Next generation bend-insensitive SMF for FttH networks

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Abstract *A new trench-assisted generation of single-mode fiber offers strongly reduced bending sensitivity. We report the lowest bending loss for a fiber still compliant with G.652 ITU-T standard and with losses below 0.2dB/km over C+L wavelength bands.*

Introduction

Increasing demand for Fiber to the Home (FttH) has induced interest for a fiber showing reduced bending sensitivity [1-4]. Two main drivers are supporting such interest. At first, splicing boxes containing fiber over-length need to be miniaturized without inducing any loss degradation. Fiber with negligible bending losses, i.e. typically lower than 0.1dB in a box, for bending radius as low as 15 mm would be of great help in that miniaturization objective. At second, FttH installation is less secured than for longer distance networks. This is due to the simultaneous need for lower installation costs together with a harsher environment. A way to solve this installation issue would be a fiber with negligible loss increase when submitted to incidental bends, with bending radius as low as 7.5 or 5 mm. Good resistance to microbendings would be an additional asset for the fiber.

One solution consists in step index fiber with reduced Mode Field Diameter (MFD) compared to Standard Single Mode Fiber (SSMF) [1,5]. This is done at the expense of high losses when spliced with SSMF. Another solution consists in designing step index fibers assisted by surrounding holes in the clad [2, 4]. Such solution seems very attractive but is not sufficiently mature to allow fiber loss levels equivalent to that of SSMF. A third attractive solution consists in a solid structure with a step core index assisted by a trench layer in the clad. Previous solutions [4] did not meet with the stringent G.652 ITU-T standard [5].

In this paper, we demonstrate the feasibility of a trench-assisted G.652 compliant fiber presenting unequaled low bending and micro-bending losses level up to the 1625 nm wavelength.

Design of a low bending loss G.652 fiber

The ITU-T G.652 standard imposes, at the 1310 nm wavelength, a MFD nominal value between 8.6 to 9.5 µm with a manufacturing tolerance of +/-0.6 µm. It is important to respect such tolerance to limit the splicing losses between fibers coming from the same manufacturing product. Moreover, it is also important to limit the splicing losses between different types of SSMF, yielding even more severe MFD constraints than what is standardized.

Compatibility with legacy systems operating at 1310 nm is the other G.652 main driver. In that aim, single-mode behavior when operating in the original wavelength band (O-band), ranging from 1260 to 1360 nm, is mandatory; cable cutoff smaller than 1260 nm is thus requested. Moreover λ_0, ranging from 1300 to 1324 nm and chromatic dispersion slope at this wavelength lower than 0.092 ps/nm²-km is specified.

G.652 specified MFD constraints and single-mode behavior in the O-band are still of major importance for FttH purpose. Its dispersion-related request seems intuitively less relevant for such application. However, targeting a longer zero dispersion wavelength may increase the Rayleigh scattering level due to the need of a higher core index, thus increasing the fiber losses and a smaller zero dispersion wavelength may deteriorate the transmission in the L-band due to a chromatic dispersion increase. Here it must be taken into account also that the G.652 recommendation is the most common standard for single-mode fibers, and bending insensitivity is an interesting advantage, which should not be restricted to the FttH only area. These factors justify the interest for a bending insensitive fiber fully compatible with G.652 standard.

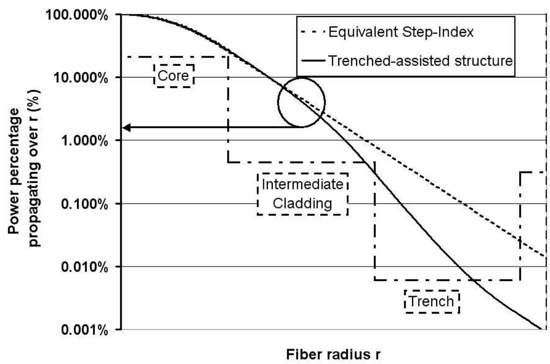

Figure 1: Trench-assisted step index structure (dash-dotted line) and modeled fundamental mode power percentage propagating over the radius r for this profile (full line) and for an equivalent step index profile (dotted line).

Trench-assisted step index profile shape is represented in Figure 1 (dash-dotted line). An intermediate cladding layer is positioned between the core and the trench. Modeled fundamental mode power percentage propagating over the radius r (full line) is compared with an equivalent step index (no trench) having the same cutoff and MFD (dotted line). We can see that the trench confines the fundamental mode in the core in modifying the tail of the mode but without strongly affecting its general shape. It is thus well adapted for an efficient bending loss reduction without having to change the MFD. However, the trench needs to start sufficiently far from the core to prevent any significant impact on the fundamental mode properties (MFD, chromatic dispersion). Moreover, the trench should end sufficiently close to the core to limit its increasing impact on the manufacturing cost.

Fiber Realizations

A series of 1000 km of fibers have been developed and characterized. Excellent losses are obtained: average level @1550nm is 0.187 dB/km (see Figure 2) thus insuring losses lower than 0.200 dB/km all over C+L wavelength bands (ranging from 1530 to 1625 nm).

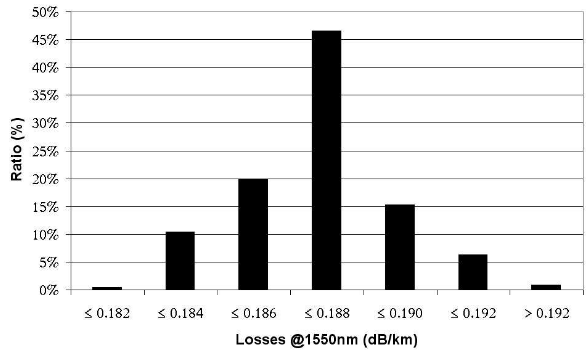

Figure 2: Histogram of losses @1550 nm for a 1000 km fiber manufactured population.

Bending losses have been characterized at 1625nm for a set of different bending radius ranging from 4 to 20 mm. Figure 3 represents the results for typical developed sample and is compared with typical, equal MFD value, SSMF: bending losses of developed samples are lower than typical SSMF for each tested bending radius; moreover they show an improvement of one order of magnitude for bending radius lower or equal to 10 mm with remarkable value lower than 1 dB/turn down to 4 mm radius. At last, micro-bending characterizations with grid test (double pass through a grid consisting of 10 x 1.5 mm pins) show a reduction of one order of magnitude compared to typical SSMF.

Table 1 presents characteristics of one typical sample. These results show that it is fully compatible with the G652.D attributes (which are the best G652 class).

At last, splicing tests show results below 0.05 dB on average when splicing two trenched-assisted fibers or when splicing a trenched-assisted fiber with a SSMF.

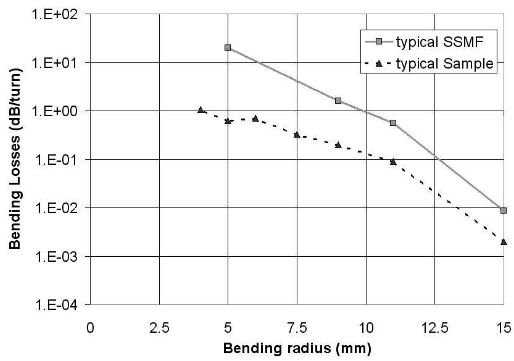

Figure 3: bending losses dependence with bending radius of one typical developed sample (dotted line) and of one typical SSMF with the same MFD.

Table 1: Propagation characteristics of a typical sample.

Bending Losses @1625nm (dB/turn)	R=5mm	6.3×10^{-1}
	R=7.5mm	3.3×10^{-1}
	R=10mm	1.3×10^{-1}
	R=15mm	2.0×10^{-3}
Mode Field Diameter (µm)	@1310nm	9.1
	@1550nm	10.3
λ_c (nm)		1316
λ_{cc} (nm)		<1260

Losses (dB/km)	@1550nm	0.187
Splicing Losses (dB)	@ 1310 & @1550 nm	<0.05
λ_0 (nm)		1316
Slope @λ_0 (ps/nm²-km)		0.090
Dispersion (ps/nm-km)	@1550nm	17.3
	@1625nm	21.9
PMD (ps/km$^{1/2}$)		0.04

Conclusions

We have demonstrated the feasibility of a fiber combining low bending loss behavior for a large set of bending radii, low micro-bending losses and full compatibility with ITU-T G.652.D standard attributes.

References

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[4] K. Himeno et al., JLT, Vol. 23 (2005), p. 3494
[5] ITU-T Recommendation G.652