendation L.340 (Maintenance of cable tunnels) to include all underground facilities, such as maintenance holes (MH) and hand holes, for which inspection work is similar to that for cable tunnels. This revision also aims to include examples of using the latest technologies that can improve maintenance efficiency such as no-entry MH inspection technology using camera drones and omnidirectional cameras (see Appendix of the revised Recommendation). Progress is being made toward completion of this Recommendation in 2023.

As with the revision of ITU-T Recommendation L.340, there has been standardization activity to reflect the results of research and development studies on improving the efficiency of the maintenance and operation of outdoor facilities through the application of advanced technologies. One example is ITU-T Recommendation L.316 (Cable identification for the construction and maintenance of optical fiber cable networks by using optical sensing techniques). Established in 2022, ITU-T Recommendation L.316 describes a method for identifying the optical cables to be serviced from among congested optical cables by monitoring the vibrations intentionally applied to the optical cable by the workers at the maintenance site. Optical-fiber vibration-measuring equipment installed in a central office can monitor the intentional vibrations. Related to this Recommendation, in May 2022, NTT EAST began a maintenance scheme using optical-fiber vibration-sensing technology. By using optical fiber-vibration-measuring equipment installed in a central office to detect the vibration created by striking the iron lid of the MH, it is possible to determine whether the failure of an optical cable lies in the MH space without entering the MH, thus reducing the time required to manually search for the failure point. Further improvements in maintenance and operation efficiency are expected as a result of technological advances and the timely creation of international standards.

4. Future prospects

On the basis of the technical report on SDM optical fibers agreed to at ITU-T SG15 in September 2022, concrete discussions will be held toward the international standardization of SDM optical fiber technology. Discussions on standardizations for SDM connectors and optical amplification technology, which are essential for the construction of SDM transmission systems, are also progressing at the International Electrotechnical Commission (IEC), and it is expected that the collaboration between ITU-T and IEC will advance standardization activities toward the implementation of next-generation large-capacity transmission systems. In addition, the series of Recommendations related to the maintenance and operation of outdoor facilities will continue to be established and revised in consideration of the efficiency, homogeneity, and digitization of maintenance and

operation tasks.

References

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