Reduced Single-Coating Diameter Fiber

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Abstract: We report the fabrication of a colored 170µm single-coating diameter fiber with standard 125µm cladding diameter. This fiber shows good optical properties, including micro-bending sensitivity, and improved mechanical properties compared to reduced dual-coating diameter fibers. ©2024 The Authors.

1. Introduction

Reducing the legacy 245µm and the well-established 200µm [1] coating diameters of single-mode fibers to 180µm [2] and below [3-5], while keeping a standard 125µm cladding diameter (see Fig.1), is an elegant solution to increase cable densities. It ensures compatibility with legacy fibers and with standard field equipment and procedures, and thus allows meeting the cost and connectivity challenges of high-density-cable applications.

Most of the reduced coating diameter fibers, however, have dual-coating systems that limit their lower diameter to ~165µm, with primary and secondary coatings thicknesses ~10µm. Indeed, further reducing the primary coating thickness would decrease the coating strip force and create delamination issues, while further reducing the secondary coating thickness would impact tensile strength and handling robustness. Another option is to use a single-coating system. Ref.[4] reported fibers with a single "secondary" coating with a Young's modulus of 1751MPa and diameters of 140 and 156µm. Attenuations were equivalent to those of reduced dual-coating diameter fibers but the micro-bend losses that are critical for such fibers, especially without a soft primary coating for protection, and the mechanical properties were not disclosed.

In this paper, we report the fabrication of a colored 170µm single-coating diameter fiber with a standard 125µm cladding diameter (see Fig.1). We study its optical properties, particularly the micro-bend losses, and mechanical performance and show how robust this option is and how it can lead to 150µm single-coating diameter fibers.

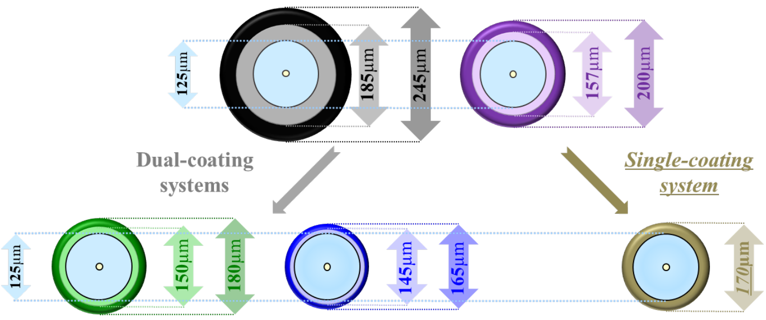

Fig.1. Cross-section scheme of the 170µm single-coating diameter fiber compared to dual-coating diameter fibers (to scale).

2. Optical Properties

Reduced coating diameter fibers have higher micro-bending sensitivities than legacy 245µm coating diameter fibers [3], which can lead to cable-induced losses and ultimately prevent from increasing cable densities. To limit this deleterious effect while at the same time improve mechanical properties (see next Section), we chose to remove the primary coating and to keep a "secondary" coating with a lower Young's modulus (900MPa) than most secondary coatings [4]. We also chose a trench-assisted step-index profile that allows reducing micro-bend losses by a factor of up to 10 compared to non-trench step-index profiles [2]. Table 1 summarizes the optical properties of the 170µm-single-coated fiber in comparison with recently reported 180µm- and 165µm-dual-coated trench fibers [2,5] (taken as References). The fiber is compliant with ITU-T recommendations G.652.D and G.657.A2. It is worth mentioning that all fibers presented here are colored fibers (no need to add a colored layer that increases the diameter by ~5µm).

Micro-bend losses were measured using the fixed diameter drum Method B of the IEC-62221 document. Fig.2 shows the results of the 170µm-single-coated fiber compared to those of our References. The typical flat spectrum of trench fibers is recognizable and confirms the positive effect of the trench (see Fig.2(a)). What is noticeable is that the high Young's modulus of the single coating (900MPa compared to ≤1MPa for the primary coatings of dual-coating systems) has a limited impact. The micro-bend losses are only slightly higher than those of the 165µm-dual-coated fiber, for which the primary thickness of 8µm is close to the lowest acceptable value. This high Young's modulus is nevertheless the main factor explaining the micro-bending sensitivity of the 170µm-single-coated fiber. Reducing its thickness to 12.5µm, leading to 150µm diameter, is not expected to significantly change the results. Note that attenuations were higher than those of our References (due to fabrication imperfections that can be improved [4]) but that no micro-bend induced losses were observed at long wavelengths (≥1625nm).

Table 1: Optical properties of the 170µm-single-coated fiber compared to those of our References.

	λ (nm)	**180**µm Fiber	**165**µm Fiber	*170*µm Fiber	*G.657.A2*
Colored Secondary Coating diameter (µm)	-	**180**	**165**	**170**	-
Colored Secondary Coating thickness (µm)	-	**15**	**12**	**22.5**	-
Colored Secondary Coating Young's Modulus (MPa)	-	900	900	900	-
Primary Coating thickness (µm)	-	**12.5**	**8**	-	-
Primary Coating Young's Modulus (MPa)	-	0.15	0.15	-	-
Cladding diameter (µm)	-	125	125	125	*125±0.7*
Mode Field Diameter (µm)	*1310*	8.8	8.7	**8.6**	*8.6-9.2*
Cable Cutoff Wavelength (nm)	-	1190	1208	**1252**	*≤1260*
Zero-Dispersion Wavelength (nm)	-	1318	1314	**1319**	*1300-1324*
Zero-Dispersion Slope ($ps/nm^2/km$)	-	0.089	0.090	**0.090**	*≤0.092*
PMD$_{(Q)}$ (ps/√km)	*1550*	0.028	0.020	**0.043**	*≤0.20*
Attenuation (dB/km)	*1310*	0.338	0.336	**0.394**	*≤0.40*
	1383	0.306	0.294	**0.373**	*≤0.40*
	1550	0.189	0.191	**0.252**	*≤0.30*
	1625	0.197	0.198	**0.262**	*≤0.40*
Macro-Bend Loss at 15mm bend radius (dB/10turn)	*1550*	0.007	0.002	**0.002**	*≤0.03*
	1625	0.027	0.013	**0.006**	*≤0.1*
Macro-Bend Loss at 10mm bend radius (dB/turn)	*1550*	0.015	0.014	**0.012**	*≤0.1*
	1625	0.036	0.044	**0.034**	*≤0.2*
Macro-Bend Loss at 7.5mm bend radius (dB/turn)	*1550*	0.156	0.115	**0.026**	*≤0.5*
	1625	0.306	0.196	**0.068**	*≤1*
Micro-Bend Loss (IEC-62221, Method B) (dB/km)	*1550*	1.4	4.5	**6.4**	-
	1625	1.5	4.8	**6.7**	-

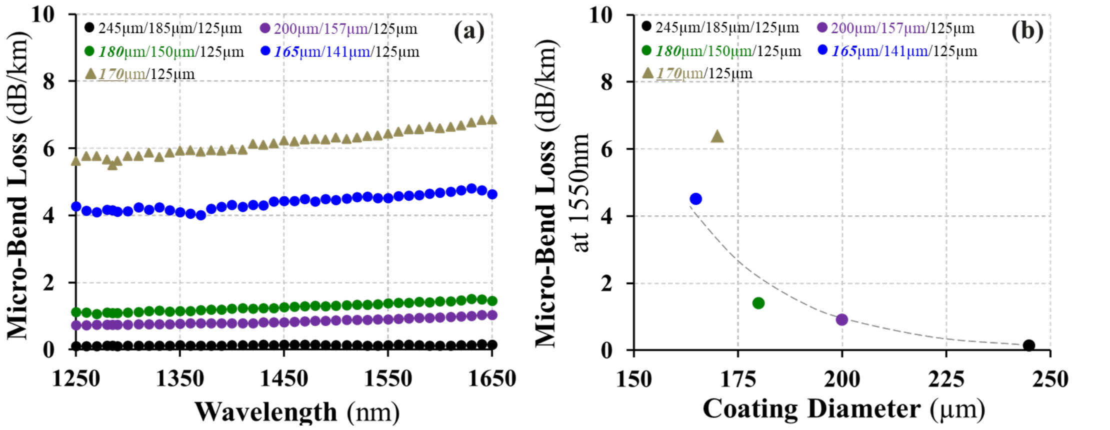

Fig.2. Micro-bend loss spectrum (a) and at 1550nm (b) of the 170µm-single-coated fiber compared to those of our References. Legacy 245µm- and 200µm-dual-coated fibers are also shown for context. The dashed line is a guide for the eye.

3. Mechanical Properties

Micro-bending performance is not the only concern for reduced coating diameter fibers. Thin coatings can also severely impact the mechanical attributes that are required for cable fabrication, installation, and operational lifetime. Fibers must be compliant with the International Standard IEC 60793-2-50 for stress corrosion susceptibility, coating strip force and tensile strength. Table 2 summarizes the mechanical properties of the 170µm-single-coated fiber in comparison with our References. The stress corrosion susceptibility parameter, n_d, was estimated by dynamic fatigue testing. n_d was consistently ≥20, exceeding the ≥18 specification. If this parameter was comparable to those of our References, the coating strip force and tensile strength were significantly improved.

The strip force required to mechanically remove the coating along the longitudinal axis, without issues such as breakage, multiple stripping passes or excessive coating residue, was at 2N compared to 0.7N and 0.5N (close to the ≥0.4N specification) for the 180µm- and 165µm-dual-coated fibers, respectively (see Fig.3(a)). This better adhesion to glass is due to the higher Young's modulus and the higher cohesion of the single coating compared to the primary coatings of dual-coating systems. Note that there was no difficulty in cleanly stripping the 170µm-single-coated fiber using a thermo-mechanical method.

The tensile strength is a measure of the fiber ability to withstand dynamic and static stress applied longitudinally during processing, installation, and use. For the test, 30 samples were stretched till breakage. The maximum forces needed were measured and plotted in a Weibull graph to determine the strength at 50% probability of breakage. Fig.3(b) shows the result of the 170µm-single-coated fiber compared to that of the 180µm-dual-coated fiber. We could not obtain reliable results for the 165µm-dual-coated fiber because the equipment was not adapted to such a thin dual-coating system. But this fiber is still expected to pass the test with results close to the ≥550kpsi specification. The 170µm-single-coated fiber had a higher strength at 50% probability of breakage (≥710kpsi) than the 180µm-dual-coated fiber (≥650kpsi). This improvement is again due to the absence of soft primary coating and to the high Young's modulus of the single coating that is directly applied to glass.

These results show that there are sufficient margins for this single-coating system to meet the industry mechanical requirements with a diameter of 150µm, when reduced dual-coating diameter fibers reach their limits.

Table 2. Mechanical properties of the 170µm-single-coated fiber compared to those of our References.

	180µm Fiber	**165**µm Fiber	***170***µm Fiber	*IEC 60793-2-50*
Stress corrosion susceptibility parameter, n_d	≥20	≥19	**≥20**	*≥18*
Coating strip Force (N)	0.7	0.5	**2**	*≥0.4*
Tensile strength at 50% probability of breakage (kpsi)	≥650	-	**≥710**	*≥550*

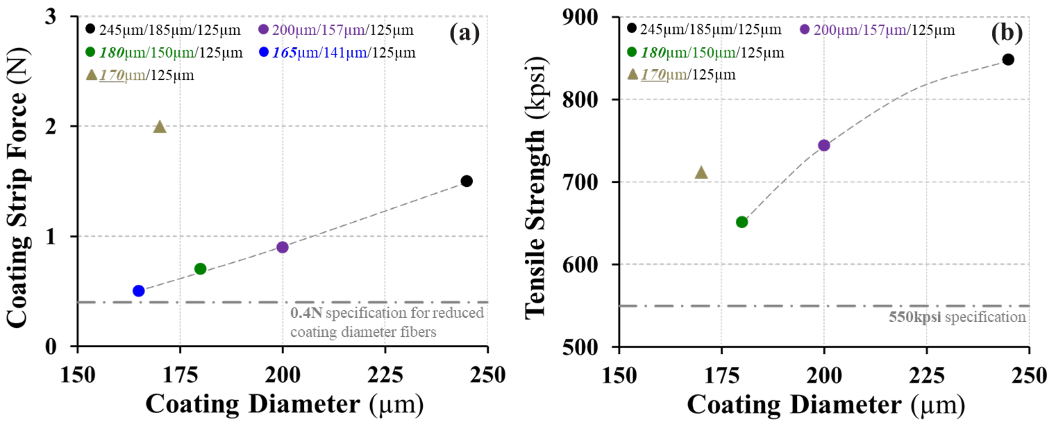

Fig.3. Coating strip force (a) and tensile strength at 50% probability of breakage (b) of the 170µm-single-coated fiber compared to those of our References. Legacy 245µm- and 200µm-dual-coated fibers are also shown for context. Dashed lines are guides for the eye.

We also proof-tested few 100s of km of the 170µm-single-coated fiber at 100kpsi. Proof-testing ensures that there are zero flaws with inert strength below a certain limit (100kpsi for terrestrial applications). This allows fibers to be handled and cabled without significant breaks. The break rate was ≤5breaks/100km, which is comparable to ≤4breaks/100km for the 180µm-dual-coated fiber and much better than ≤10breaks/100km for the 165µm-dual-coated fiber [5] (legacy 245µm- and 200µm-dual-coated fibers are ≤2breaks/100km). More volumes are however needed to confirm this good result. Finally, such a single-coated fiber shows better handling characteristics than reduced dual-coated fibers thanks to its tough and resilient single coating [1].

4. Conclusion

A new G.657.A2 trench fiber with a colored single coating of 170µm diameter and Young's modulus of 900MPa and a standard 125µm cladding diameter was fabricated. The micro-bend-losses were only slightly higher than those of a 165µm-dual-coated fiber, and the coating strip force and tensile strength were significantly improved. These results show that this single-coating system can provide good optical properties while overcoming the limitations of dual-coating systems caused by degraded mechanical properties when reducing the coating diameters.

Such G.657.A2 trench fibers with single-coating diameters ≤170µm and Young's moduli ≤~900MPa and a standard 125µm cladding diameter appear as good candidates to increase cable densities.

5. References

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