

# SM – Series Singlemode Fibers

## Whatever your application – we have the fiber!

### Three application-specific product ranges:

- **Visible and NIR** singlemode transmission 476 – 1100+ nm – for biotechnology, medical and laser delivery
- **Telecommunications** – fibers for high reliability, small form-factor components and EDFA pigtailed
- **Sensors** – low-profile and ultra-low profile, bend-insensitive fibers for de-polarized FOGs, acoustic sensors and small form-factor components.

Whilst it could be argued that the application of any Fibercore Specialty Fiber is only limited by the imagination and technical resources of the user, the SM-series singlemode fibers fall into three main product ranges, each engineered to give you significant performance benefits in a specific application area: Visible and near infra-red singlemode transmission, telecommunications and sensors.

### Visible and Near Infra-Red:

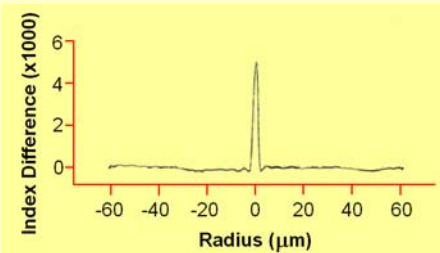
SM450, SM600, SM750, SM800(5.6/125) and SM980(5.8/125) are all 125 µm diameter fibers with singlemode transmission characteristics well-matched to those of commonly-used optical sources found in both laboratories and instrumentation:

Fiber Type	Matching Laser Source
<b>SM450</b>	Argon – ion (Ar+) at 476 – 514 nm, frequency doubled YAG at 532 nm
<b>SM600</b>	HeNe at 633 nm, diode lasers around 680 nm
<b>SM750</b>	Diode lasers around 780 – 850 nm
<b>SM800(5.6/125)</b>	Diode lasers 810 nm – 850 nm +
<b>SM980(5.8/125)</b>	Diode lasers at 980 nm, YLF and YAG around 1047 – 1064 nm, ytterbium (Yb) fiber lasers around 1100 nm

All Fibercore Limited visible and near infra-red singlemode fibers have typical numerical apertures in the range 0.11 – 0.13, providing resistance to bend induced loss similar to that of conventional, telecommunications-type fibers.

### Component Fibers for Non-Telecoms Wavelengths

- Excellent geometric precision (<0.3 µm typical) minimizes connector insertion loss
- Matched-clad design enables the fabrication of low-loss, fused-taper components

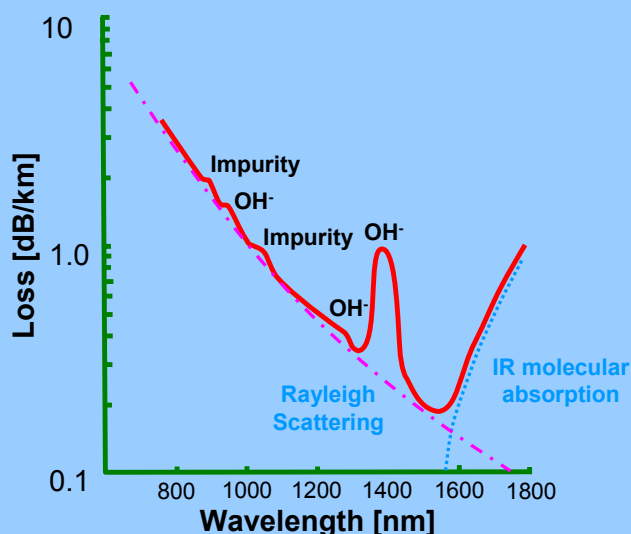


- Singlemode transmission at all common Visible and NIR source wavelengths
- 125 µm glass diameter enables the use of standard ferrules, v-grooves and connectors
- Typical 0.11 – 0.13 NA gives good resistance to bend induced loss without creating an unmanageably small mode.

### Attenuation at Visible and NIR Wavelengths:

For anyone familiar with the 0.25 dB/km or even lower attenuation values of telecommunications-type singlemode fibers, attenuations of 5dB/km or even 50 dB/km may come as a bit of a shock! The reason for these high values, encountered in the visible and near infra-red, is that the spectrum is actually a summation of four components: wavelength-independent scattering, absorption caused by vibration of the silica lattice in the IR, Rayleigh scattering and absorption caused by electronic transitions in the UV (the 'Urbach Edge').

Wavelength independent scattering is caused by macroscopic inclusions and/or defects (bubbles, cracks or geometric irregularities) within the core and waveguide structure and should not be significant in Fibercore SM fibers or, for that matter, any state-of-the-art optical fiber. The fundamental frequencies of vibrational absorptions are far into the IR and their overtones barely extend into the visible therefore also have minimal influence. In the visible and very near IT wavelengths for which the SM450 – SM980 range has been designed it is Rayleigh scattering and the Urbach Edge that are most significant. Rayleigh scattering varies as wavelength<sup>-4</sup> and the Urbach Edge is approximately exponential in shape (in fact, we typically only see the long-wavelength edge of a very intense absorption band centered in the UV) and both therefore have a disproportionately strong effect at shorter wavelengths.



For further information, see 'Key Fiber Parameters factnote: Attenuation

### Power Handling:

Care should be taken when using singlemode fibers in the near-UV through to green wavelengths to avoid inducing high and irreversible increases in attenuation. The very small cores necessary to sustain a single mode at short wavelengths generate exceptionally high power densities, even one Milliwatt of 488 nm light, launched into a typical SM450 fiber, will create a power density of greater than 100 Watts / mm<sup>2</sup>. The effects of this high power density, combined with those of the short wavelength actually knock electrons out of the structure of the germano-silicate core material, creating defects that intensify the UV absorption edge. The result is that fiber attenuation may increase significantly and, in most, circumstances, irreversibly. The magnitude of this induced attenuation varies inversely with wavelength and directly with both fiber length and time. It should also be considered that, whilst the transmission of light at a longer wavelength may appear unaffected, it may still be causing damage and lead to difficulties if the same fiber were then required to transmit at a shorter wavelength. For example, a fiber used to transmit 100 mW at 514 nm may show little or no degradation but, if then used to transmit even a few Milliwatts at 488 nm, the fiber attenuation may have increased several fold.

It is difficult to predict exactly what will happen in each case, but as a 'Rule of Thumb', if you need to keep the fiber illuminated for hours or days, a few tens of Milliwatts over a few tens of metres are probably alright at 532 nm, but at 488 nm transmission should be restricted to a few Milliwatts over a few metres.

Whilst these effects are most often encountered when working with the near-UV through to green, they can also occur in the red, or even longer wavelengths, however the power levels required to do so (eg many watts of krypton, transmitted for several hours) are only found in specialized laboratories.

## Telecommunications:

When standard telecommunications singlemode just isn't right for your application

Fibercore Limited's 'Telecommunications' SM fibers are purpose designed for applications in components where transmission wavelength, package form-factor and/or bend radius are critical.

Fiber Type	What it is / where to use it
<b>SM980(5.8/125)</b>	Standard EDFA 980 nm pigtailed fiber – provides low-loss fusion splicing and excellent compatibility with all Industry-Standard EDFs and component fibers
<b>SM980(4.5/125)</b>	High NA EDFA 980 nm pigtailed fiber – provides improved resistance to bend-induced attenuation and reduced splice loss to Industry Standard EDFs
<b>SM1500(4.2/125)</b>	Ultra high NA (0.30) provides exceptional resistance to bend-induced attenuation and reduced nonlinear threshold. High germania content of core enhances intrinsic photosensitivity enabling the fabrication of fiber Bragg gratings without hydrogenation
<b>SM1250(9/80)</b>	A dual-wavelength telecommunications fiber with a reduced (80 $\mu\text{m}$ ) OD for use in small form-factor components
<b>SM980(4.5/80)</b>	High NA EDFA 980 nm pigtailed fiber with reduced (80 $\mu\text{m}$ ) OD for use in small form-factor components

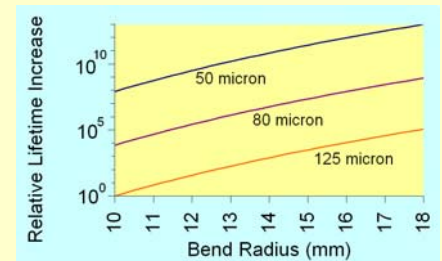
## Sensors and Tethered / Payout Applications:

Fibercore Limited offers a broad range of bend-insensitive singlemode fibers, purpose designed for applications in fiber sensors including the highly challenging environments found in FOG and acoustic sensors/hydrophones.

All fibers benefit from Fibercore Limited's 'matched-clad' refractive index profile, enabling the fabrication of low-loss fused, tapered components, eg 2x2 or 3x3 splitters and taps. The wide range of standard NAs available at 1550 nm (0.20 – 0.24 – 0.30) also enables users to select the best balance of bend-induced loss and connections loss (demountable connector or fusion splice) for their application whilst standard proof-test levels of up to 35 strain/300 kpsi enable lifetimes of up to 30 years to be predicted, even in miniature 10 mm OD sensor coils. The recent addition of a single, 50  $\mu\text{m}$  variant

### Fibers for EDFA Pigtailed, Small Form-Fabrication Components and FBGs

- 80 micron fiber diameter provides 25+ year lifetimes in small form-factor packages
- NAs up to 0.30 enable bend-diameters of 10 mm or less without loss of guidance
- EDFA pigtailed fibers compatible with all industry-standard EDFs and component fibers
- High Germania cores enhance intrinsic photosensitivity, facilitating fiber Bragg grating formation



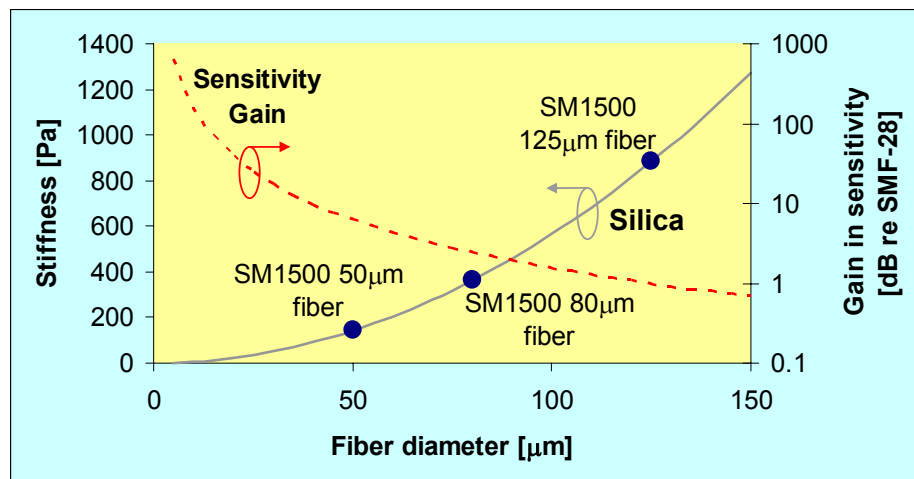
### High Strength Low and Ultra-Low Profile Fibers

- Standard 80  $\mu\text{m}$  fiber OD for enhanced lifetime/reliability and reduced volume in typical coiled applications
- 50  $\mu\text{m}$  fiber OD for enhanced lifetime/reliability and reduced volume in miniature coiled applications and enhanced device sensitivity
- Proof-tests to 300 kpsi/3% strain for ultra-high reliability
- Compatible with specific Fibercore Limited HB-G products for use in fiber optic gyro (FOG) components
- High strength and bend-insensitivity – ideal for tethered-vehicle/payout applications

takes reliability and packing-factor to the next level, whilst measurably improving the sensitivity of devices by reducing the tendency for the fiber to restrict or ‘bind’ the sensor mandrel.

Fiber Type	What it is / where to use it
<b>SM800(4.2/80)</b>	80 $\mu\text{m}$ bend-insensitive product designed to match Fibercore HB800G PM fiber – used extensively in 810 nm – 850 nm fused-taper splitters for the FOG Industry
<b>SM1250(5.4/80)</b>	80 $\mu\text{m}$ bend-insensitive, dual wavelength (1310 nm / 550 nm) fiber – used extensively in fused-taper splitters for the FOG Industry
<b>SM1500(4.2/80)</b>	80 $\mu\text{m}$ , ultra bend-insensitive and intrinsically photosensitive 1550 nm fiber used in acoustic sensor coils and quasi-distributed FBG based sensor arrays
<b>SM1500(5.3/80)</b>	As SM1500(4.2/80) but providing slightly less bend-insensitivity in return for reduced connector and/or fusion-splice loss
<b>SM1500(6.4/80)</b>	80 $\mu\text{m}$ bend-insensitive product designed to match Fibercore HB1500G-HI PM fiber – used extensively in 1550 nm fused-taper splitters for the FOG Industry
<b>SM1500(4.2/50)</b>	50 $\mu\text{m}$ , ultra low-profile fiber providing enhanced lifetime and sensitivity in small diameter hydrophone coils

### Low and Ultra-Low Profile Fibers Enhance Device Sensitivity



### The benefits of reduced diameter, low and ultra-low profile fibers:

If a fiber is to be used in a small diameter sensor coil, an 80  $\mu\text{m}$  glass diameter will offer a significant increase in lifetime because of its enhanced resistance to mechanical failure through static fatigue. Ultra low-profile 50  $\mu\text{m}$  fiber will last even longer.

Static fatigue is a phenomenon by which optical fibers can fracture spontaneously if subjected to bending stress or an invariant tensile load. The stress induces intrinsic and microscopic flaws located on the fiber surface to grow, causing fracture as soon as any flaw grows beyond the critical limit for the material. Fibers are made more resistant to static fatigue by increasing proof test level and /or reducing glass diameter.

Proof test involves straining the fiber to destruction to screen-out intrinsic flaws – the higher the proof test level, the smaller the size of intrinsic flaw that will remain in the surviving fiber and the lower the probability that the fiber will fail under static fatigue. The Telecommunications Industry standard for proof-test is 1% strain. Deploy such a fiber in a 10 mm diameter hydrophone coil and it could fracture within hours.

A more direct way to enhance lifetime is to limit bending stress levels by reducing the outside diameter of the fiber itself. When bent, an 80  $\mu\text{m}$  fiber is under c 40% less stress than a standard 125  $\mu\text{m}$ . The corresponding figure for a 50  $\mu\text{m}$  fiber is around 60% less. Lower stress levels within the fiber slow the growth of intrinsic flaws and boosting lifetimes from mere months to 20 years or more.

Low and ultra-low profile fibers also enhance sensitivity in any strain-based sensor, for the simple reason that they are easier to stretch, with a 50  $\mu\text{m}$  fiber proving around a 5 dB improvement over its 125  $\mu\text{m}$  counterpart.



# Specifications

## 125 μm diameter SM Specialty fiber

	SM450 <sup>a</sup>	SM600	SM750	SM800 (5.6/125)	SM980 (5.8/125)	SM980 (4.5/125)	SM1500 (4.2/125)
Design Wavelength, $\lambda_{op}$ (nm)	488 514	633 680	780	830	980 1064 1550	980 1550	1550
Cut-off Wavelength (nm)	350 - 450	500- 600	610- 750	660- 800	870- 970	870 - 970	1350- 1500
Numerical Aperture	0.10 - 0.14				0.13- 0.15	0.17 - 0.19	0.29 - 0.31
MFD (μm) @ $\lambda_{op}$ (nm) nominal	3.3 @ 488 3.4 @ 514	4.3 @ 633 4.6 @ 680	5.3	5.6	5.8 @ 980 6.2 @ 1064 10.4 @ 1550	4.5 @ 980 7.5 @ 1550	4.2
Attenuation (dB/km) @ $\lambda_{op}$	≤ 50	≤ 15	≤ 5		≤ 3		
Proof Test (%)	1						
Fiber Diameter (μm)	125 ± 1						
Core Cladding Concentricity (μm)	≤ 1.0			≤ 0.75			
Coating Diameter (μm)	245 ± 5%						
Coating Type	Dual Acrylate						

Notes: <sup>a</sup> Color centre generation can affect power handling capability at short wavelengths, more details on request

# Specifications

## Reduced diameter SM Specialty fiber

	SM800 (4.2/80)	SM980 (4.5/80)	SM1250 (9/80)	SM1250 (5.4/80)	SM1500 (5.3/80)	SM1500 (6.4/80)	SM1500 (4.2/80)	SM1500 (4.2/50)
Design Wavelength, $\lambda_{op}$ (nm)	830	980 1550	1310 1550		1550			
Cut-off Wavelength (nm)	600 - 800	870 - 970	1150 – 1250			1350 - 1500		
Numerical Aperture	0.14 - 0.18		0.11 - 0.13	0.19- 0.21	0.23 - 0.25	0.19 - 0.21	0.29 – 0.31	
MFD (μm) @ $\lambda_{op}$ (nm) nominal	4.2	4.5 @ 980 7.5 @ 1550	9.0 @ 1310 10.5 @ 1550	5.4 @ 1310 6.4 @ 1550	5.3	6.4	4.2	
Attenuation (dB/km) @ $\lambda_{op}$	≤ 5	≤ 3	≤ 2				≤ 3	≤ 2
Proof Test (%)	1							
Fiber Diameter (μm)	80 ± 1							50 ± 1
Core Cladding Concentricity (μm)	≤ 0.75							
Coating Diameter (μm)	175 ± 5%							110 ± 5%
Coating Type	Dual Acrylate							Single Acrylate