Ultra-High-Density Microduct Optic Cable with 200µm Freeform Ribbons for Air-Blown Installation

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Abstract

This paper describes a newly designed ultra-high-density (UHD) microduct optical cable to be installed into microducts with air-blowing technique. The UHD microduct cable employs Freeform Ribbon, in which fibers meet and split out in turn in longitudinal and transverse directions, thus allowing high fiber density and mass fusion splicing. In order to enhance the blowing efficiency, we employed a thin and lightweight cable design and low friction jacket material. In addition, we have significantly increased fiber density owing to a bend-insensitive and thin optical fiber and Freeform Ribbon technology.

We also evaluated the blowing performance in collaboration with Plumettaz S.A. to confirm the excellent blowing property of the developed cable.

Keywords: Microduct, Ultra-high-density, Freeform Ribbon^{TM}, Slot, Non-slot, Low friction, Blowing performance

1. Introduction

In recent years, communication traffic has increased rapidly due to progresses in cloud computing and video subscription services and support for 5G. Meanwhile, there is a growing demand for thin ultra-high-density (UHD) fiber-optic cables that contain optical fibers at a high density due in part to physical constraints in the internal spaces of ducts. In Europe and North America, air-blown optical cables are in widespread use in fiber-to-the-home (FTTH) applications. The air-blown optical cable enables networks to be constructed economically because once a duct (microduct) has been installed, it can be additionally installed without the need for additional roadwork. Small-diameter ducts, or microducts, are used for air-blown installations. Recent increases in transmission capacity and advances in FTTH have spurred the need to use high-fiber-count, UHD microduct optical cables.

Air-blown installation that uses high-pressure compressed air determines properties required of this cable. Namely, it should be thin, lightweight, low-friction, and adequately rigid so as not to yield during air-blown installation. The authors have developed a Freeform Ribbon optical cable that reduces the connection cost more than single-fiber optical cables do, while being compatible with the above-described installations in microducts.

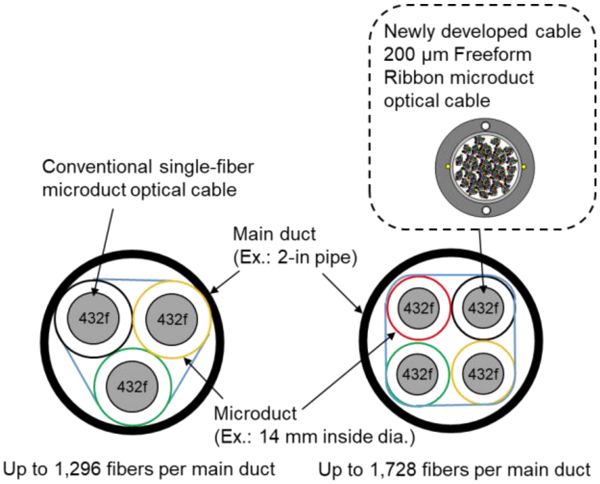


Figure 1 Schematic diagram of microduct installation

2. Design and Features of 200 µm Freeform Ribbon

2.1 Design of 200 µm optical fiber

Figure 2 provides a schematic cross section of the thin 200 µm optical fiber used for the recent development. The thin 200 µm optical fiber has its cross-sectional area reduced by 36% by reducing the cladding thickness, with the glass diameter remaining at 125 µm, as before.

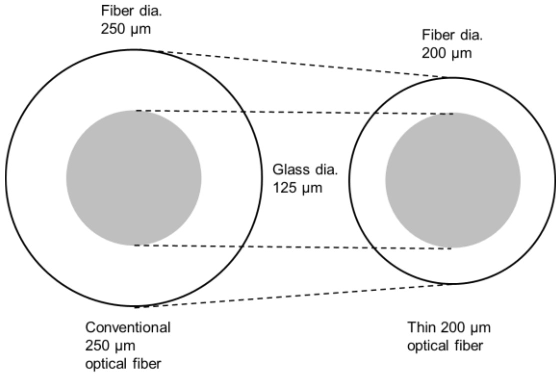
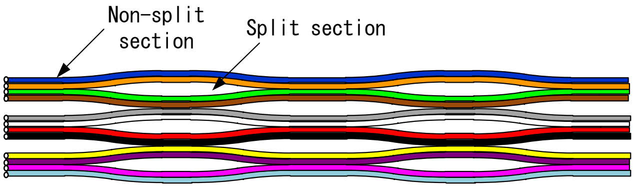


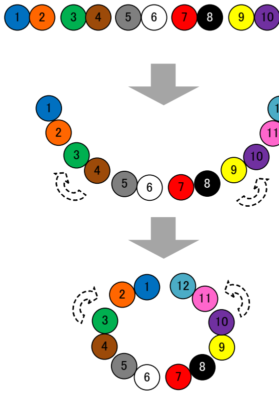
Figure 2 Schematic cross section of thin 200 µm optical fiber

2.2 Design of 200 µm Freeform Ribbon

The 200 µm Freeform Ribbon used for the recent development is a 12-fiber ribbon in predominant use in overseas countries. Figure 3 shows a schematic diagram.



(a) Longitudinal schematic diagram



(b) Schematic cross-sectional view illustrating the ribbon's flexibility

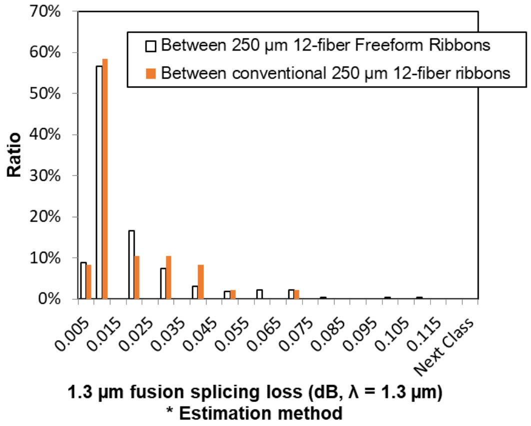
Figure 3 Schematic diagram of 200 µm 12-fiber Freeform Ribbon

The flexibility of the pliable ribbons and ribbon alignment for mass-fusion splicing can be controlled by changing the slit length/non-slit length ratio and length. The slit length/non-slit length ratio of the structure was optimized by taking into account ribbon flexibility based on the mass fusion splicing workability and cable characteristics.

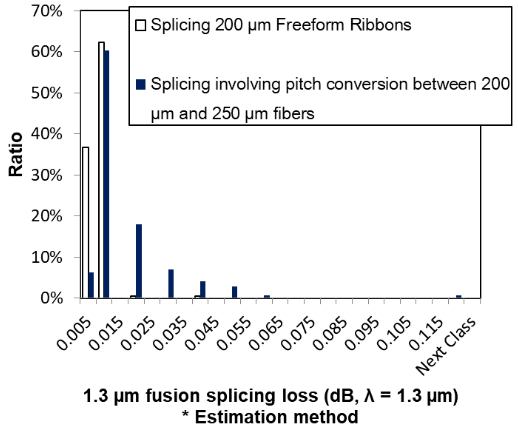
2.3 Splicing technique for 200 µm Freeform Ribbons

To ensure compatibility with existing optical cable installations, the authors envisioned scenarios, including splicing between the newly developed 200 µm 12-fiber Freeform Ribbon and the conventional 250 µm 12-fiber Freeform Ribbon, a path consisting exclusively of 200 µm 12-fiber Freeform Ribbons, and mass fusion splicing between the newly developed 200 µm 12-fiber Freeform Ribbon and a 200 µm single-fiber ribbon. Two types of connecting techniques have been developed. One is to enable the use of existing fusion splicers by rearranging the fiber holder; the other is to use a newly developed fusion splicer model designed to connect between 200 µm fiber Freeform Ribbons.

Figure 4 (b) presents distributions of splicing losses (estimates) produced by mass fusion splicing between 200 µm and 250 µm and between 200 µm and 200 µm fibers. Figure 4 reveals no significant difference, or similarity, between loss distributions estimated for the conventional ribbon (a) and the newly developed ribbon (b).



(a) Distribution of splicing loss of conventional 250 µm 12-fiber ribbons



(b) Distribution of splicing loss of thin 200 µm 12-fiber ribbons

Figure 4 Comparison of fusion splicing losses of different 12-fiber ribbons

3. Structure and Characteristics of Microduct Optical Cable

3.1 432-fiber cable structure

The authors have developed two types of structures for the newly developed optical cable: non-slot structure (Figure 5) with emphasis on thin and lightweight construction for blowing performance and a slotted structure (Figure 6) incorporating a central tension member to conserve the conventional ease of installation. The non-slot structure was implemented in two structural types, using conventional tension members made of steel wire or incorporating dielectric tension members predominantly used in overseas countries. Meanwhile, the optical fiber was a bend-insensitive single-mode fiber (ITU-T G.657A1 and G.652D specifications) incorporating a 200 µm core.

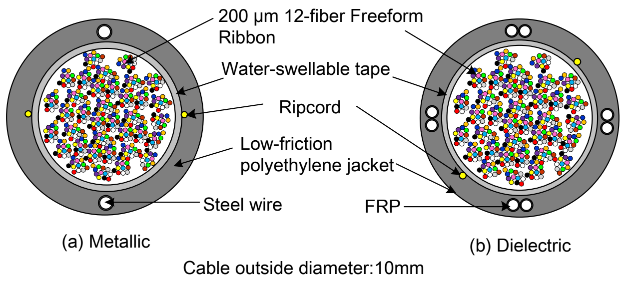


Figure 5 Schematic cross section of 432-fiber microduct optical cable (non-slot)

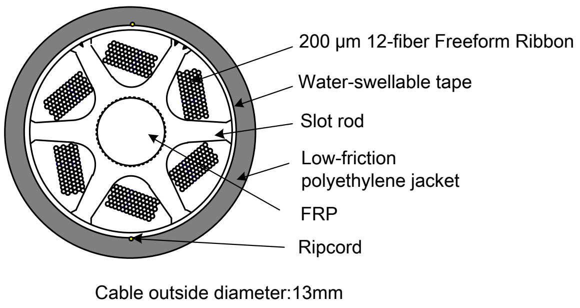


Figure 6 Schematic cross section of 432-fiber microduct optical cable (slotted core)

For improved blowing performance, a low-friction jacket was used for the new development. The coefficient of friction of the newly developed low-friction jacket material has been confirmed to be approximately one-sixth of that of conventional general-purpose jacket materials. The dielectric structure presented in Figure 5 (b) had tension members located in four positions to be less directional when bending.

In addition to the above-described 432-fiber microduct cable, cable varieties ranging from 144 to 432 fiber count have been developed as options. Figure 7 presents graphs comparing outside diameters of a conventional single-fiber loose-tube microduct optical cable and the newly developed cable.

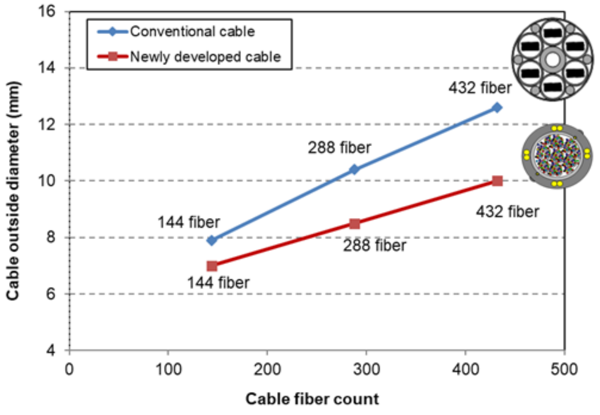


Figure 7 Comparison of outside diameters of conventional and newly developed cables

The outside diameter of the newly developed cable is substantially smaller than that of the conventional cable, as shown in Figure 7. A comparison of 432-fiber cables reveals that the newly developed structure enables the fiber count (fiber density) per unit cross-sectional area of cable to increase by a factor of approximately 1.6.

3.2 Transmission and mechanical characteristics

The characteristics of the recently developed 432-fiber microduct optical cable were evaluated. Table 1 shows the evaluation results, including those of mechanical testing. The favorable characteristics of the recently developed cable have been ascertained by mechanical testing as well.

Table 1 Characteristics evaluation results for 432-fiber microduct cable

Item	Test Method	Evaluation Result
Attenuation Coefficient	IEC60793-1-40 λ=1550nm	< 0.21dB/km (1550nm)
Temperature Cycling	EIA/TIA-455-4 -40°C / +70°C , 2 cyc. λ=1550nm	Loss variation < 0.10 dB/km
Compressive Loading	EIA/TIA-455-41 500N/100mm λ=1550nm	Loss variation < 0.10 dB/km No faulty condition in cable appearance
Impact Test	EIA/TIA-455-25 Impact Energy:10 N-m 2 drop impacts, 3 locations, λ = 1550 nm	
Cyclic Flexing	EIA/TIA-455-104 I and IV bending cycles at bending radius of 10D ("D" denotes the outside diameter of the cable.) 25 cycles, λ = 1550 nm	
Cable Twist Test	EIA/TIA-455-85 Sample Length ≤ 2 m 10 cycles ± 180 ° λ = 1550 nm	
Long Tensile Loading and Fiber Strain Test	EIA/TIA-455-33 Tension: 500 N	Fiber strain under application of 500 N <0.1%

3.3 Blowing performance

Using blowing equipment manufactured by the Swiss cable blower manufacturer Plumettaz S.A., the blowing performance of the newly developed 432-fiber microduct optical cable was evaluated. The blowing test was conducted along an IEC-compliant 1,000 m route illustrated in Figure 8, by unwinding the cable from a drum as shown in Photo 1 and using MiniJet, a cable blower manufactured by Plumettaz,to blow the cable through a microduct 14 mm in inside diameter. Figure 9 illustrates the structure of the cable used for the blowing test.

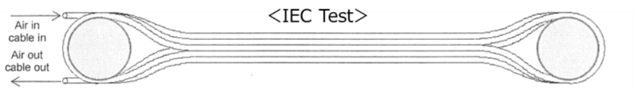


Figure 8 IEC-compliant route for blowing testing (Route length: 1,000 m)

Photo 1 Cable and cable blower used in blowing test

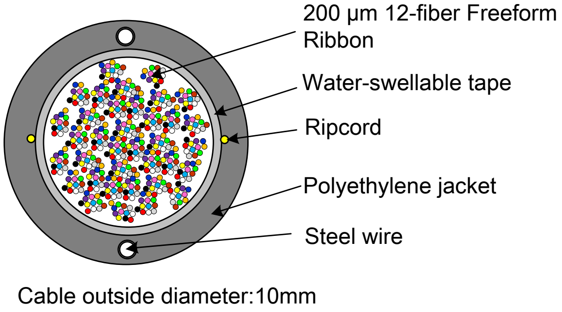


Figure 9 Structure of cable used in blowing test

Table 2 presents the blowing test results. An optical cable with a conventional polyethylene jacket was investigated for the effect of lubricant in a dynamic friction test [9], the lubricated cable showing about half the coefficient of friction. The cable could be blown for the specified 1,000 m in this tough (50 m long) IEC trajectory only when using a lubricant applied inside the duct. When using lubricant, the optical cable with the conventional jacket could be blown through 1,000 m in the IEC-compliant test system. Moreover, using simulation software produced by Plumettaz and assuming an actual cable installation route, the blowing distance of the newly developed cable was estimated. According to the estimation results, the cable can be blown for 1500-1600 m. For installation with the floating technique (using water) even much longer length are expected, 2000 m, at low speed maybe 3-4 times higher!

Table 2 Comparison of blowing performance of 432-fiber microduct optical cables

Test	Structure	IEC-compliant blowing test	General installation route* (suburban area)	General installation route* (rural area)
1	No lubricant	Fail (312 m)	N/A	N/A
2	Duct lubricated	Pass (1000 m)	Good (1500 m)	Excellent (1600 m)
3	Duct and cable lubricated	Pass (1000 m)	Good (1500 m)	Excellent (1600 m)

* For the general installation route, blowing distance calculation software produced by Plumettaz was used for estimation.

Furthermore, to improve the blowing distance without using lubricant, we estimated blowing distance of the newly developed microduct cable with the low friction jacket described in Section 3.1. When calculated using the coefficient of friction, it was confirmed that the blowing distance is greatly extended as shown in Table 3.

Table 3 Estimation of blowing distance of the newly developed 432-fiber cable

Sample No.	Structure	COF (relative value)	General installation route (suburban area)*
1	Normal jacket (no lubricant)	0.30	N/A
2	Normal jacket (with lubricant)	0.10	Good (1500m)
3	Low-friction jacket (no lubricant) Newly developed cable	0.05	Excellent (>2500m)

* For the general installation route, blowing distance calculation software produced by Plumettaz was used for estimation.

We also applied bendable cable structure with non-preferential bending axis as shown in Figure 5(b), it is possible to further extend the blowing distance and improve coiling the excess length of installed cable.

4. Conclusions

While air-blown microduct optical cables are predominantly used in Europe and other areas, the authors have developed a low-friction ultra-high-density microduct optical cable incorporating thin 200 µm 12-fiber Freeform Ribbons to enable both mass fusion splicing and high-density construction. The 200 µm 12-fiber Freeform Ribbon has been proven to connect with conventional 250 µm 12-fiber ribbons as well as with 200 µm fibers.

Furthermore, the newly developed microduct optical cables comprising up to 432 fibers ensure a fiber density higher than that of the conventional microduct cable by a factor of 1.6. By combining it with a low-friction jacket, the cable can be air-blown and installed over a distance of 2500 m along a general installation route (and with floating even much more!). Combined with air-blown installation, the above-described Freeform Ribbon microduct cable will enable a low installation cost and flexible cabling styles.

5. Acknowledgments

The authors will express gratitude to all the people who cooperated in the completion of this paper.

6. References

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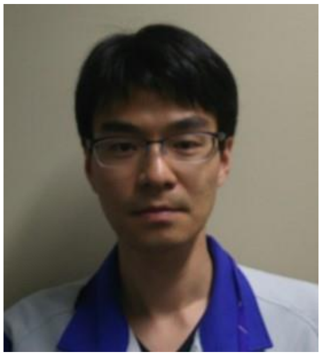

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