Designs of New UHFC Optical Fiber Cables with Freeform Ribbons and Installation Characteristics

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Abstract

In this paper, the first half describes a newly designed ultra-high-fiber-count (UHFC) optical fiber cable for Outside Plant and Indoor-outdoor applications. The UHFC cable employs Freeform Ribbon, in which fibers meet and split out in turns in a longitudinal and transverse direction, thus allowing high fiber density and mass fusion splicing. Having a non-preferential bend axis, the cable can easy be installed in space-constrained areas.

We combined the Freeform Ribbon technology with a new cable design to significantly increase fiber density compared to conventional underground cables while retaining their advantageous features such as easy handling, identification, and mass fusion splicing. Furthermore, we have developed Indoor-outdoor cable which is flame retardant type of UHFC cable complied with UL and CPR standard.

The latter part describes the installation characteristics of UHFC cables. Two types of UHFC optical fiber cables were compared to verify the workability: a slotted core cable (flexible in all directions) and a non-slotted core cable (incorporating a tensile strength member on both sides). Finally, with the cooperation with Plumettaz S.A., an experiment was conducted, at their facilities in Switzerland, using the cable blowing method which is mainly used in Europe etc.

Keywords: ultra-high-fiber-count, Freeform Ribbon, slotted core cable, Indoor-outdoor cable, installation

1. Introduction

Recently, a growing number of large-scale data centers (DCs) have been constructed due to the advancement of cloud computing, etc. Demand for high-count, high-density optical fiber cables for connecting DCs has been growing to meet the need for increased transmission capacity. Cables that connect DCs are usually installed in outdoor ducts. Technology for achieving high-density installation of optical fiber cables in limited duct space plays a key role (see Figure 1).

Against this backdrop, we have developed a series of high-count, high-density optical fiber cables by using 12-fiber Freeform Ribbons that help ensure high flexibility and facilitate mass-fusion splicing. Notably, these optical fiber cables are highly flexible in all directions by using a slotted core cable structure with a strength member passing through the center of the core.

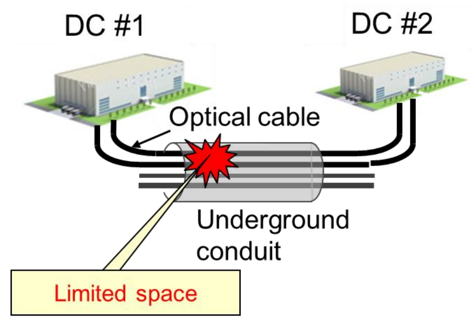
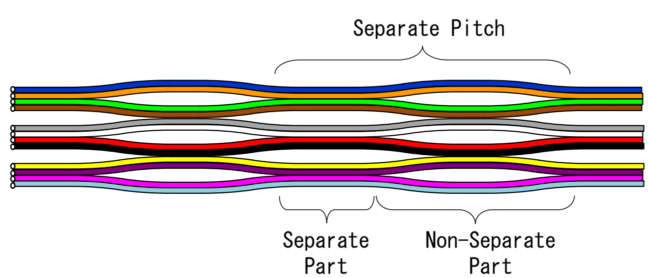


Figure 1. Schematic illustration of wiring configuration between DCs

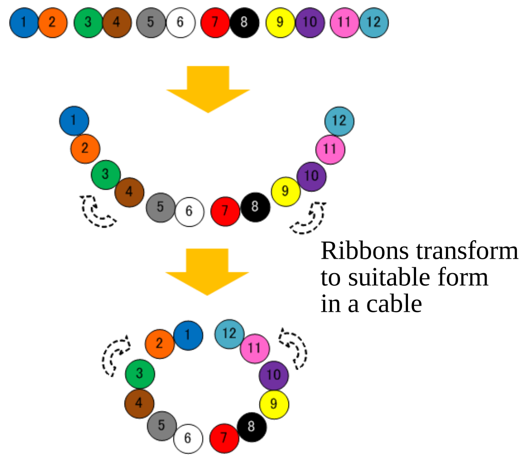
Last 2 years, we reported the design and evaluation results of the UHFC optical slotted core cables using Freeform Ribbons. In this report, we report the designs of new UHFC cables, the results of cable evaluation and the advantages in terms of installation.

2. Design of Freeform Ribbon

We used 12-fiber pliable ribbon that are mainly used outside Japan. The schematic diagram is shown in Figure 2. The flexibility of the pliable ribbon and ribbon alignment for mass-fusion splicing can be controlled by changing the separate length/non-separate ratio and length. The Separate length/Non-separate length ratio of the structure was optimized by taking into account ribbon flexibility based on the mass fusion splicing workability and cable characteristics.



(a) Schematic drawing of longitudinal direction



(b) Schematic diagram of cross-sectional deformation

Figure 2. Schematic diagram of the 12-fiber Freeform Ribbon

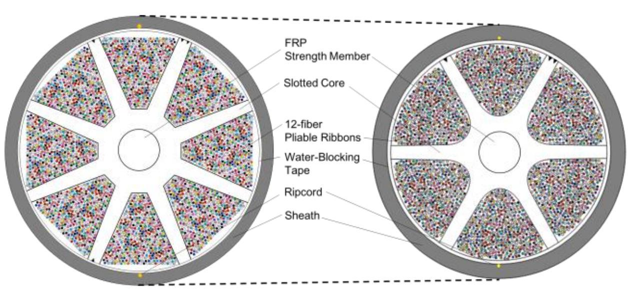
3. Cable Design and Evaluations

3.1 New Design of 3456-fiber count cable

The slotted core cable structure design has been used to ensure high flexibility in all directions by inserting a fiber reinforced plastic (FRP) tension member through the center of the core. This nonmetallic structure is expected to reduce cable weight by 10–15% compared to the conventional structure using a steel wire as the tension member.

As optimizing slot structure and cable process, we realized downsized cable design. Figure 3 shows the schematic diagram of the cross section of a 3456-fiber-count optical cables, we have developed new 3456-fiber cable whose diameter is 32mm.

The optical fibers used in these cables are single-mode fibers (ITU-T G.657A1, G.652D standard) with enhanced bending property. These bendable fibers, in combination with Freeform Ribbons, have significantly increased the fiber density in the cable core, achieving a significant reduction in cable diameter and weight compared to conventional cables.



Outer Diameter 34 mm **Outer Diameter 32 mm (New Design)**

Figure 3. Cross-section of 3456-fiber count cable

3.2 Ribbon Identification

In a high-fiber-count optical cable, each fiber ribbon needs to be identified, so we printed a series of bars on each fiber ribbon as shown in Figure 4. The use of bars in place of conventional numerical figures offers better legibility and makes the ribbons easier to identify.

In addition, to shorten working time for identifying each ribbon, we adopted color binder for several subunit in each slot. Figure 5 shows picture of subunit bound by color tape. It was confirmed the identification of each ribbon in UHFC cables was greatly improved by combination with ribbon marking, slot and color binders.

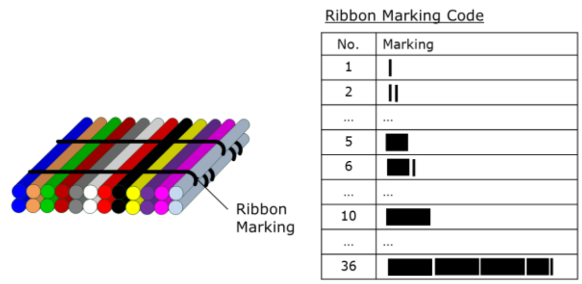


Figure 4. Schematic diagram of a ribbon identification pattern for UHFC cable

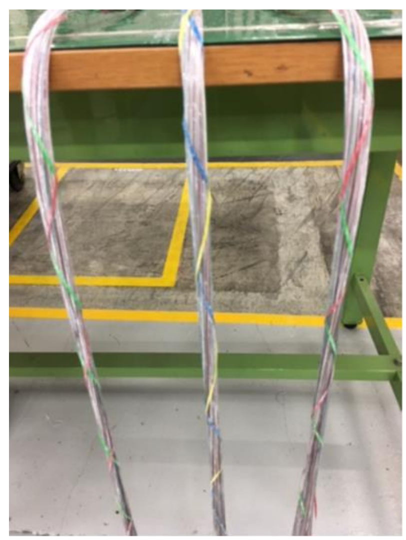
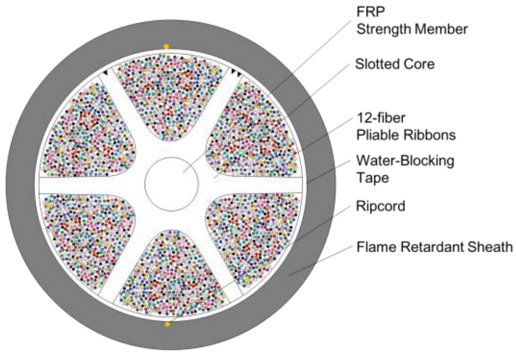


Figure 5. Picture of subunits bound by color tape in UHFC cable

3.3 Indoor-outdoor Cable Design

Indoor-outdoor cables are generally derived from outdoor cable designs having the thermal and mechanical robustness that makes them suitable for use in the Outside Plant.

In order to install around data center including data hall, we have also developed 3456-fiber Indoor-outdoor cable which is flame retardant type complied with UL and CPR standard. Figure 6 shows the design of 3456-fiber Indoor-outdoor cable.



Outer Diameter 33 mm

Figure 6. Cross-section of 3456-fiber Indoor-outdoor cable

This cable is covered LSZH and Flame Retardant Sheath with the core of new 3456-fiber cable as shown in Figure 3. The cable properties such as temperature property and mechanical property are comparable to conventional cables used at Outside Plant.

3.4 Cable Performance

We performed temperature cycling and mechanical tests on the new 3456-fiber count cable. The test items, conditions and results are summarized in Table 1. It was confirmed that attenuation changes of these cables were met the requirements.

Table 1 Transmission and mechanical performance of new 3456-fiber count cable

Item	Method	Result
Attenuation Coefficient	IEC60793-1-40	< 0.25 dB/km (λ = 1550 nm)
Temperature Cycling	FOTP-3 -40°C / +70°C x 2 cyc.	Δ α < 0.10 dB/km
Compressive Loading	FOTP-41 220 N/cm, 1 minute followed by 110 N/cm, 10 minutes	< 0.1 dB
Impact Test	FOTP-25 Impact Energy:4.4 N-m 2 impacts, 3 locations λ = 1550 nm	< 0.1 dB
Cyclic Flexing	FOTP-104 I and IV Sheave diam. ≤ 20 x cable diameter 25 cycles at 30cyc./min λ = 1550 nm	< 0.1 dB
Cable Twist Test	FOTP-85 Sample Length ≤ 2 m 10 cycles ± 180 ° λ = 1550 nm	< 0.1 dB
Long Tensile and Bending and Fiber Strain	FOTP-33 a) 600 lb (rated) b) 180lb(residual)	Fiber strain(Rated) ≤ 60% fiber proof strain Fiber strain(Residual) ≤ 20% fiber proof strain < 0.1 dB

We also evaluated flame test complied with UL1666 riser grade using 3456-fiber Indoor-outdoor cable. The test items, conditions and results are summarized in Table 2. It was confirmed that it was confirmed that the flame test result was complied with UL1666.

Table 2 UL1666 test result of 3456-fiber Indoor-outdoor cable

Item	Requirements	Results
Maximum Flame Propagation Height (cm)	366 >	215
Maximum Temperature (℃)	454.4 >	281.7

Furthermore, we conducted the flame test complied with EN50399 and EN60332-1-2 standardized in Europe, and it was confirmed the cable passed these CPR standards.

4. Installation Characteristics

In general, the higher the fiber count of an optical cable, the larger the outside diameter and higher the rigidity, making it difficult to install cables in a conduit and store the excess length in handhole enclosures, etc. due to the decreased cable flexibility, in particular.

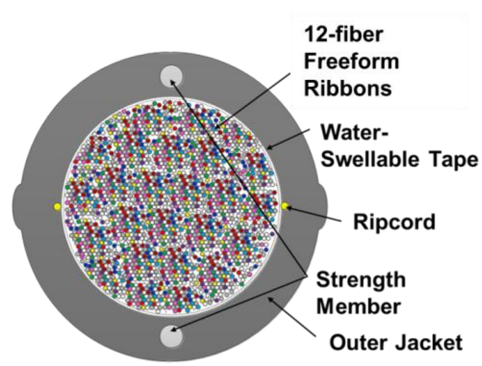
Two types of UHFC optical fiber cables were compared to verify the workability: 3456-fiber non-slotted core cable (incorporating a tensile strength member on both sides) and 3456-fiber ribbon slotted core cable (flexible in all directions).

Finally, an experiment was conducted using the cable blowing method which is the mainstream cable installation method outside Japan.

4.1 Pulling test in a 1.5 inch duct

In order to evaluate the influence of preferential bending axis of cable on pulling property in a duct, we prepared two kinds of cable samples whose diameters are about 30.5-34.0mm. The cable sample cross-section are shown in Figure 7.

A. 3456f Non-slotted Core Cable



Outer Diameter 30.5 mm

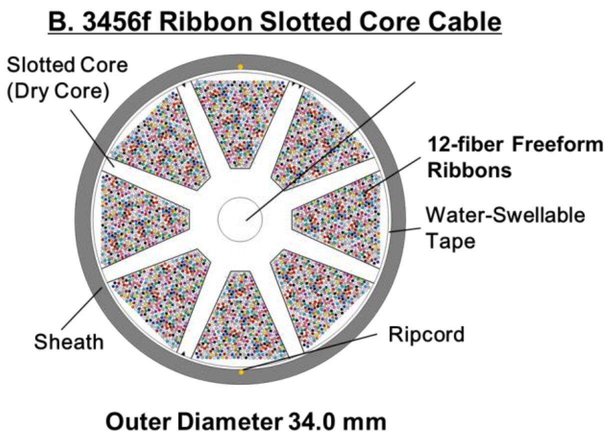


Figure 7. Cross-sections of UHFC cable samples for installation tests

We evaluated the pulling tension of the non-slotted core cable and slotted core cable in a duct to confirm the installation characteristics of these cables.

Figure 8 shows the scheme of the cable installation test. We used flexible ducts, total length 28.5 m, and the inner diameter of the duct was almost 2.0 inch. Firstly, we made 8-figure coil of each cable in front of duct mouth, then we measured pulling tension on each cable during pulling cables in the first duct.

Figure 9 shows the pulling test results.

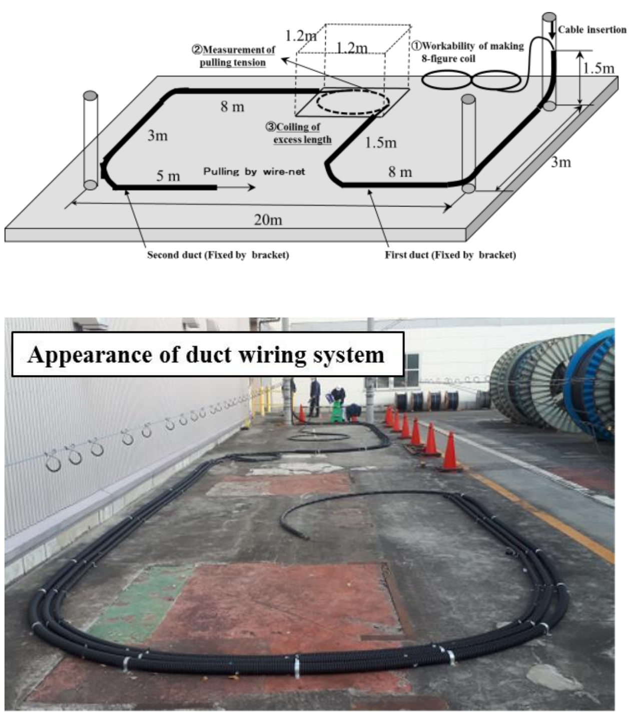


Figure 8. Scheme of cable installation test

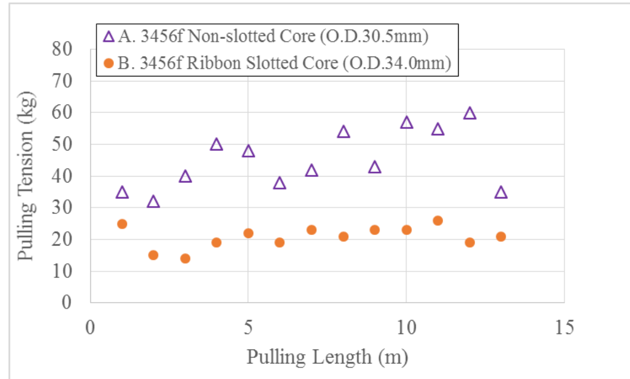


Figure 9. Pulling test result of UHFC cables

It was confirmed that the pulling tension of the non-slot type cable was higher than the slotted core cable. Since the non-slot type cable has high twisting stiffness, the resistance at the curved position increases, whereas the slotted core type has non-preferential bending axis, so the increase of pulling tension was small.

We also investigated whether the coiled status changes due to the effect of cable bending directionality. After installing cables in the first duct and second duct shown in Figure 8, we coiled excess length of the installed cable.

Figure 10 shows the coiled status of the non-slot type cable, and Figure 11 shows the coiled status of the slotted core cable.

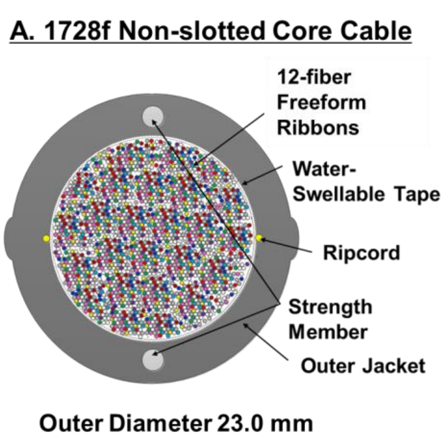
Figure 10. Coiled status of the 3456f non-slot cable

Figure 11. Coiled status of the 3456f slotted core cable

The comparison results of the non-slotted core cable and slotted core cable indicated that a thick non-slotted core cable (equivalent to 30.5 mm in outside diameter) may not be able to be stored properly due to the influence of the specific bending direction attributed to the tension members provided on both sides. Based on this result, it is considered that the cable structure which has non-preferential bending axis is effective for the cable installation in case of wiring large outer diameter cable.

4.2 Cable Blowing Test

At the end of the installability verification, a cable blowing method using a cable jetting machine (which is widely used in Europe and North America, etc. to fit optical fiber cables into ducts) was employed to conduct an experiment to install a 1728-fiber-count slotted core cable and 1728-fiber-count non-slot type cable as shown in Figure 12.



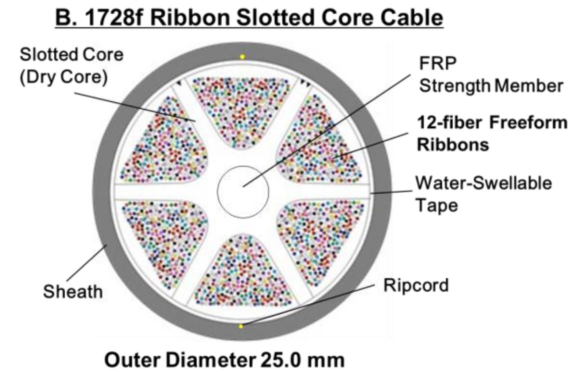


Figure 12. Cross-sections of UHFC cable samples for blowing tests

Figure 13 shows the scheme of the cable blowing test. A trajectory with 40/35 mm duct with a total length of 200 m was made containing two times the 25 m trajectory with each 2 subsequent bends of 90 degrees in planes rectangular to each other.

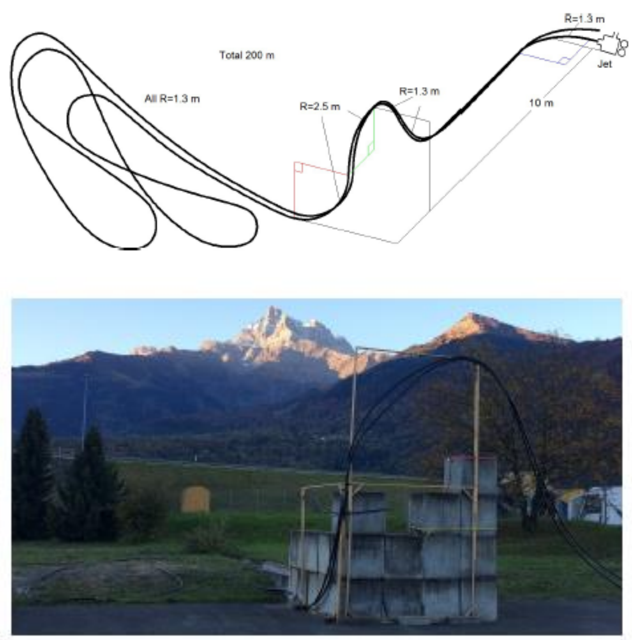


Figure 13. Scheme of cable blowing test

A SuperJet cable blowing machine which is shown in Figure 14 was used to conduct the experiment with cooperation from Plumettaz S.A., a cable blowing equipment manufacturer, at their facilities in Switzerland. The SuperJet machine was used in simulated difficult conduit conditions.

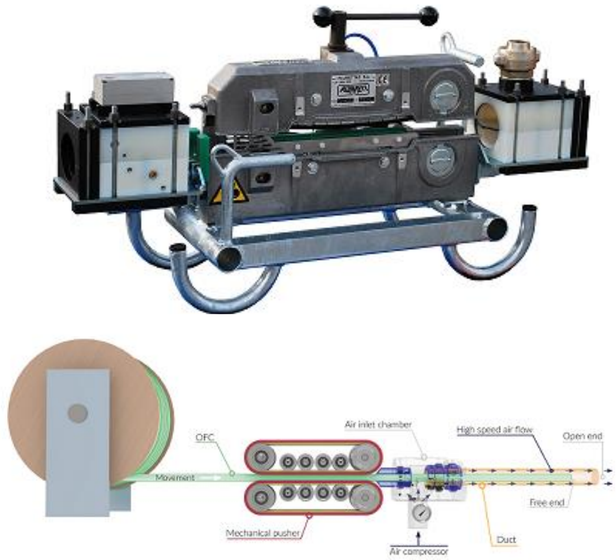


Figure 14 Photo of a SuperJet and schematic diagram of the cable blowing test

During preparation of the test, the non-slotted core cable was also tested with a Sonic Head coupled to the cable head, see Figure 15, where a small local pulling force was generated while the airflow could still pass.

Figure 15 Photo of a Sonic Head

After the test, the following conclusions were drawn from the short length tests at low pressures, extrapolated to longer lengths reachable with 8 bar for trajectories extended with the same difficult conduit conditions.

1) 1108 m for the slotted core cable
2) 1171 m for the slotted core cable using a sonic head
3) 823 m for the non-slotted core cable
4) 966 m for the non-slotted core cable using a sonic head

The jetting behavior of especially the non-slotted core cable is enhanced when using a sonic head, but the jetting behavior for the slotted core cable will be better in all cases.

5. Conclusions

We have described a newly designed ultra-high-fiber-count (UHFC) optical fiber cable for Outside Plant and Indoor-outdoor applications.

We combined the Freeform Ribbon technology with a new cable design to significantly increase fiber density compared to conventional underground cables while retaining their advantageous features such as easy handling, identification, and mass fusion splicing.

Two types of UHFC optical fiber cables were compared to verify the workability: a slotted core cable (flexible in all directions) and a non-slotted core cable (incorporating a tensile strength member on both sides). Finally, with the cooperation with Plumettaz S.A., an experiment was conducted using the cable blowing method which is mainly used in Europe etc. It was concluded that the slotted core cable has advantage of the point of view of cable installation.

6. Acknowledgments

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7. References

[1] Y. Yamada et al, “Ultra-High-Density Optical Fiber Cable with Rollable Optical Fiber Ribbons,” The Institute of Electronics, Information and Communication Engineers (2008), p.292.

[2] Y. Yamada et al, “High-Fiber-Count and Ultra-High-Density Optical Fiber Cable with Rollable Optical Fiber Ribbons,” The Institute of Electronics, Information and Communication Engineers (2009), p.503.

[3] K. Okada et al, “Enhanced Peelable Ribbon and Its Application to Access Network Cables,” Proc. of 53rd IWCS (2005), p.55-60.

[4] F. Satou et al, “Low Polarization Mode Dispersion and Thin Ribbon Type Optical Cable with Peelable Ribbon “EZbranch®”,” Proc. of 55th IWCS (2007), p.55-60.

[5] M. Takami et al, “Design of Ultra-High-Density Optical Fiber Cable with Rollable 4-Fiber Ribbons for Aerial Deployment,” Proc. of 61st. IWCS (2012), p.433-436.

[6] F. Satou et al, “Flame Retardant Optical Fiber Cords with Pliable Ribbons for Easy MPO terminations,” Proc. of 63rd. IWCS (2014), p.742-746.

[7] F. Sato et al, “Design of Ultra-High-Density 2000-Optical Fiber Cable with Pliable 8-fiber Ribbons for Underground Deployment,” IWCS (2015), p.659.

[8] F. Sato et al, “Ultra-High-Fiber-Count and High-Density Slotted Core Cables with Pliable 12-fiber Ribbons,” IWCS (2016), p.604.

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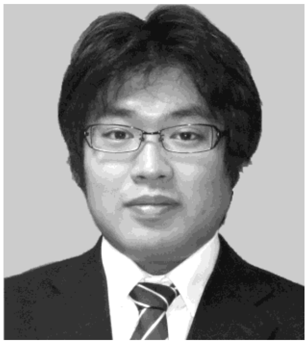

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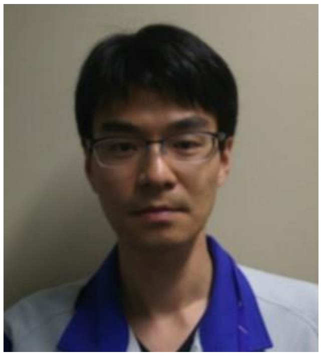

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Netherlands on outside-plant and cable (in duct) installation techniques. During this job he invented cable jetting, a technique to install optical cables into ducts using a synergy of pushing and blowing (now widely used all over the world). He received his Ph.D. (Reliability of Optical Fibers) in 1995 from the Eindhoven Technical University, The Netherlands. From 1998 to 2009 he worked at Draka Comteq (Delft, Gouda and Amsterdam, The Netherlands), on connectivity of Fiber to the Home. Currently he works at Plumettaz SA, Route de la Gribannaz 7, CH-1880 Bex, Switzerland, willem.griffioen@plumettaz.com and is responsible for R&D of cable (in duct) installation techniques, not only for telecom but also for energy applications. Currently he works on new techniques to install energy cables into ducts, like Water PushPull (with winch or water-pressured pulling pig), Floating and FreeFloating techniques. Also he works on special techniques to install sensor optical fibres, e.g. for distributive temperature sensing of energy cables.