Reduced-Coated Fibers and Micro-Duct Cables

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Abstract: We investigate the cable miniaturizations and densities enabled by 180µm-coated fibers with standard 125µm cladding. We then explore the possibility to reduce the coating diameter down to 165µm while keeping a standard 125µm cladding. ©2022 The Authors.

1. Introduction

High-density cables are being extensively investigated because of their ability to meet traffic demand in limited duct spaces, but also because they enable faster, more cost-effective, and eco-friendlier installations.

If multi-core and few-mode fibers appear as promising solutions to increase densities in cables [1]; single-core, single-mode fibers with reduced sizes are still the preferred option. These fibers benefit from a mature technology that allows to meet the cost and connectivity challenges. Reducing the legacy 245µm coating diameter to 200µm, and more recently to 180µm, while keeping a standard 125µm cladding diameter has allowed for noteworthy cable demonstrations [2,3], and preliminary reports of <180µm-coated fibers with standard 125µm cladding [4,5] have shown the potential of this reduced-size option.

In this paper, we investigate the cable miniaturizations and densities enabled by 180µm-coated fibers with standard 125µm cladding in micro-duct-cable structures. We then explore the possibility to reduce the coating diameter down to 165µm while keeping a standard 125µm cladding, in comparison with the 80µm-cladding approach [6-9] (see Fig.1).

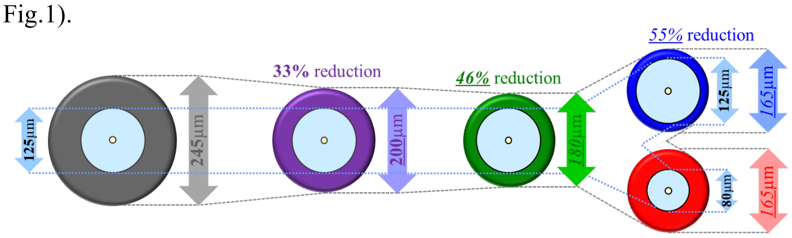

Fig.1: Cross-section schemes of reduced-size fibers compared to legacy 245µm-coated fibers (to scale).

2. 180µm-Coated Fibers with Standard 125µm Cladding and Micro-Duct Cables

200µm-coated fibers with ~160µm primary coating diameter and standard 125µm cladding (200µm/~160µm/125µm) are now a well-established technology. These fibers can also benefit from trench-assisted step-index designs (compliant with ITU-T recommendations G.652.D and G.657.A2) and low primary coating Young's moduli (≤0.35MPa) that allow to reach the small macro- and micro-bending sensitivities required by high-density-cable structures [10]. Based on this technology, we recently introduced a 180µm-coated G.657.A2 trench fiber with a primary modulus of 0.15MPa and diameter of 150µm (180µm/150µm(0.15MPa)/125µm) [3]. This fiber shows good micro-bending behavior and meets all the existing requirements for stripping, tensile strength, and fatigue properties (in accordance with IEC 60793-2-50 for type B fibers). Combining this reduced-coated fiber (cross-section area 46% smaller than that of legacy 245µm-coated fibers, see Fig.1) with loose tubes with reduced sizes (1.2mm outer diameter for 24 fibers thanks to improved processes and raw materials, compared to >>1mm diameters few years ago) allows to develop micro-duct cables with record densities.

Fig.2 shows the diameters of these micro-duct cables with 180µm-coated G.657.A2 trench fibers and their corresponding densities as a function of the fiber count, in comparison with 200µm-coated G.657.A2 trench fibers and legacy 245µm-coated G.652.D non-trench fibers. The solid symbols are for cables fully qualified and compliant with the optical and mechanical specifications of IEC 60794-1-21, and the open symbols are for cables under development. The solid lines give the minimum inner diameters of the ducts that can be used while keeping the duct fill ratios below the 70% limit required for efficient installations. The 288×180µm-coated micro-duct cable of Ref.[3] (12×24-fiber loose tubes, cable diameter of 6.5mm, density of 8.7fiber/mm²) has recently been installed for a public utility supplier in Germany. Blowing in the 1.8km cable into an 8mm inner diameter duct was easy and fast at a speed of 70mpm. It is thus proved possible to install such cables where only 192×200µm-coated trench fibers and 144×legacy-245µm-coated non-trench fibers (so, 2 times less fibers) normally fit. Increasing the fiber count to 576 with 180µm-coated trench fibers leads to a micro-duct cable (24×24-fiber loose tubes, cable diameter of 8.2mm, density of 10.9fiber/mm²) that should allow to use 10mm inner diameter ducts where it is currently only possible to install 432×200µm-coated trench fibers and 192×legacy-245µm-coated non-trench fibers (so, 3 times less fibers).

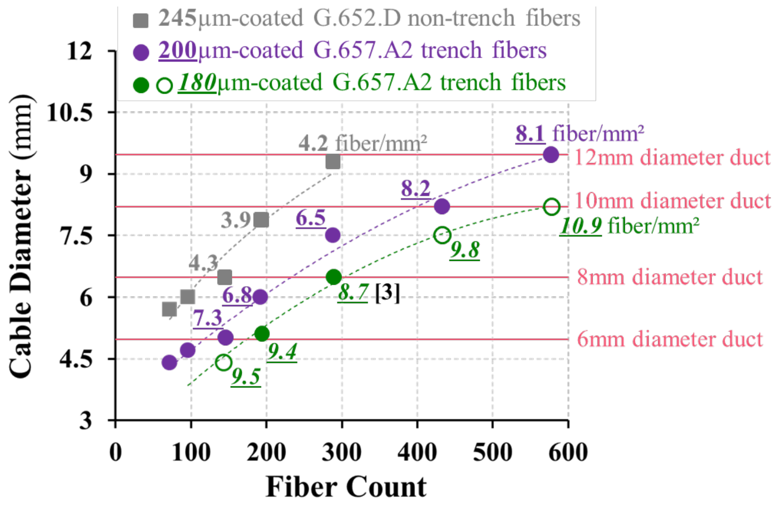

Fig.2: Diameters of micro-duct cables and corresponding densities as a function of the fiber count for 180µm-coated G.657.A2 trench fibers (green circles) with standard 125µm cladding, in comparison with 200µm-coated G.657.A2 trench fibers (purple circles) and legacy 245µm-coated G.652.D non-trench fibers (gray squares). Fabricated and qualified cables (solid symbols), on-going cable developments (open symbols). Dashed lines are guides for the eye. Solid lines are the minimum inner diameters of the ducts that can be used.

We also fabricated and qualified a new 192×180µm-coated-fiber micro-duct cable, composed of 8×24-fiber loose tubes disposed around a 1.6mm diameter central strength member. The cable diameter is 5.1mm (record density of 9.4fiber/mm²) compared to diameters of 6 and 7.9mm when using 200µm-coated fibers and legacy 245µm-coated fibers, respectively (see Fig.2). 180µm-coated fibers allow to use up to ~50% smaller micro-ducts compared to legacy 245µm-coated fibers for same number of deployed fibers. This represents ~50% less polyethylene material used for fabrication. These small micro-ducts can also be installed faster because they retain less shape memory and can thus be laid straight more easily than larger micro-ducts. Finally, ~70% longer lengths can be fitted on a drum, which reduces the number of drums needed for a project (less truckloads to deliver the material at site, and less waste of micro-ducts because scrap is ~proportional to the number of drums). This provides significant benefits for both the total cost of deployment and the environmental footprint.

3. 165µm-Coated Fibers

There are 2 different approaches to reduce the secondary coating diameter to 165µm (cross-section area 55% smaller than that of legacy 245µm-coated fibers and possibility to reach higher densities in cables): keep a standard 125µm cladding or decrease it to 80µm (see Fig.1). In both approaches, the primary concern is the increase of the micro-bending sensitivity [4-7]. To have a comprehensive view, we investigate the dependence of the micro-bending sensitivity at 1550nm on cladding diameter for G.657.A2 trench fibers with different primary moduli and diameters and different secondary diameters but same ~1000MPa secondary modulus, and we then compare possible coating solutions for both approaches (see Fig.3). The micro-bending sensitivities, calculated with the model of Ref.[11] (lines and open circles), are normalized to that of a 245µm/185µm(0.35MPa)/125µm G.657.A2 trench fiber. The theoretical lines are obtained for constant 30µm primary- and secondary-coating thicknesses. The experimental solid circles were obtained using the fixed diameter drum Method B of the IEC-62221 document and correspond to a 165µm/135µm(0.50MPa)/80µm G.657.A2 trench fiber that we specifically fabricated, to the 155µm/120µm/80µm deep-trench fiber of Ref.[7] (micro-bending sensitivity ~3.3 times higher than that of a legacy 245µm/200µm/125µm G.652.D non-trench fiber and thus ~25 times higher than that of a 245µm/185µm/125µm G.657.A2 trench fiber), and to the 200µm/157µm(0.35MPa)/125µm and 180µm/150µm(0.15MPa)/125µm G.657.A2 trench fibers of the previous section. Theory agrees well with experiment.

The micro-bending sensitivity steeply increases when the cladding diameter decreases but reducing the primary modulus from 0.50 to 0.15MPa has also more impact. As a result, a 165µm/135µm(0.15MPa)/80µm G.657.A2 trench fiber (open circle at 80µm) is expected to have a micro-bending sensitivity ~15 times higher than that of a 245µm/185µm(0.35MPa)/125µm G.657.A2 trench fiber. Keeping a standard 125µm cladding clearly helps but the decrease of the primary thickness finally results in a similar micro-bending sensitivity for a 165µm/~145µm(0.15MPa)/125µm G.657.A2 trench fiber (open circle at 125µm). This level is not so far from that of the 180µm/150µm(0.15MPa)/125µm G.657.A2 trench fiber that has excellent performance in micro-duct cables (Fig.2) and would thus be acceptable. Note that using a primary coating with a lower modulus of ~0.10MPa would bring some improvements, but it would also cause cohesion issues that need specific investigations.

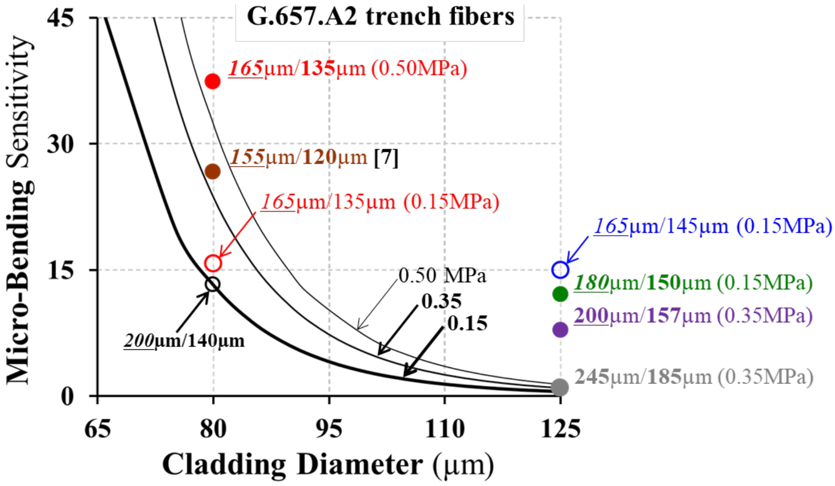

Fig.3: Theoretical (lines and open circles) and experimental (solid circles) micro-bending sensitivities at 1550nm as a function of cladding diameter for G.657.A2 trench fibers with different coatings properties (except for the secondary modulus that is kept constant).

Micro-bending performance is not the only concern. The reduced-size fibers should also adapt well to standard field equipment and installation procedures without special needs for stripping the coatings or splicing, ensure backward compatibility with legacy fibers with standard 125µm cladding, and provide sufficient mechanical protection during cable fabrication, installation and lifetime. A 165µm/~145µm(0.15MPa)/125µm fiber offers significant advantages for splicing (use of conventional instruments with standard recipes) and backward compatibility over a 165µm/135µm(0.15MPa)/80µm fiber. But the smaller coatings thicknesses will have more impacts on the stripping and mechanical properties. Given the good stripping, tensile strength, and fatigue performance of the 180µm/150µm(0.15MPa)/125µm fiber [3], there are some margins to exploit. Increasing the secondary modulus can also help. Further work is needed on these aspects to fully grasp the potential of this fiber.

4. Conclusion

Combining reduced-coated fibers with standard 125µm cladding, benefiting from G.657.A2 trench designs and low primary moduli, with reduced-size loose tubes allows to develop micro-duct cables with record densities. A 576×180µm-coated-fiber micro-duct cable (density of 10.9fiber/mm²) should allow to use 10mm inner diameter ducts where it is currently only possible to install 192×legacy-245µm-coated G.652.D non-trench fibers. This makes it possible to install more fibers into congested duct spaces and enables the use of smaller ducts for new installations, resulting in lower deployment costs and environmental footprints.

Further reducing the coating diameter to 165µm and reach even higher densities with a standard 125µm cladding seems possible in term of micro-bending performance and offers significant advantages for compatibility with legacy fibers and standard field equipment and procedures. But the impacts of the small coatings thicknesses on the stripping, tensile strength, and fatigue performance need to be fully studied before practical use can be made.

5. References

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