Macro Bend-Loss Enhanced Specialty Fibers with Wideband Operating Wavelengths for Fiber Optic Devices and Modules

Application Note

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Introduction and background:

Specialty fibers are keystone components for fiber optic devices and modules used in telecommunication networks, fiber lasers and fiber optic sensors. They are deployed in multiple passive and active devices and modules that are all-fiber technology and/or hybrid (micro-optics and fibers). In telecommunications, the general trends are high speed — moving from 10G to 40 G & 100G systems—, small size, highly integrated and energy efficient fiber optic devices and modules. At a tight bend diameter of 20 mm or 10 mm, the induced macro-bend loss in non-bend optimized fibers is significantly higher than the loss from a fusion splice.

Corning specialty fibers are manufactured by the patented OVD (Outside Vapor Deposition) process, the same method used to produce Corning transmission fibers for long haul, metro, access, FTTH/P networks. The OVD process has been demonstrated and proven as the best manufacturing method to produce optical fibers with high quality, consistency and reliability.

This paper addresses macro-bend enhanced specialty fibers that are designed and optimized for wideband – of more than 600 nm – and with operating wavelength ranging from 980 nm throughout S, C to L – band. We highlight the key attributes and advantages of Corning specialty fiber HI 1060 FLEX compared to other commercialized fibers from various suppliers. Also, we present measurements results of induced macro-bend loss in a limited number of samples of Corning HI 1060 FLEX fiber and others commercialized by different suppliers per turn for 30 mm, 20 mm and 10 mm bend diameter. We demonstrate and compare the induced loss in a typical EDFA module using HI 1060 FLEX pigtailed fibers bent at a diameter of 20 mm versus other commercialized fibers.

Discussions and results:

Specialty fibers with a low cutoff wavelength are required in active and passive fiber optic devices such as: WDM combiner coupler, splitter and 980 nm laser pumps for EDFAs, 14xx nm pumps, and signal and pump combiners for Raman amplifiers etc. The fiber design is the key to achieving low macro-bend loss in fibers with standard step index profile. The bend loss is minimized when the fundamental mode – LP_{01} – is tightly confined within the core of the fiber. The tight confinement of the fundamental mode can be achieved by high Δ (normalized refractive index difference) and high V (normalized frequency parameter) while attaining single-mode operation with a safety margin. The induced macro-bend loss in fibers is higher for long wavelengths and small bend radii.

Corning HI 1060 FLEX is a patented fiber. The advantage of Corning HI 1060 FLEX fiber is its simple waveguide design with a standard step index profile which makes it compatible, easy to use with standard fibers and pigtailed components.

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By design, the attributes of HI 1060 FLEX fiber enable low induced bend-loss compared to other fibers supplied by different vendors. Table 1 lists a few key attributes of Corning HI 1060 FLEX fiber versus other suppliers' fiber. Compared to other fibers, HI 1060 FLEX fiber has a lower cutoff wavelength, 53% higher Δ compared to fiber A from supplier x and 25% higher NA compared to both fiber A & B. A fiber with high NA can additionally contribute to improved performance by increasing the coupling efficiency from laser sources to fiber and from fiber to planar waveguides. Also, the MFD of HI 1060 FLEX fiber at the operating wavelength of 980 nm and 1550 nm is smaller than fiber A & B. The MFD of HI 1060 FLEX fiber is smaller than standard transmission fibers – such as SMF-28e® – and could induce splice loss due to MFD mismatch. But, with an optimized splicing process; the splice loss between HI 1060 fiber and standard transmission fibers can be minimized. A typical splice loss of about 0.07 dB between HI 1060 FLEX and SMF-28e® can be achieved easily. The typical splice loss of HI 1060 FLEX to erbium doped fibers is as low as 0.03 dB. Corning HI 1060 FLEX fibers have been successfully designed and used in high grade and all-fiber couplers such as: WDM signal / 980 nm pump combiner, tap couplers, power divider / splitter. In the experimental section, we will further discuss and compare the induced loss due to fusion splice versus bend.

Corning HI 1060 FLEX	Fiber A from supplier *x*	Fiber B from supplier *y*
$\lambda c = (930 \pm 40)$ nm	$\lambda \leq 960$ nm	$\lambda c = 930$ nm*
$\Delta = 1\%$ (typical)	$\Delta = 0.65\%$	–
NA = 0.2	NA =0.16	NA = 0.16
MFD @ 980 nm = (4 ± 0.3) µm @ 1550 nm = (6.3 ± 0.3) µm	MFD @ 980 nm = (5 ± 0.3) µm @ 1550 nm = (7.5 ± 0.75) µm	MFD @ 980 nm = (4.9 ± 0.3) µm @ 1550 nm = (7.7 ± 0.3) µm

Table 1 Key attributes for Corning HI 1060 FLEX bend insensitive fiber and other fibers

* Secondary cutoff wavelength

Experimental results:

Samples of Corning HI 1060 FLEX fiber and fiber A from another supplier have been evaluated and measured under the same setup and test conditions. The measurement setup includes a tunable laser source covering the wavelength range of 800 nm to 1700 nm, fibers under test, various mandrels with a diameter of 10 mm, 20 mm and 30 mm diameter, and an optical power meter. The measurement results are presented in Figure 1, 2 and 3.

Figure 1 illustrates the induced macro-bend loss/turn versus wavelength when tested fibers are subjected to a bend diameter of 30 mm. At a bend diameter of 30 mm, HI 1060 FLEX has very low induced bend over the pump and signal wavelength throughout the C to L band; however, bend loss of fiber A starts increasing in the L – band and at 1625 nm it is 0.14 dB/turn higher than FLEX fiber. At a bend diameter of 20 mm, the induced bend loss of fiber A begins to increase in the C – Band and at 1550 nm it is about 0.19 dB/turn higher than HI 1060 FLEX fiber (Figure 2). At a bend diameter of 10 mm, the induced bend loss of fiber A commences to become significant in the E – band and at 1460 nm it is 1.28 dB / turn higher than HI 1060 FLEX (Figure 3).

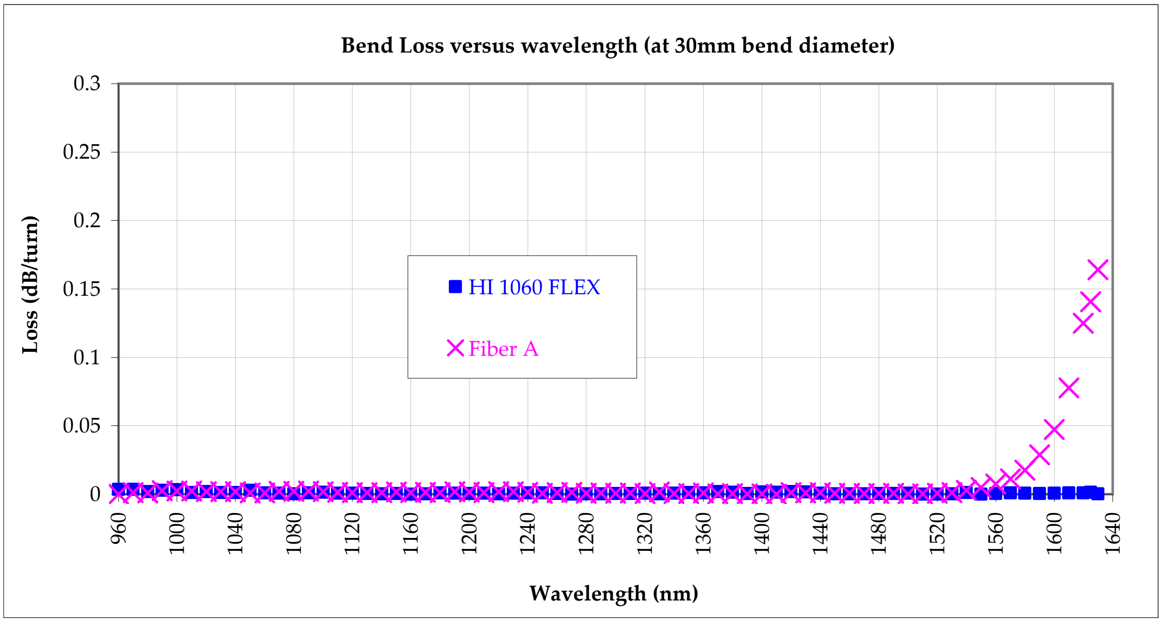

Figure 1 Induced macro-bend loss / turn versus wavelength for HI 1060 FLEX and fiber A from another supplier under 30 mm bend diameter

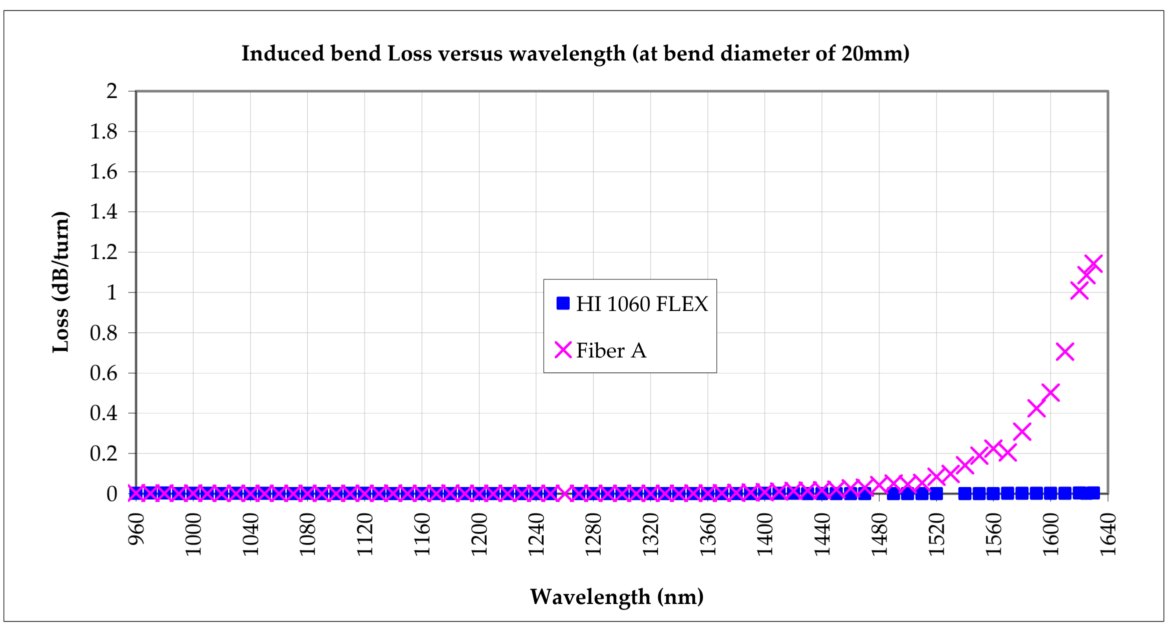

Figure 2 Induced macro-bend loss / turn versus wavelength for HI 1060 FLEX and fiber A from another supplier under 20 mm bend diameter

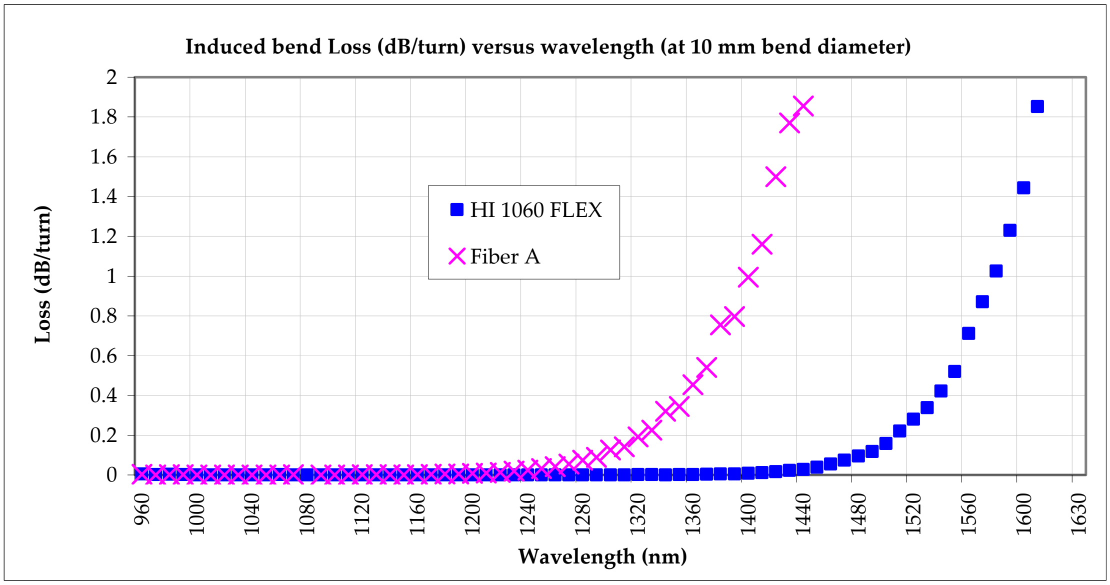

Figure 3 Induced macro-bend loss / turn versus wavelength for HI 1060 FLEX and fiber A from under 10 mm bend diameter

Compared to other fibers and at bend diameter of 20 mm and 10 mm, Corning HI 1060 FLEX exhibits lower bend loss of at least 2 dB/turn. At 1550 nm operating wavelength and 20 mm bend diameter, fiber A has about 0.19 dB/turn higher induced bend loss than HI 1060 FLEX and about 2.5 dB/turn higher at 10 mm bend diameter (Figure 4). The loss for 10mm bend diameter is saturated for fiber A data and should be worse. The saturation of data is due to the measurement setup bench.

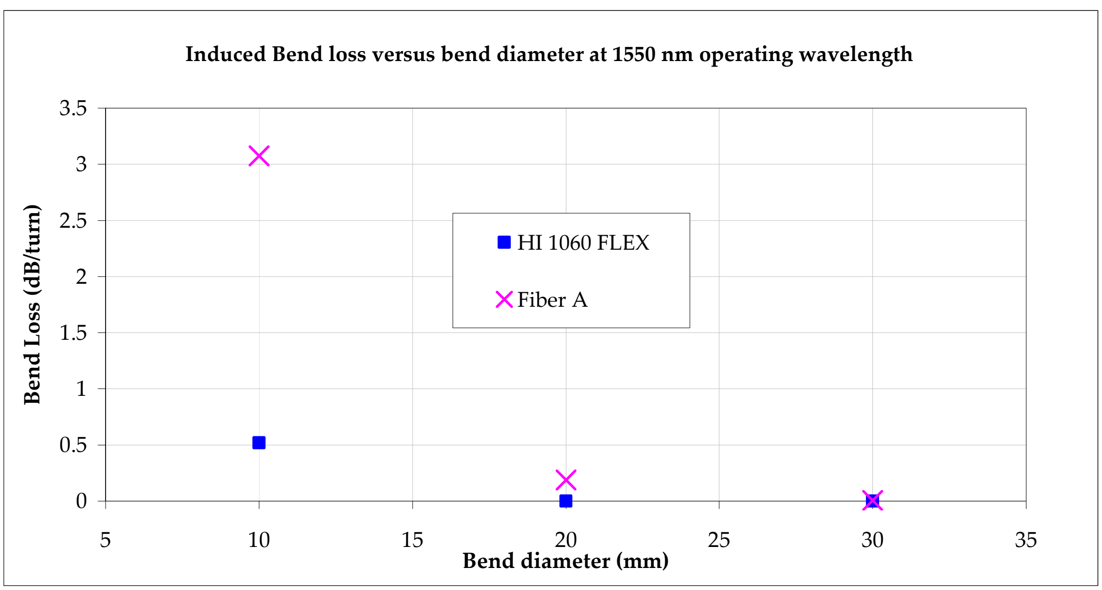

Figure 4 Induced macro-bend loss / turn in HI 1060 FLEX and fiber A from another supplier at operating wavelength of 1550 nm versus bend diameter

During the past few decades, makers of photonics and fiber optic devices and modules have been focusing to optimize and reduce the loss from fusion splices. Now, the general trends and technology roadmap in telecommunications are directed toward increasing bandwidth, achieve higher speed (40 and 100 Gbps per each wavelength) and optical devices and modules are becoming miniaturized, highly integrated and energy efficient. Bend insensitive specialty fibers are the key to attain small size, highly integrated and energy efficient optical devices and modules. In small size devices and modules, the induced bend loss is significant higher (few orders of magnitude) compared to splice loss when bend non – tolerant fibers are deployed. Although there is no standard or ITU recommendations for minimum bend diameter of specialty fibers used in photonics and fiber optics devices and modules, the minimum bend diameter is moving from 30 mm to 20 mm and 10 mm.

Bend-tolerant HI 1060 FLEX fibers can enable small form factor and reduced size devices and modules with no effect on their long-term reliability [2, 3]. HI 1060 FLEX fiber products are proof tested under stress tension of 100 kpsi or 200 kpsi [4].

In a typical and simple design of an EDFA module (Figure 5) there are at least 6 pigtailed specialty fibers in the pump path and each has approximately 2 turns. At 20 mm bend diameter, the overall induced bend loss at 1550 nm in an EDFA module which uses components having HI 1060 FLEX pigtail fibers is 0.002 dB compared to about 2.28 dB with fiber A (Table 2). Also, the total loss, including splice losses, in an EDFA module is 0.722 dB when HI 1060 FLEX is utilized versus 2.604 dB for fiber A.

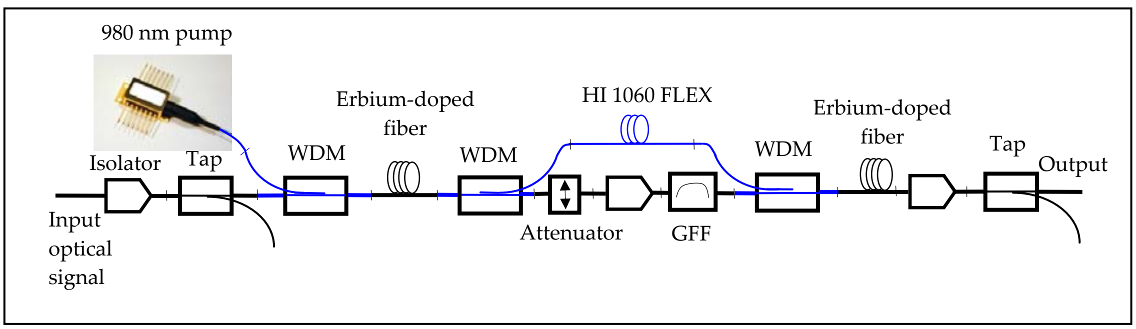

Figure 5 Schematic design of a typical EDFA module

Loss Type/Origin	Count	HI 1060 FLEX		Fiber A	
Macro Bend Loss	12 turns	0.0002 dB /turn	0.0024 dB/turn (sub-total)	0.19 dB/turn	2.28 dB (sub-total)
Splice Loss	6 splices	0.07 dB/splice	0.42 dB (sub-total)	0.04 dB/splice	0.024 dB (sub-total)
Device Loss	3 devices	0.1 dB/device	0.3 dB (sub-total)	0.1 dB/device	0.3 dB (sub-total)
Total Loss			0.722 dB		2.604 dB

Table 2 Details of typical loss at 1550 nm operating wavelength in the pump path of an EDFA module having HI 1060 FLEX fiber and other (fiber A) which are coiled at 20 mm bend diameter

Conclusions:

The use of Corning HI 1060 FLEX fiber lowers the induced bend loss, improves product consistency; increases manufacturing yields and eases the manufacturing and in particular the routing and management of fibers inside active and passive fiber optic devices and modules. At a bend diameter of 20 mm and in a typical EDFA module, Corning HI 1060 FLEX fiber presents an estimate of >2 dB overall lower induced bend loss compared to other fibers. In designs incorporating tighter bend diameters (≤ 20 mm), bend loss becomes the major loss component and design consideration versus losses due to splicing. A tighter bend diameter does not affect the long-term reliability of photonics and fiber optics devices and modules which use Corning HI 1060 FLEX fiber. Also, HI 1060 FLEX fibers enable lower costs, reduced assembly time, lower energy consumption and high integration of devices and modules and in particular those for 40 G and 100 G systems. With low macro-bend loss, HI 1060 FLEX fibers improve the OSNR (Optical Signal to Noise Ratio) for telecom gears and hardware of 100 G systems which have greater sensitivity to physical effects such as OSNR.

Acknowledgment:

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References:

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