6912-fiber Optical Cable using 160 μm fiber for Data center

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Recently the demand of fibers has been greatly increasing with the growth of cloud services, 5G commercialization, automated car driving systems and so on. To achieve these developments, we need to deploy fiber communication networks in an economical and efficient way. We have developed 6912-fiber cable using fibers having 160 μm coating diameter and 80 μm cladding diameter. New cable has succeeded in reducing the cable diameter and weight significantly. Also by reducing the cable outer diameter, the fill ratio in a 1.5-inch underground conduit is 50%. The cable has satisfactory mechanical and environmental performance in accordance with GR-20-CORE Issue4.

1. Introduction

The demand of fibers has been increasing with the growth of communication networks. There is a strong demand for small-diameter and high-density cables to increase the fiber density in a conduit to achieve both lower installation cost reduction and larger fiber capacity. In order to improve further fiber packing density in a cable, reduction of the diameter of fiber coating is one of the effective methods. So far, in areas such as North America and Europe, the highest fiber-count cable is 6912-fiber cable that uses 200 μm fiber with 125 μm cladding. 6912-fiber cables are often installed in underground conduits that has an inner diameter of 1.5-inch. However, this cable has a high fill ratio that makes it difficult to install in the conduit. Thus we have tried to develop 6912-fiber cable using 160 μm fiber with 80 μm cladding. Traditionally, 160 μm fibers have been used in optical devices, but it has not been applied to fiber cables for telecommunications. We have applied 160 μm fiber to our SWR/WTC technology. This paper introduces the smallest diameter 6912-fiber cable and related connectivity solutions.

2. Data center solutions

2-1 Wiring diagram in a data center

In recent years, demand for optical cables for data centers has been increasing. There are several kinds of cables that are used in a data center such as Outdoor Cables, Indoor Cables and Indoor-Outdoor Cables. The wiring diagram of data center is as shown in figure 1. Outdoor cables are installed in underground conduit and have the role of connecting the network between the two buildings. Indoor cables are used between optical termination box and patch panels in a building. Indoor-outdoor cables have a role of connecting between outdoor cables and indoor cables.

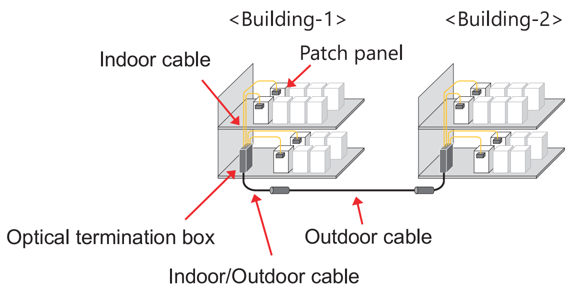

Fig. 1. Wiring diagram of cables in Data Center.

2-2 Fill ratio of a cable in an underground conduit.

Outdoor cables are installed in existing underground conduits. If existing underground conduits for laying cables can be effectively utilized, they should contribute greatly to cost reduction because it is unnecessary to construct new underground conduit. When the cables are laid in existing conduit, the fill ratio of the cable to the conduit is important for smooth installation. The cross-sectional view of 6912-fiber cable inside a conduit with an inner diameter of 1.5-inch (approx. 38 mm) is as shown in figure 2. So far, 6912-fiber cables that use 200 μm fiber with 125 μm cladding with an outer diameter of 30mm have been reported [1][2]. However, even if the outer diameter of the cable is kept at 30 mm, the fill ratio of the 1.5-inch conduit exceeds 60 %. If 60 % is exceeded, laying cable in a conduit may not be sometimes easy as cables may get stuck along the way, or may be required more manpower for installation.

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Abbreviations, Acronyms, and Terms.

Abbreviations, Acronyms, and Terms.—Formal Notation Explanation

SWR—Spider Web Ribbon
Intermittently fixed fiber ribbon. Due to partially fixing multiple fibers in the longitudinal direction, this is an epoch-making fiber tape that combines the benefit of a single fiber with the convenience of a fiber ribbon.

WTC—Wrapping Tube Cable
An optical cable with a wrapping tube structure. Since the cable is made of only optical fiber, presser winding and sheath, the cable achieved the ultimate optical fiber cable structure with no waste.

MT ferrule—Mechanically Transferable Ferrule
A resin-molded part with high-precision holes for fiber alignment to connect multiple optical fibers all at once.

MPO connector—Multi-fiber Push-On Connector
A connector with a MT ferrule to connect easily.

ITU-T—International Telecommunication Union Telecommunication Standardization Sector
Department responsible for the standardisation of technologies related to telecommunications

IEC—International Electrotechnical Commission
International organisation for the standardisation of standards in the field of electrical and electronic technology

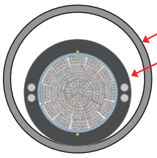

Fig. 2. Cross section of underground conduit.

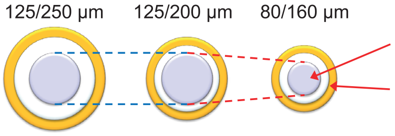

Fig. 3. Cross section of three types of fiber.

3. Fiber coating and fiber ribbon design

3-1. Fiber coating design

Reduction of the diameter of fiber coating is one of the effective methods to increase the fiber count in a limited space of the cable. Figure 3 shows cross section of conventional and new fibers. 250 μm fiber was commonly used, although 200 μm fiber has become widely utilized for high fiber count cables. The cross sectional area of 200 μm fiber is 36 % smaller than that of 250 μm fiber.

On the other hand, research results for a further reduced coating diameter fiber have been presented recently [3][4][5]. Researchers have proposed the reduction of the cladding diameter from 125 μm to 80 μm to realize a coating diameter from 200 μm to 160 μm. Consequently, we have applied 80 μm cladding fiber instead of 125 μm cladding fiber to reduce the cable outer diameter. However, when the fiber diameter is reduced and used in a high fiber density cable, lateral forces and tension are added to the fibers. These lateral forces and tension generate tiny bends on fibers, called micro-bending which causes attenuation increase. We have conducted tests on 160 μm fiber and already optimized thickness and Young's modulus of primary and secondary coating of 160 μm fiber to reduce micro-bending sensitivity. 160 μm fiber has already shown that it is possible to apply them to the cables [6][7]. Fiber characteristics with ITU-T G.657.A2 category [8], except that for the cladding diameter, are applied to this fiber.

3-2. Fiber ribbon design

As 250 μm and 200 μm fiber ribbons, 160 μm fiber ribbon was also designed in intermittently bonded 12-fiber structure called "Spider Web Ribbon" (SWR) as shown in figure 4. In recent years, intermittently bonded ribbon has been introduced to obtain a high density cable. SWR enables high fiber packing density cable due to its flexibility and easy deformation.

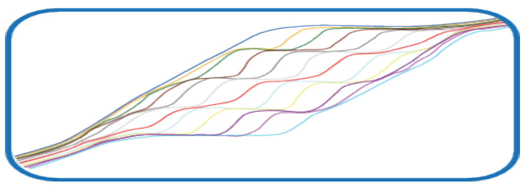

Fig. 4. Structure of 12-fiber SWR.

In addition, in order to identify fibers easily and correctly, SWR has a stripe ring marking on it as shown in Figure 5, 6 and 7. Since the stripe ring marking is marked on the SWR in the width direction which continues in longitudinally, it can be easily identified even when the fiber diameter is smaller such as 160 μm or even if 12-fiber SWR gets separated to a single fibers.

4. Fiber connection technology

4-1. Compatibility with conventional fibers

When a new fiber having different cladding diameter is applied, the connection with the conventional fiber should be considered. It is difficult to connect 160 μm fiber with 80 μm cladding and 250 μm fiber with 125 μm cladding by using general fusion splicers. Thus, we introduce an MPO connector for connection between fibers having different cladding diameter as shown in figure 8. Conventional MPO connector for 250 μm fiber has a fiber pitch of 250 μm. Therefore, the MPO connector for 160 μm fiber is

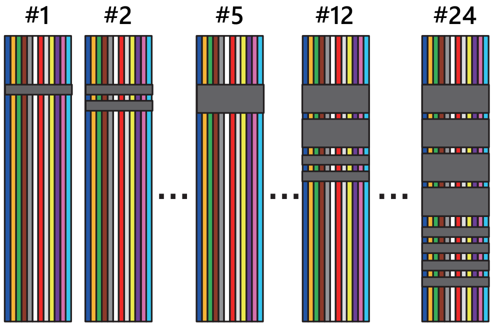

Fig. 5. Schematic of stripe ring marking.

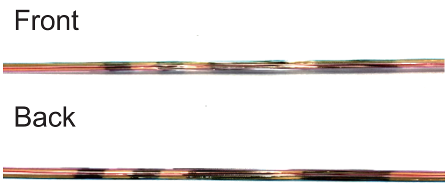

Fig. 6. Stripe ring marking visibility on both sides of SWR (#12).

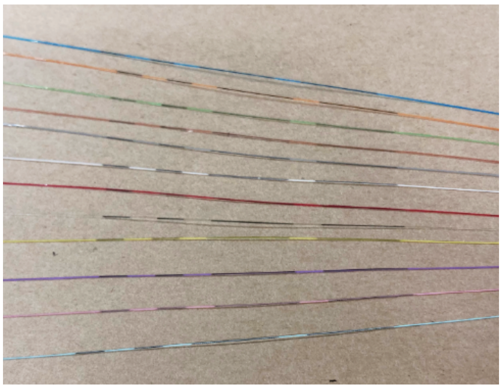

Fig. 7. Stripe ring marking visibility with a single fiber (#12).

controlled to have 250 μm pitch between fibers in order to connect with conventional fibers. The figure 9 shows the measuring insertion loss between fibers having different cladding diameter using 12-fiber MPO connector. Excellent insertion loss was confirmed and IEC 61753-1 Grade B was achieved.

4-2. Fusion splicing workability among 160 μm fiber SWR

Mass fusion splicing among 160 μm fiber SWR can be done by replacing the V-groove made for general fusion splicer. The measured results of splicing loss and splicing time for 160 μm 12f-SWR using general fusion splicer also known as 90R are shown in figure 10 and 11 respectively. It was confirmed that there was no difference between 160 μm SWR and conventional fiber ribbon in fusion splicing workability even if the cladding diameter was reduced from 125 μm to 80 μm. Also V-groove can be installed and removed easily as shown in figure 12. Furthermore, mass fusion splicer can be immediately available after the V-groove is replaced because the spare V-groove is equipped with an electrode rod that has undergone discharge treatment.

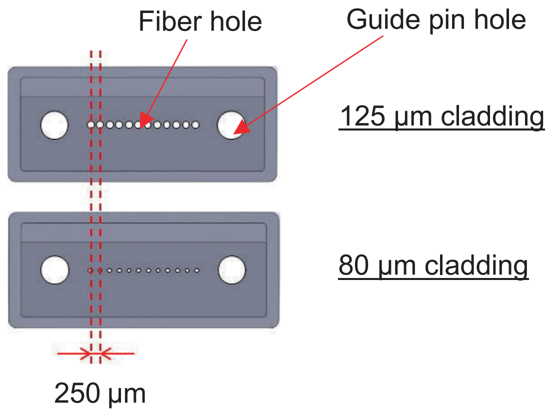

Fig. 8. End faces of 12-fiber MPO connector applied with each fiber having different cladding diameter.

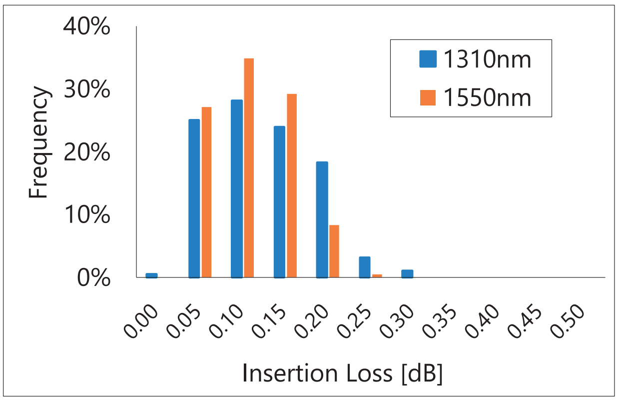

Fig. 9. Insertion loss between fibers having different cladding diameter(12-fiber MPO).

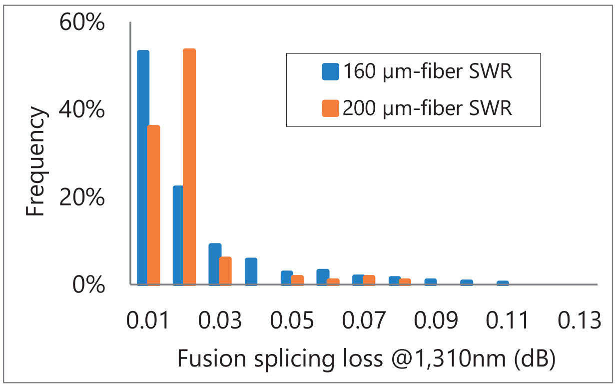

Fig. 10. Fusion splicing loss between SWR respectively.

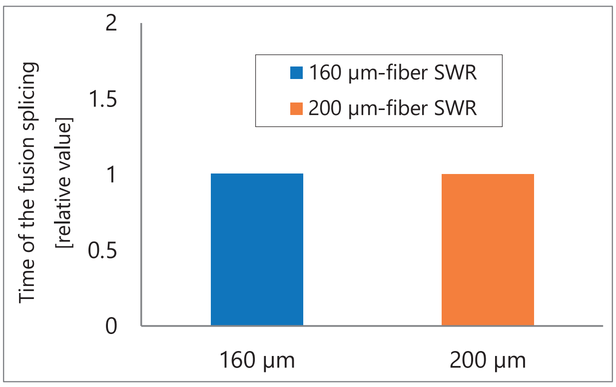

Fig. 11. Relative value of fusion splicing time between SWR respectively.

Table 1. Mechanical and Environmental Characteristics of 6912-fiber WTC.

Item	Condition	Result
Low-and High-Temperature Cable bend	Bending radius: 15D (D: cable diameter) -30/+60 degree C, 2 cycles	< 0.05 dB No damage
Impact Resistance	4.4 J	< 0.05 dB No damage
Compressive Strength	110 N/cm, 10 minutes	< 0.05 dB No damage
Tensile strength of Cable	2700 N, 1 hour	< 0.1 % No damage
	810 N, 10 minutes	< 0.05 % < 0.05 dB
Cable Twist	Sample length: 2 m ±90 degree, 10 cycles	< 0.05 dB No damage
Cable Cyclic Flexing	Bending radius: 10D (D: cable diameter), 25 cycles	< 0.05 dB No damage
Temperature Cycling	-40/+70 degree C, 2 cycles	< Δ0.15 dB/km
Water Penetration	Height of water: 1 m Sample length: 3 m 24 hours, Tap water	< 3 m

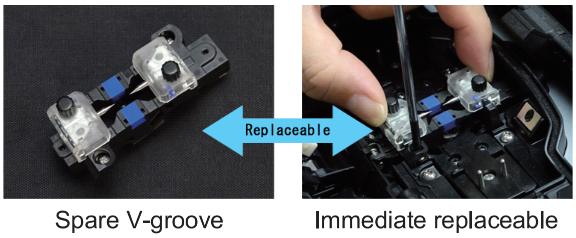

Fig. 12. Replacing work of V-groove for fusion splicer(90R12).

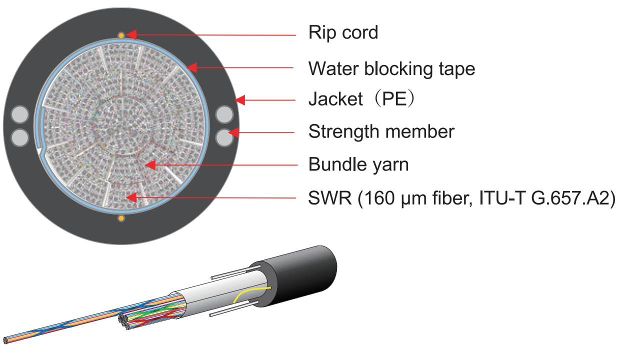

Fig. 13. Construction of 6912-fiber WTC.

5. Fiber cable

5-1. High density 6912-fiber cable

The cable structure is called "Wrapping Tube Cable" (WTC) and it is suitable for high density [9]. The figure 13 shows 6912-fiber WTC using 160 μm fiber. The fiber core is wrapped around by a water blocking tape and covered with a PE jacket in which two pairs of embedded strength members.

5-2. Cable characteristics

Table 1 shows the mechanical and environmental characteristics of 6912-fiber WTC. The test methods were

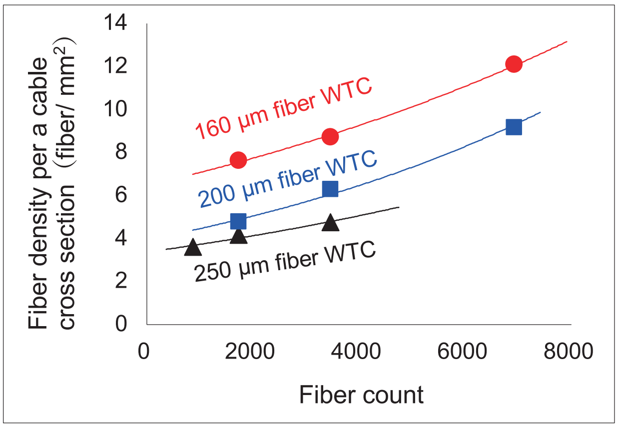

Fig. 14. Relation between fiber count in a cable and fiber packing density per a cable cross section.

based on Telcordia GR-20-CORE [10]. The wavelength for the tests was 1550 nm. It was confirmed that 6912-fiber WTC has shown good mechanical and environmental characteristics.

5-3. Comparison of Conventional and New 6912-fiber WTC

Table 2 shows the comparison of two types of 6912-fiber cable. It indicates that the new cable with 160 μm fiber has achieved 10% cable diameter and 24% weight reduction compared to conventional cable using 200 μm fiber, and offers a fill ratio of 50% in a 1.5-inch conduit. In addition, by reducing a diameter of the cable, the cable winding length on shipping drum becomes longer and it also contributes to lower installation costs by reducing the number of fiber splice points.

5-4. Changes of high fiber count cables in a history

Table 3 shows the diameter of three types of cables using 160 μm fiber and Figure 14 shows the relation between the

Table 2. Comparison of two types of 6912-fiber WTC.

Item	200 µm fiber	160 µm fiber
Cable outer diameter (mm)	30.0	27.0
Cable weight (kg/km)	640	485
Fiber packing density per a cable cross section (fibers/mm^2)	9.8	12.1
1.5-inch conduit Fill ratio (%)	62	50
Standard cable winding length on shipping drum (Relative value)	1.0	1.7

Table 3. Lineup of high fiber count outdoor WTC using 160 µm fiber.

Item	1728-fiber	3456-fiber	6912-fiber
Cable outer diameter (mm)	17.0	23.0	27.0
Cable weight (kg/km)	210	340	485
Fiber packing density per a cable cross section (fibers/mm^2)	7.6	8.3	12.1

cable outer diameter and the fiber density in a cable. It can be seen that as fibers become smaller in diameter, cables are also becoming smaller in diameter and lighter in weight.

6. Conclusion

6912-fiber WTC using 160 µm fiber with an outer diameter of 27.0 mm or less was developed. By SWR/WTC technology, the fiber density has been significantly increased and the cable outer diameter and weight have been reduced when compared to the conventional cables using 200 µm fiber. As a result, new cable enables smooth installation inside the conduit with an inner diameter of 1.5-inch and contributes to Green Transformation (GX) initiatives by reducing the environmental impacts. This innovative cable will contribute to the economical and effective construction of optical fiber network.

References

1) Tomoaki Gonohe, et al. "6912F Ultra High Density Optical Cable with 200 µm fiber 16F Rollable Ribbon", Proceedings of 69th IWCS, 2020
2) Takemasa Akiyama, et al. "New Ultra-High-Density UHFC cable for easy installation", Proceedings of 71st IWCS, 2022
3) S. R. Bickham, "Optical Fibers for Short-Reach High-Density Interconnects," in Proc. Opt. Fiber Commun. Confer., 2019, Paper M3C.1.
4) K. Mukasa, T. Mihálffy, and Z. Várallyay, "Optimizations of thin glass diameter fibers," in Proc. Opt. Fiber Commun. Confer., 2021, paper M3C.1.
5) W. Niu, M. Drake, B. R Knowlton, Y. Zhang, A. L Wallace, J.S Stone, Y. Gu, S. D. Hart, H.M de Pedro, A. R. Zakharian, and M-J Li, "Thin-Coated Fibers for High-Density Optical Interconnects," in Proc. Opt. Fiber Commun. Confer., 2021, paper M3C.2
6) H. Sato, et al. "160 µm Coating Optical Fiber with 80 µm Cladding for 1,728 Fiber Cable", Proceedings of 70th IWCS, 2021
7) S. Matsuo, K. Yamashiro, K. Hoshi, Y. Tsujimoto, M. Miyata, H. Asada, T. Nakajima, and K. Osato, "1,728-Fiber Cable with 12-Fiber Ribbons Comprising 160-µm Coating Fiber with 80-µm Cladding," in Proc. Opt. Fiber Commun. Confer., 2021, paper M3C.3.
8) "Characteristics of a bending-loss insensitive single-mode optical fibre and cable," ITU-T Recommendation G.657, 2016.
9) M. Isaji, et al. "Ultra-High Density Wrapping Tube Optical Fiber Cable with 12-Fiber Spider Web Ribbon", Proceedings of 62nd IWCS, 2021
10) Telcordia Technologies Generic Requirements GR-20-CORE issue4(2013)