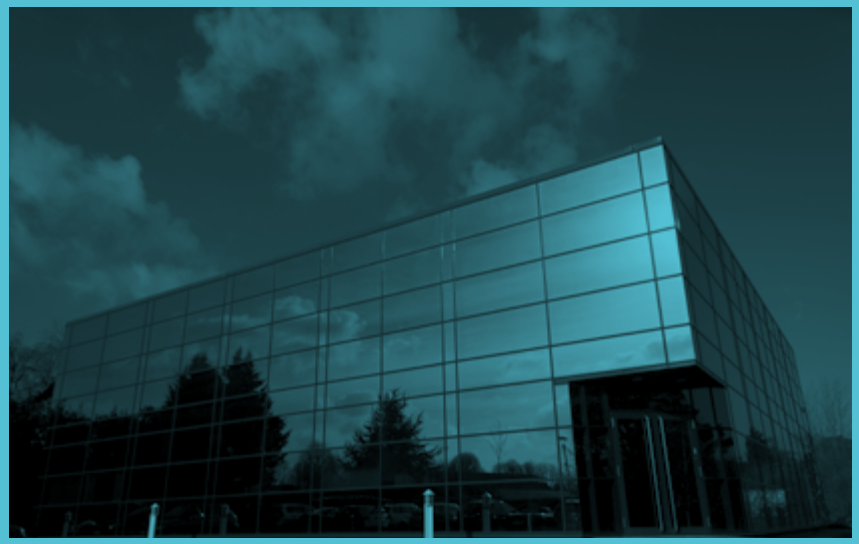
FIBERCORE
A HUMANETICS COMPANY

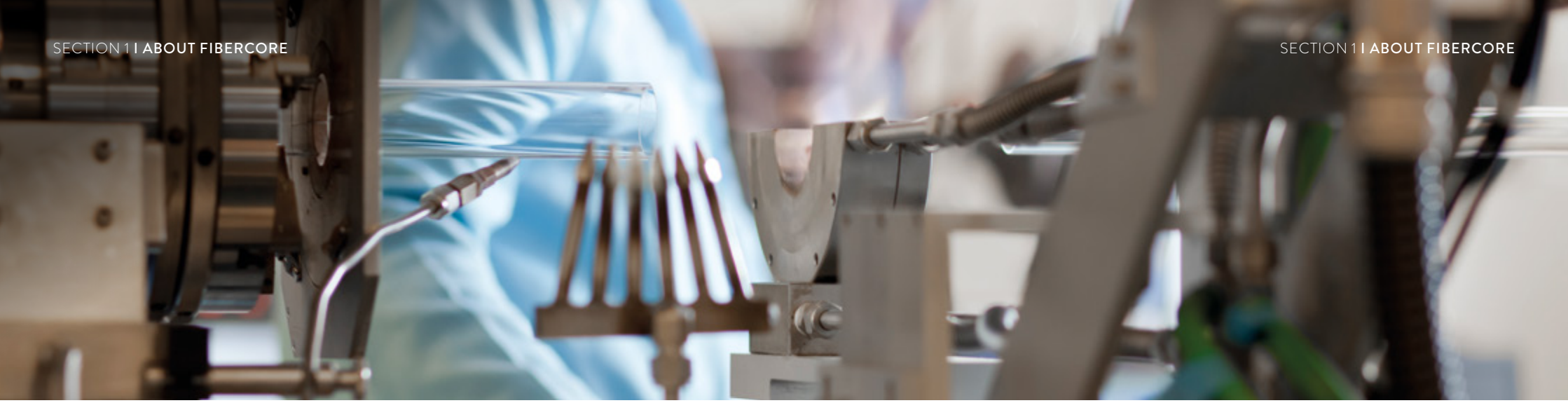
# PRODUCTS AND SERVICES

9th Edition




INNOVATION
IN EVERY FIBER

# CONTENTS



SECTION 1 I ABOUT FIBERCORE

# ABOUT FIBERCORE

Fibercore has delivered over 40 years of innovation and excellence at the top of its profession, developing and manufacturing specialty optical fibers.

The company continues to embody the spirit of innovation, technical excellence and quality, which has seen it flourish through the first four decades of monumental changes in both technology and its impact on society.

Established in 1982, Fibercore was formed as a spin-out from the world renowned Optical Fiber Group of the University of Southampton, to offer the specialty optical fibers developed at the University, commercially.

Since 2003, Fibercore has increased its manufacturing capabilities tenfold and introduced 'World-Class Manufacturing' philosophies to what was traditionally viewed as a scaled-up laboratory process. Our focus is firmly on the future, the recent expansion of the sales, marketing and development teams and the introduction of new photonics engineers into our skill base enables us to continue our commitment to the specialty fiber industry.

Fibercore products are used in an exceptionally broad and growing range of applications spread throughout more than 50 countries. The applications include Oil & Gas, Fiber Optic Gyroscopes (FOGs), fiber optic hydrophones, fiber lasers, fiber amplifiers (EDFAs), current sensors, embedded sensors, medical devices, government and corporate research agencies and fibers for next generation telecommunications systems. The list just keeps on growing!

Fibercore was acquired by Safety Technology Holdings (STH) in 2017. STH's key business division, Humanetics, is the world's leader in crash test dummies. These dummies are no dummies as they have a considerable number of sensors built within the structure. The proper name is anthropomorphic test device (ATD)! Fibercore brings to the table customized optical fiber for sensing which can further enhance the capability of an ATD. STH continues to make acquisitions, such as HITEC Sensors and OpTek Systems, which further enhance our sensing offering within the Humanetics Group.

Fibercore's differentiator is in our consultative sales approach. We don't start telling you about our products and capabilities but rather we listen. We strive to understand what you are trying to achieve and what it will take to make your efforts successful. Only then, will we begin to formulate a solution that will meet your needs. We are your partner and our success is intimately tied to your success. Many of our customers have been with us over 20 years as we continue to win their business every day. We strive to ensure they have no reason to look elsewhere. We look forward to discussions with you and your team!

For more information about Fibercore, new products and career options visit us at fibercore.com

# HERITAGE

**1982**
Spun Low-Birefringence Fiber

**1983**
Bow-Tie Polarization Maintaining Fiber and
Zing™ Polarizing Fiber

**1987**
Neodymium Doped Fiber

**1988**
Erbium Doped Fiber

**1989**
Spun Bow-Tie, Elliptically-Birefringent Fiber

**1993**
Erbium-Ytterbium Co-Doped Fiber

**1998**
Intrinsically Photosensitive Boron Co-Doped Fiber

**1999**
All-Silica, 'Cladding Pump' Rare-Earth Doped Fiber

**2002**
50µm, Low-Loss and Highly Bend-insensitive
Single-Mode Fiber

**2009**
Pure-Silica Core Single-Mode Fiber for use
in UV-Visible Applications





# HERITAGE

**2010**
Re-introduction of improved Zing™ Polarizing Fiber

**2012**
Re-introduction of improved Spun Bow-Tie, Elliptically-Birefringent Fiber

**2013**
High Temperature Coatings, Pure Silica Core Fiber,
Portfolio for Oil & Gas industry

**2014**
Acquisition of Fibertronix. Multicore Fiber, Multimode Fiber, through
the coating FBGs, cables for Oil & Gas, Double Clad Passive Fiber

**2017**
Silicon Photonic Fiber TC Fiber High NA/High Bandwidth Fiber

**2018**
New Gyroscope Fibers, New 7-Core Fiber, B3 Fibers, PMCP Fiber
Introduction of large diameter multimode fibers

**2019**
New generation of PM Fiber Optic Gyroscope (FOG) fibers launched
Multimode Multicore Fibers developed for multibeam laser power delivery
World's first demonstration of a Double Clad Fiber with a graded index
inner cladding for simultaneous DAS and DTS

**2020**
Extension of ErYb Amplifier Fiber and Passive Fiber range for
LiDAR and satellite free-space communications

**2022**
Enhanced distributed acoustic sensing (eDAS) fiber launched
Capacity expansion with new draw tower facilities

# TECHNICAL PARTNERSHIP

The success of your project is all that matters. Fibercore doesn't just sell specialty fibers – we'll work with you, putting everything that we have learned in the Industry at your disposal.

Fibercore has the depth and breadth of experience and engineering expertise in specialty fiber to make a real contribution to your project – from the very first contact, through supporting you in the selection of exactly the right fiber, all the way to on-time delivery and beyond. It is this exceptional level of intense, technical support that makes our customers return, year after year. We design the right solution for your need beyond the 100+ pages of this brochure. And if we cannot assist you with anything, then we will say so and do our utmost to use our unmatched knowledge to direct you towards someone who can.

## 1. DO YOU NEED SPECIALTY FIBER?

- Have you got unanswered questions about fiber?
- Would you like more support from a fiber expert?
- Contact us

**E:** info@fibercore.com
**T:** +44 (0)23 8076 9893
**fibercore.com/ask**

## 2. DISCUSS WITH OUR FIBER ENGINEERS

- Receive detailed feedback and analysis
- Research in the industry's online source of specialty fiber information – Fiberpaedia™

**fibercore.com/applications**
**fibercore.com/fiberpaedia**

## 3. DO YOU NEED A SAMPLE?

- Request a sample
- Request more in-depth data
- Request a solution

**fibercore.com/sample**

## 4. FINALIZE YOUR FIBER SELECTION

- SM Fiber
- Photosensitive
- Multicore Fiber
- PM Fiber
- Spun Fiber
- Doped Fiber
- Passive Cladding Pumped
- Multimode Fiber
- Fiber Bragg Gratings
- Complementary

**fibercore.com/products**

## 5. IS FIBERCORE THE RIGHT PARTNER?

- Over 30 years at the forefront of specialty fiber technology
- Purpose built state-of-the-art facilities
- ISO9001 quality
- ISO14001 environment
- OHSAS45001 health and safety
- ISO10012 test and measurement

**fibercore.com/facilities**

## 6. WHAT ELSE DO YOU NEED?

- Fiber qualification and reliability testing
- Fiber test and measurement
- Fusion splicing
- Hydrogen testing
- Custom preform and fiber development
- Custom and Multifiber
- Fiber calculator and EDF S/W
- Development projects

**fibercore.com/ask**
**fibercore.com/calculator**

SECTION 2 I SECTORS

# HARSH ENVIRONMENT

The use of optical fiber sensors by the Oil & Gas, Nuclear, Chemical Processing, Civil Engineering and Space Vehicle industries has grown dramatically over the past decade. This growth can only accelerate and with it, the demand for optical fibers capable of delivering their performance reliably in these challenging environments.

Typical telecommunications fiber is designed for benign environments in temperatures that range from -55°C to +85°C, degrading optically when used outside of this temperature range and when in certain environments with hydrogen, chemicals or radiation. Due to these factors, special coatings are available to address a greater temperature range and to handle certain chemical environments. In addition, the glass chemistry must be modified to address environments with hydrogen or radiation.

## APPLICATIONS

### Radiation (Nuclear and Aerospace)

There are multiple applications where optical fiber is exposed to ionizing radiation such as nuclear power plants, nuclear storage facilities, space applications and some research facilities containing high energy physics/particle accelerators. Fibercore has both single-mode and multimode fiber that has been designed specifically to be minimally impacted by ionizing radiation. These optical fibers are used for communication links that go through such environments and are also used for a variety of sensing applications such as distributed temperature sensing (DTS) and strain sensing. Products ideal for a radiation environment include: pure silica core single-mode (pg. 54-55) and graded index pure core multimode (pg. 99).

### Oil and Gas

The Oil and Gas (O&G) industry has been using downhole optical fiber in wells where the temperatures can reach beyond 300°C and where hydrogen is present. These fibers are often used for distributed temperature (DTS) and acoustic (DAS) sensing for multiple applications such as frack monitoring and other process optimization, telemetry for downhole tools, pressure sensing and for strain monitoring. Fibercore offers coatings suitable for 150°C, 300°C and beyond, along with a carbon coating over the glass to prevent water or hydrogen ingress. Fibercore offers pure silica core single-mode fiber (pg. 54-55) and a graded index pure core multimode fiber (pg. 99) that has been designed and manufactured to minimize optical loss due to hydrogen exposure.

Products ideally suited to O&G environments, especially downhole, include single-mode and multimode fiber with carbon high temperature acrylate coating (pg. 98), pure silica core single-mode and graded index pure core multimode with polyimide or carbon polyimide (pg. 54 & 99), fiber Bragg gratings (FBGs) (pg. 102) and fiber optic cables (pg. 108-114).

### Cryogenic

For applications where temperatures will be below -60°C, standard telecommunications fiber will not perform optimally and a special polyimide coating is necessary. Liquid natural gas facilities and pipelines, where temperatures can drop to approximately -180°C, commonly use optical fiber for monitoring temperatures (DTS and/or DAS) to look for signs of leakage. These optical fibers are housed in fiber optic cables to allow for protection of the fiber during placement of the cable. Deployment of optical fiber in cryogenic applications is typically in cable (pg. 108-114) and uses polyimide coated single-mode and multimode fibers (pg. 50 & 98).

### Acoustic/Seismic

In the O&G industry, fiber optic hydrophones and geophones are used to aid in the evaluation of existing reservoirs and to search for new reservoirs. In these devices, optical fiber is either deployed straight or wound in a coil over a compliant mandrel at relatively small diameters, which is challenging if not impossible for standard telecommunications fiber to maintain guidance of the light.

These sensors are either lowered downhole into the oil or gas well for vertical seismic profiling (VSP), laid on the subsea floor for ocean bottom seismic (OBS) in permanent reservoir monitoring (PRM) systems or placed on the surface for seismic profiling.

Fibercore offers a variety of smaller clad diameter fibers with reduced diameter coatings and higher NAs to allow for superior performance in these challenging devices; 50µm and 80µm single-mode fibers (pg. 46, 48 & 51). To further boost distributed acoustic sensing (DAS) systems, enhanced DAS (eDAS) fibers are also available (pg. 105).

### Chemical

In some applications, optical fiber is conveyed into the area where optical sensing is desired. The fluid to convey the fiber can be detrimental to the optical fiber coatings. Fibercore has suitable coatings to not only survive the conveyance of the fiber but also to withstand the residual chemical environment that remains after the operation. Pure silica core single-mode and graded index pure core multimode polyimide coated fiber (pg. 54-55 & 99) are ideally suited for harsh chemical environments. In addition, the single-mode fibers can have FBGs written into them as well and this area can be coated with chemically sensitive materials that will expand/contract in the presence of certain target chemicals. In this way, the fiber can become a distributed chemical sensor. FBGs (pg. 102) and our pure silica core single-mode polyimide coated fiber (pg. 54-55) provide the components for this type of sensing.





# AEROSPACE AND DEFENCE

The fundamental benefits of lightweight, small size and immunity from EMI have enabled optical fiber technology to gain widespread acceptance in Aerospace and Defence. Today, an ever-growing list of applications for specialty fiber is topped by Fiber Optic Gyroscopes (FOG), Avionics, LiDAR, Asset Monitoring, Sonar and Perimeter Security.

The Aerospace and Defence (A&D) sectors were amongst the very first to embrace optical fiber technology. Originally this was for communications and now, increasingly for sensing.

A broad spectrum of A&D applications use specialty optical fibers to enhance performance and reliability from fiber optic gyroscopes (FOGs), through hydrophones, geophones, phased array radar, avionics, perimeter and asset security and LiDAR to inter-satellite communications.





## APPLICATIONS

### Fiber Optic Gyroscopes (FOGs)

FOGs are interferometric sensors that make use of the Sagnac effect to detect and measure rotation. They are used in ship, submarine, ROV and aircraft navigation, helicopter, missile and gun-sight stabilization, precision positioning of artillery and satellite receivers to name but a few.

The sensing element in a FOG is typically a precision-wound coil of PM fiber with a length of fiber between 100m and 5,000m, depending on the degree of sensitivity required. FOGs can equal the performance of the very best ring laser (RLGs) and iron ('spinning mass') gyros, with the benefits of reduced manufacturing costs and a higher reliability of up to thirty times that of competing technologies. This negates the need for servicing the product, saving lifetime costs.

The entire optical circuit of a high precision FOG may be formed using a range of fibers that have been developed in unison to be fully compatible, delivering optimal performance with minimal effort.

FOG specific Fibercore products include:

- **PM Gyro Fiber (pg. 70):** Reduced diameter for sensing coils, delivering enhanced mechanical reliability and reduced package size
- **Zing™ Polarizing Fiber (pg. 73):** Single polarisation fiber to increase PER
- **Erbium Doped Fiber IsoGain™ I-25H (pg. 81):** High absorption EDF for ASE light sources
- **Fiber coils (upon request):** Ultra high precision, quadrupole-wound sensor coils

### Space Environments

**Space qualified FOGs:**
Radiation tolerant (RT) variants of both PM (pg. 71) and SM (pg. 54-55) fibers have been used in FOGs deployed by most of the World's space agencies for spacecraft and satellite use. The proprietary core and cladding formulation reduces radiation induced attenuation (RIA) by up to fifty times, when compared with conventional fibers. Fibercore products are delivering their performance in geostationary orbit, on the surface of Mars and to the furthest reaches of our Solar System.

**Laser Communications:**
Fiber lasers and amplifiers are increasingly used in free-space inter-satellite and satellite-to-ground communications. Fiber based Laser Communications Terminals (LCTs) offer reduced weight, lower power requirements and 100X faster data rates than comparable RF systems and are therefore ideally suited for satellite and spacecraft deployment. Fibercore's Erbium Doped Fiber AstroGain™ range (pg. 82) has been developed specifically for this task.

### Embedded Sensors/Asset Monitoring

By embedding optical fibers into an airframe or other structure (with or without the inclusion of fiber Bragg gratings (FBGs) (pg. 102) that structure becomes 'smart', capable of sensing its environment with respect to temperature, vibration, pressure, strain, shape etc. These techniques were pioneered in the 1980s, notably by McDonnell Douglas Aircraft Corporation and were also used by NASA in the development of adaptive wing aircraft. Fibercore's low and ultra-low profile fibers (pg. 46, 48 & 71) are ideally suited to embedded use, particularly when combined with specialized, harsh environment coatings.

### Light Detection and Ranging (LiDAR)

Primarily used for ultra-precise, 3D distance measurement, LiDAR has many applications from atmospheric sensing, wind-shear detection, geological mapping, surveying in mines/quarries to obstacle detection in autonomous vehicles. Fibercore's EDF (pg. 80-84) and EYDF (pg. 86 & 88) active fiber products and matching passive fibers (pg. 90) are ideally suited to use in LiDAR.

### In-Flight Network and Entertainment Systems

Optical fiber has higher bandwidth and lower weight than copper cable and is ideally suited to avionics use, from flight systems through to in-flight entertainment. Relatively short distances tend to favour the use of multimode (MM) fiber (pg. 96), including radiation resistant and bend insensitive variants. These fibers are ideal for the tight bend-radii encountered in the increasingly dense fiber environment of a typical airframe.

### Acoustic and Seismic Sensors

Fiber based 'listening devices', hydrophones and geophones are being used in marine, submarine and terrestrial security. High strength (300+ kpsi), very highly bend insensitive fibers (pg. 44 & 59), often combined with FBGs (pg. 102) are ideally suited to this class of sensor.

### Perimeter and Border Security

Both distributed acoustic sensors (DAS) and 3-axis point sensing can deliver exceptional perimeter and border security. These are capable of detecting and analysing footfall and pinpointing tunnelling activity in real time. A number of police stations have already been equipped with these systems, with excellent results.

Fibercore has developed both cable (pg. 108-114) and fiber solutions that are now being deployed in these applications.



# ENERGY AND INFRASTRUCTURE

The entire world is critically dependent upon the security and integrity of its transport, data and energy infrastructures. Increasingly, it is fiber optic sensing technologies using specialty optical fibers that are responsible for monitoring these infrastructures to ensure their smooth running.

This applies equally to the supply of energy, distribution of internet data and the transportation of people and goods. Optical fibers are widely used throughout these industries with a growing use of fiber optic monitoring of electrical power distribution, structural health monitoring and intrusion sensing.



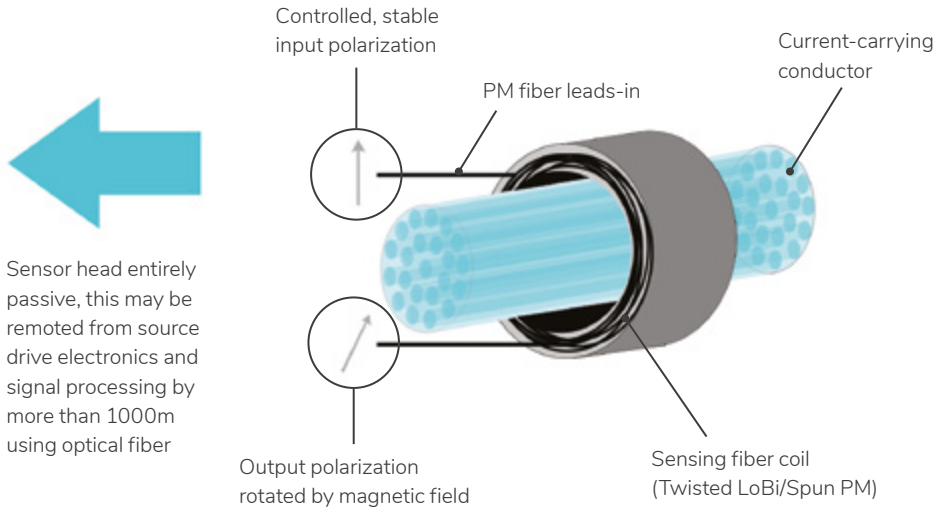


## APPLICATIONS

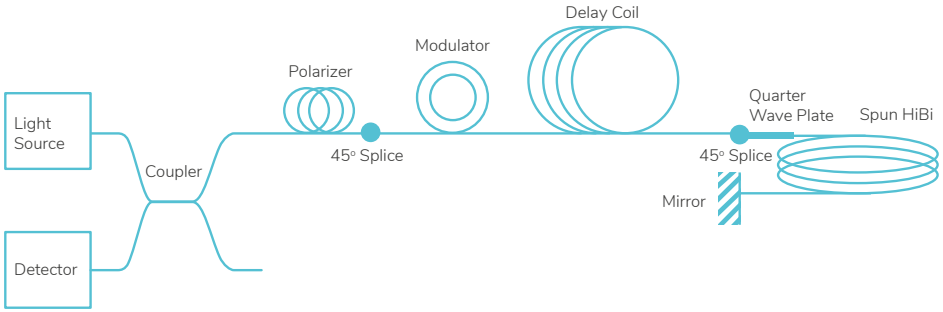
### Energy (for Oil & Gas see pg. 12)

As the smart grid develops, accurate and instant information on the electrical power loading is required. Subsequently, fiber optic current sensors have been developed, which allow almost instant measurement of the electrical current at any point within the network. These fiber optic current sensors (FOCS), also known as optical current transformers, utilise the fiber optic Faraday effect to allow monitoring of current in high voltage power lines and transformers. Fibercore's spun fiber (pg. 76) is at the heart of products where high stability fiber design is critical to enable high accuracy current sensing. The fibers allow highly sensitive and accurate current sensing over a wide range of environmental conditions, including: temperature variation and vibration, suitable for the rigors of real life applications. In addition to the spun fiber within the product, Fibercore's PM fiber (pg. 66) for delay lines and Zing™ (pg. 73) for polarization control are used in combination to result in world-class current sensors.

### Faraday Effect Current Sensor Schematic



## Details of Current Sensor Architecture




### Infrastructure

With optical fiber having the ability to be used as a sensor or have sensors written into the fiber directly, information can be gained on the health of a component or system remotely and over long lengths. Some examples are:

1. Embedding optical fiber into power cables to look for hot spots along the cable, which would indicate insulation breakdown or cable damage and to maximize the potential of the insulated power cable by allowing increased current flow up to the temperature rating of the cable.
2. Embedding fiber Bragg gratings (FBGs) (pg. 102) into wind turbine blades to monitor strain and to count the number of flex cycles to evaluate component fatigue.
3. Using radiation resistant optical fiber (pg. 71-72 & 99), for use in communication and sensing (distributed temperature,strain and point sensors) in nuclear storage and operations facilities.
4. Embedding optical fiber into dams to monitor leakage via distributed temperature sensing and monitoring strain either through FBGs or through Brillouin scattering for distributed strain.
5. Using optical fiber at critical junctures on bridges to monitor movement and strain through the use of FBGs (pg. 102) or Brillouin (pg. 45-46) scattering for distributed strain.
6. Small fiber optic cables can be embedded into concrete structures allowing for monitoring of the concrete curing process via temperature (DTS) (pg. 98) and strain (Brillouin (pg. 45-46) or FBG's (pg. 102) allowing the user to optimize the process.
7. LiDAR, Light Detection and Ranging, uses specialty optical fiber for the transmission of the light. LiDAR is being used for driverless cars and aerial mapping (pg. 80-81 & 84).





# BIOMEDICAL

The use of optical fiber in the Biomedical industry has grown rapidly from simple light and image guides and power delivery for cutting and cauterizing through to next generation imaging, advanced diagnostics, 'smart' catheters and robotics. This escalation in sophistication requires a greater need for more refined specialty optical fibers.

With a full range of ultraviolet (UV) (pg. 54), visible and near-IR single-mode (SM) fibers (pg. 44) in both polarization maintaining (PM) (pg. 66) and non-PM variants, multicore (MCF) fiber (pg. 60), fiber Bragg gratings (FBGs) (pg. 102), small clad, high numerical aperture (NA) (pg. 46), polyimide coated fiber and side hole fiber (upon request), Fibercore's range of advanced optical fibers are suitable for a wide range of biomedical applications. These fibers find use within in vivo and in vitro applications, ranging from medical probes to advanced microscopy techniques.

Fibercore can offer coatings suitable for both EtO (ethylene oxide), autoclave and other sterilization techniques.

The use of optical fiber in biomedical applications such as minimally invasive surgery (MIS), vascular intervention, ophthalmology, cosmetic procedures and dentistry is increasing with ever evolving, custom designed optical fibers. Fibercore's culture is to partner with our customers to find creative and innovative solutions to provide the optimal specialty optical fiber, resulting in robust and reliable imaging guidance and diagnostic tools.





## APPLICATIONS

### 3D Shape Sensing

Vascular and interventional radiology (VIR) requires imaging systems, such as X-rays or CT scanners, to assist with the guidance of angioplasty and catheter delivered stents. However, through the use of Fibercore's multicore fiber with FBGs inscribed along the length, the need for constant imaging using these techniques can be removed. The fiber is able to sense its own shape, enabling a 3D reconstruction of the path it is taking within the body in real time.

### Pressure Sensing

Twin hole (or side hole) fibers can be optimized to be sensitive to the hydrostatic pressures experienced within the body. This opens up various biomedical applications such as the precise location and measurement of pressure fluctuations within an artery, which can be an indicator of coronary artery disease (atherosclerosis).

### Haptic Sensing

Haptic sensing, or the ability to give touch feedback remotely, allows robotic surgery tools and non-direct mechanically coupled tools to be used with a greater dexterity. The use of Fibercore's reduced cladding diameter fibers with FBGs allows miniature strain sensors to be embedded within the tool, which enables a signal to be returned and converted into a mechanical feedback at the surgeon's hands. This gives surgeons a natural feel when using such tools as if they were touching the soft tissue of the body directly.

### Optical Coherence Tomography (OCT)

OCT is an optical imaging acquisition technique that uses light waves to form images of translucent or opaque materials. Images appear as either 2D or 3D layered cross-section of an optical scattering media. One of the most well-known areas of OCT imaging is for ophthalmology for retinal mapping. In ophthalmology, OCT measurements allow an ophthalmologist to thoroughly map and measure the thickness of the retina as well as aide in the early detection, diagnosis and treatment for retina disease and other conditions.

### Spectroscopy

Spectroscopy is the technology of the dispersion of an object's light into its component colours (i.e. energies). By performing this dissection and analysis of an object's light, we are able to infer the physical properties of that object such as luminosity, temperature, mass and composition. This technology can be used in medical diagnostics such as blood sugar, pulse oximetry, neonatal research, urology, neurology and many other biomedical applications.

### Laser Power Delivery

Large core optical fibers can be used for delivering high optical power for surgical needs in Lithotripsy, eye surgery, cardio vascular intervention and dentistry. Biocompatible coatings and buffer materials are offered with these fibers.

# TELECOMMUNICATION

The continual growth in bandwidth demand, fuelled by an internet connected society is driving technical developments of devices and components used in the telecommunication architecture.

These devices are required to become more efficient, smaller in size and have wider bandwidth, while still driving performance forward. Such requirements have driven specialty optical fibers into volume telecommunications markets.





## Erbium Doped Fiber Amplifiers (EDFAs)

Erbium doped fibers (pg. 80-83) are the standard choice for optical amplification. However, their demands vary depending upon the application of the amplifier. Low cost, C-band, low signal power, high efficiency amplifiers typically utilize erbium doped core pump fiber, such as the IsoGain™ I-4(980/125) and I-6(980/125) (pg. 80). As power level requirements increase, for example >400mW core pump power, high cut-off wavelength fibers provide better efficiency, such as I-4(980/125)HC.

With a growing demand to push the spectral bandwidth of amplifiers, L-band amplifiers are becoming more common. These would require very long lengths of standard erbium doped fibers to be used. Where reduction of the total length is required, Fibercore offers highly doped fibers including: I-12(980/125)HC and I-15(980/125)HC (pg. 81).

Mini and micro EDFAs are popular for small package size C-band amplifiers, which require highly doped fibers, dramatically reducing the coil lengths. Higher absorption and reduced cladding diameter fibers such as I-15(980/80) HC and I-25H(1480/80) (pg. 81) give improved mechanical reliability, shorter lengths and excellent bend loss.

To address the needs of satellite-to-satellite and satellite-to-ground communication, space grade erbium doped fibers have been developed: AG980H and AG980L (pg. 82).

## High Power Amplifiers – Ytterbium Erbium Doped Fiber Amplifiers (YEDFAs)

High power amplifiers for telecoms and CATV require double or triple cladding fibers, which allow the pump light directly into the cladding of the fiber, increasing its utilization. This in turn increases the signal power level, allowing signals in excess of 1W to be used. Unique to the industry, Fibercore manufacture an all-silica double clad fiber with a circular outer cladding and a petal structure inner cladding (pg. 86). The all-silica design means it can be stripped, cleaved, spliced and recoated like a standard optical fiber, without the need for low index recoat material. The circular cladding ensures the fiber sits within V-grooves centrally, avoiding problems associated with competing octagonal cladding structures. For mode mixing, the petal structure gives efficient coupling of the pump light into the core of the fiber. For the new generation of even higher power amplifiers, around 5W, Fibercore provides a specialized fiber, TC1500Y(11/125)HD (pg. 84), also with a circular clad design.

### OEM Amplifier GainBlock

As the splice recoating technology required for double and triple clad fibers is different to a standard core pump fiber, Fibercore offers a pre-assembled unit called an OEM Amplifier GainBlock (pg. 89). This unit incorporates a WDM, high power splices, cladding pumped gain fiber and heat sinking to allow easy upgrade of lower power amplifiers to higher power levels, without significant engineering investment.

### Silicon Photonics

Fibercore have developed extremely small core diameter fibers at 1550nm which are optimized for direct coupling to silicon waveguides. These result in 1550nm SM fibers with MFDs down to 3µm and NAs up to 0.42, significantly reducing the insertion losses between fiber and chip, SM1500ES(3/125) (pg. 45).

### Multimode Large Core Fibers

Multimode pumps typically use fiber with a 105µm core diameter and a 125µm cladding diameter. Fibercore offers two variants (pg. 100) of this standard pump fiber: MMSC(105/125)0.22 with a 0.22 NA and MMSC(106.5/125)0.22 with a 0.22 NA

### Fused Taper Coupler Fibers

Fused taper coupler performance and manufacturing yields can be optimized by utilizing Fibercore's SM step index fibers, which do not have a fluorine ring, often used in telecoms fibers, which can introduce instabilities in the coupler manufacturing process.

Fibercore's SM980(5.8/125) (pg.44) dual window fiber and SM1500 (pg. 45) fiber range are ideally suited for coupler manufacturing.

### PM Fiber for Coherent Communications and Lyot Depolarizers

Polarization maintaining (PM) (pg. 66) fiber is used for coherent communications where the bandwidth of a fiber is increased 100% by utilizing two polarization states. Fibercore's Telecoms PM Fiber (pg. 68) is designed to offer outstanding core circularity and concentricity for excellent splice performance, while also ensuring low crosstalk between the polarization states. This range offers PM fibers for 1550nm, 14XXnm, 1310nm and 980nm.

Conversely, PM fibers are also used as Lyot depolarizers for depolarizing Raman amplifier pumps. By splicing two specific lengths of PM fibers together with the stress axis offset by 45°, an all-fiber depolarizer can be manufactured. The HB14XXT (pg. 69) fiber has been specifically designed to offer the best-in-class birefringence, allowing short length depolarizers to be achieved.



SECTION 2 I SECTORS

# INDUSTRIAL (PROCESS MONITORING)

Small size, lightweight, immunity from electromagnetic interference (EMI), high bandwidth and the ability to provide truly distributed measurements make fiber optic sensing the optimum technology for many aspects of process monitoring. Specialty fibers boost sensor performance and enhance functionality over other technologies.

Existing technologies today suffer from electromagnetic interference (EMI), temperature limitations or size constraints, all of which limit the accuracy or usability of such sensors. By utilizing optical fibers, these challenges can be avoided, bringing additional sensing opportunities to industrial processes.





## Metrology

Polarization Maintaining (PM) fibers, for example Fibercore's HB range of highly birefringent fibers (pg. 66), are extremely useful for measuring small distances with high accuracy. The Bow-Tie stress applying parts (SAPs) ensure the input polarization state is kept stable during movement, vibration and temperature changes, ensuring polarization dependant effects do not degrade the accuracy of the measurement. PM fibers are available from visible to near infrared (IR) wavelengths, offering various options depending upon whether the application uses interferometry, time of flight or other measurement methodology.

Visible wavelength PM fibers, for example HB450, HB450SC and HB600 (pg. 66), are often used within interferometers where the distance measurement accuracy is better than the wavelength of the light used.

For ultra-small probes, 80µm and 60µm cladding diameter PM fibers are available in our PM Gyro Fiber range (pg. 70). These allow for smaller cross sections and improved mechanical lifetime when deployed with extremely tight bends.

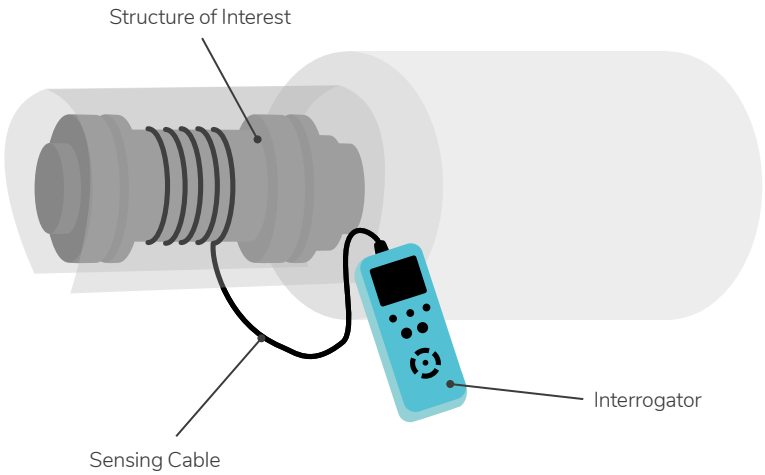
Image courtesy of Mahr

## Condition Monitoring

Movable parts are prone to wear and tear, which can result in catastrophic failure if they are not repaired or replaced when damage is induced. Statistical distributions can be used to give a probabilistic approach to maintenance but this method would not avoid a catastrophic failure in the case of abnormal wear.

Fiber Bragg gratings (FBGs) (pg. 102) provide a method of monitoring vibrations on mechanical structures, which can be indicative of wear or even manufacturing error. These vibrations can be monitored live and automatic warnings triggered when an abnormal vibration occurs. For mass transportation devices, such as trains and aircrafts, this can save lives. For difficult to access industrial equipment, such as subsea pumps, this can ensure repairs are scheduled only when they are due, avoiding costly recovery processes.

Wind turbines provide an interesting example of using FBGs for not only condition and vibration monitoring of the rotating parts, but also strain sensing along the blades. This allows active feedback to correlate the blade pitch with the strain on the blades to enable optimized energy conversion in light or heavy wind.








## Temperature Sensing

Multimode (MM) and single-mode (SM) optical fiber are used for continuous distributed temperature sensing (DTS) to provide constant thermal monitoring. Multimode based systems have a sensing reach of ~30km, while single-mode have a reach of ~100km. To help improve the temperature range of the sensing, high temperature acrylate coatings can offer continuous use up to 150°C and polyimide coatings offer use up to 300°C. For more extreme temperature ranges, metal coatings such as gold can be used to push beyond 300°C, for example in turbines. These coatings, with the exception of metal coatings, can also be used in conjunction with Fibercore's femtosecond laser written high temperature FBGs, which give extended thermal range beyond standard FBGs.

SECTION 2 I SECTORS

# FIBER LASERS AND AMPLIFIERS

With the growing range of fiber lasers and high power amplifiers available today, there is a greater need for specialty fibers, ranging from high power double or triple cladding fibers through to highly complex polarizing, Zing™ fibers.

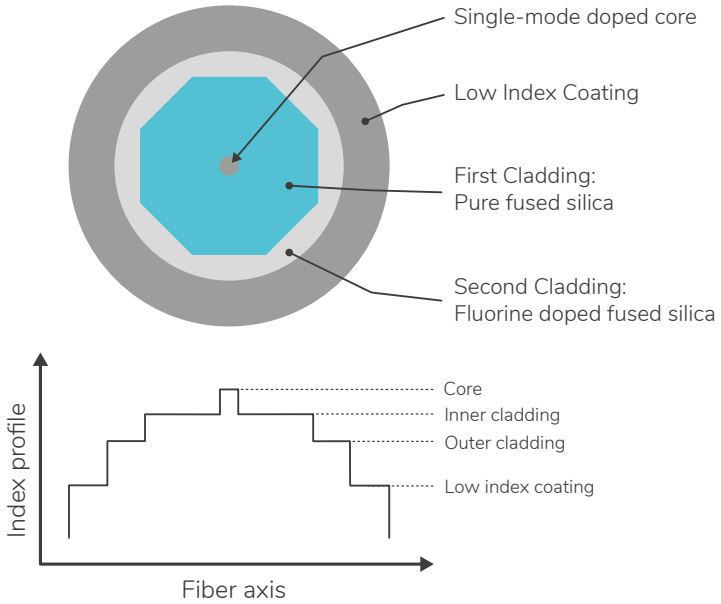
These products require high quality manufacturing to ensure outstanding reliability when used at extreme optical power levels and reassurance that the manufacturing processes can scale to meet the global demand of the market. Fibercore's position as the highest volume specialty fiber manufacturer enables us to address the fiber laser and amplifier market with high quality technical products to enable the next generation of fiber lasers to ramp to high volumes.



### Triple Cladding Ytterbium/ Erbium Doped Fibers

Fibercore's new range of triple cladding fibers (pg. 84) are designed for fiber lasers and high power CATV and telecoms amplifiers. Their unique triple cladding structure is designed to encapsulate the mode mixing octagonal pump guide within a circular outer cladding, enabling lower splice losses and lower splice variability associated with fibers with octagonal outer regions. This triple cladding structure also gives an additional mode confinement structure to reduce the amount of pump light at the cladding-coating interface to aid coating reliability. Fibercore's triple-clad erbium/ytterbium doped fibers (TC1500YHD) (pg. 84) are designed as single-mode, high-power CATV and telecommunications amplifier fibers. The TC1500Y(6/125)HD offers a smaller Mode Field Diameter (MFD) for higher efficiency levels at output signal power around 1W. The TC1500Y(11/125)HD is designed for output signal power at 5W and above.

The TC1060Y(10/125)0.08HD (pg. 84) is a ytterbium doped fiber designed for use in pulsed and CW fiber lasers. The composition is optimized to avoid the effects of photodarkening to ensure long lifetime and high reliability.




## Passive Double Cladding Fibers

Passive double cladding fibers (pg. 90) are designed to transport the single-mode (SM) signal in the core and the pump light in the cladding from one location to another. These fibers are typically utilized in multimode pump combiners where the combined power of multiple multimode pumps are combined into the passive double cladding fiber and transported to the active double or triple cladding fiber.

For the fiber laser industry, Fibercore has developed the DC1060(20/400)0.065HD and DCSC(135/155/320)LI, which enable compatibility to high power ytterbium doped fibers.

For the telecoms industry, the DC1500(11/125)0.12HD and DC1500(6/125)0.21HD enable compatibility to 11µm and 6µm MFD erbium/ytterbium doped active fibers.

To enable successful integration into components, the passive double clad fibers have been designed to be compatible with pump combiner manufacturing technology and have a germanium doped core, making the fibers photosensitive for fiber Bragg grating (FBG) inscription. Subsequently, these fibers may be used as part of the main gain stage cavity of a laser or as part of a Master Oscillator Power Amplifier (MOPA) design.

## Multimode Large Core Fibers

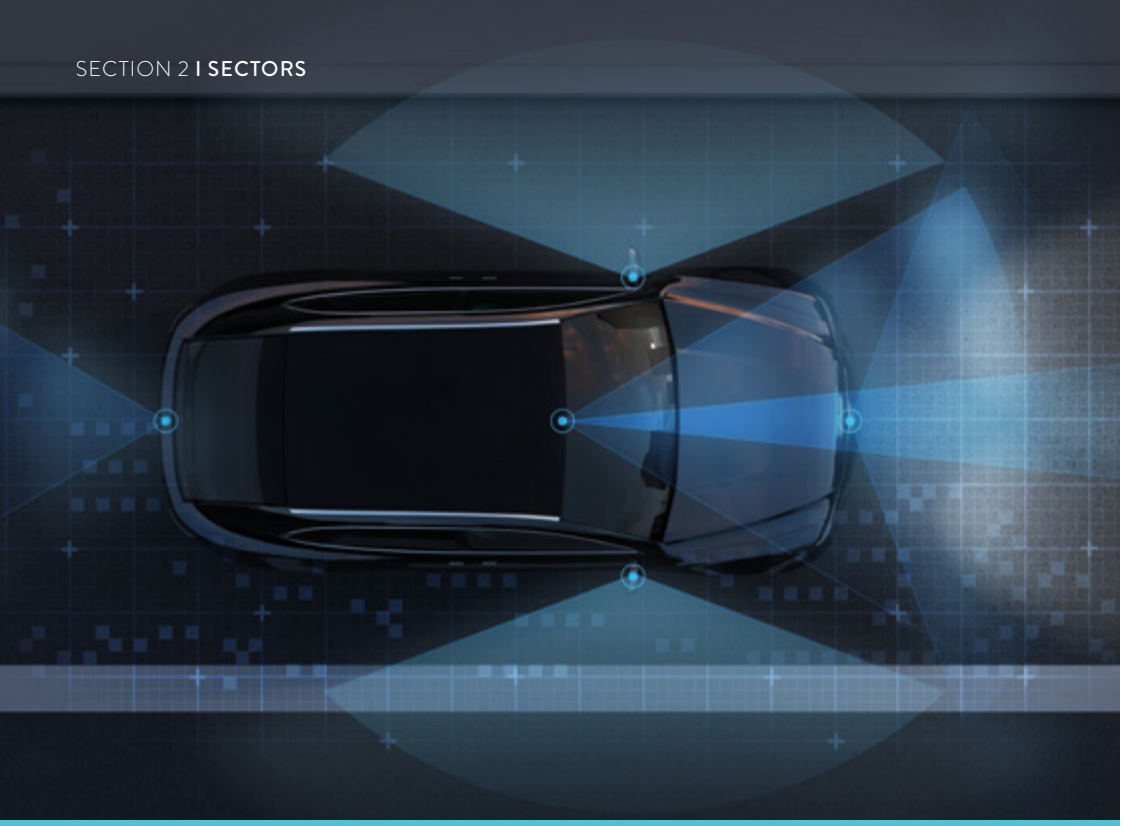
Multimode pumps typically use fiber with a 105µm core diameter and a 125µm cladding diameter. Fibercore offers two variants (pg. 100) of this standard pump fiber: MMSC(105/125)0.22 with a 0.22 NA and MMSC(106.5/125)0.22 with a 0.22 NA.

## Pre-Amplifier Fibers

Depending on the fiber laser architecture, pre-amplifiers are often used to reduce the gain level required from the power amplifier in a MOPA system. Fibercore offers a ytterbium doped, core pump fiber (pg. 88), DF1100 for a 1060nm pre-amplifier and a full range of erbium doped fibers in the IsoGain™ range (pg. 80), but specifically I-15(980/125) HC offers a high absorption level to enable short fiber lengths.

## PM and Polarizing Fibers

Fibercore offers a polarization maintaining (PM) erbium doped fiber (pg. 83), DHB1500 with the ability to amplify and maintain polarization for PM fiber laser applications. As well as the doped fibers, Fibercore offers passive PM fibers within the Telecoms PM Fiber range (pg. 68), suitable for wavelengths from 980nm though to 1550nm and beyond. For applications that require a single polarization state, the HB-Z Zing™ (pg. 73) polarizing fiber range can act as an all-fiber distributed polarizer with variants at 1060nm and 1550nm. To avoid Polarization Dependant Gain (PDG), particularly in laser diode seeded MOPA systems, Telecoms PM Fiber makes an excellent choice for use in Lyot depolarizers.



# LIGHT DETECTION AND RANGING (LiDAR)

The market demand for LiDAR products has taken a steep increase as public-facing autonomous vehicles have started to be proven on the road. Whilst the autonomous vehicle market has prime focus, other applications including wind speed monitoring, range finding and 3D scanning are more mature market areas utilizing similar, but differentiated LiDAR technologies.





### Autonomous Vehicles

Fiber based LiDAR systems currently offer the highest optical power levels for C-band “eye safe” wavelengths around 1550nm. Diode lasers are unable to match the power level and beam quality of a fiber laser solution in the C-band. Critically, the power level of the LiDAR light source correlates to the maximum vehicle speed for which the LiDAR system can give timely feedback. High energy pulses are able to travel further than low energy pulses before environmental scattering degrades the signal into the noise level. This allows fiber based LiDAR systems to detect and react to events far ahead of the vehicle. Automotive applications also require high temperature performance, capable of withstanding 125°C, which is within the performance range of various fiber coatings. Fibercore’s TC1500Y(11/125)HD erbium ytterbium doped fiber, matched passive DC1500(11/125)0.12HD fiber and GainBlock optical engines are ideal for these needs.

### Wind Speed Monitoring

LiDAR can be used to measure wind speeds at suitable stand-off distances to enable wind turbine efficiency tuning and airport safety enhancement through detection of wind sheer, wake turbulence and gusts. Such LiDAR systems require high power, polarization maintaining, large mode area double or triple clad erbium ytterbium doped fibers.

### Range Finding

Defense and civilian needs for range finding vary in optical power levels and the operational environments. These applications can range from ultra high spatial accuracy length measurements of large structures, such as aircraft wings and civil engineering structures through to airborne platform targeting systems. For the lower power end, Fibercore’s IsoGain product range offers a broad selection of fibers whilst the TC range of erbium ytterbium doped fibers are suitable for the higher power ranges.

### 3D Scanning

LiDAR is a powerful solution for scanning internal and external urban environments to aid construction planning and for scanning remote locations for metrological and environmental factors. The ability to mount the LiDAR systems onto mobile platforms including vehicles, boats, helicopters, aircraft and drones enables up-to-date 3D models of an area to be constructed rapidly, ideal for low cost, large area surveys and emergency response situations such as floods and earthquakes.

# INDUSTRY, APPLICATION AND PRODUCT GUIDE

| | | SM Fiber (pg. 42) | Photo-sensitive Fiber (pg. 56) | Multicore Fiber (pg. 60) | PM Fiber (pg. 64) | Spun Fiber (pg. 74) | Doped Fiber (pg. 78) | Passive Cladding Pumped Fiber (pg. 90) | Multimode Fiber (pg.96) | FBGs (pg. 102) | Cables (pg. 108) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Harsh Environment | Radiation (Nuclear and Aerospace) | ■ | | | ■ | | | | ■ | | |
| | Distributed Sensing-Acoustic (DAS), Strain (DSS) | ■ | ■ | | | | | | | ■ | ■ |
| | Distributed Temperature Sensing (DTS) | ■ | ■ | | | | | | ■ | | ■ |
| | Distributed Pressure Sensing (DPS) | ■ | ■ | | ■ | | | | | ■ | ■ |
| | FBG Sensing | ■ | ■ | ■ | ■ | | | | | ■ | |
| | Cable and Umbilical Integrity Sensing | ■ | ■ | | | | | | ■ | | ■ |
| | Geophones & Hydrophones | ■ | | | ■ | | | | | ■ | |
| | Cryogenic | ■ | | | | | | | ■ | | ■ |
| | Chemical Sensing | ■ | | | | | | | | | |
| Aerospace and Defence | Fiber Optic Gyroscopes (FOGs) | ■ | | | ■ | | ■ | | | | |
| | Space - Laser Communications | | | | | | ■ | | | | |
| | Embedded Sensors/Asset Monitoring | ■ | | | ■ | | | | | ■ | |
| | Light Detection and Ranging (LiDAR) | ■ | | | ■ | | ■ | ■ | | | |
| | Hydrophones | ■ | | | ■ | | | | | ■ | |
| | Perimeter Security Sensing (Acoustic & Seismic) | ■ | | | | | | | | ■ | |
| Energy and Infrastructure | Current Sensors | | | | ■ | ■ | | | | | |
| | Nuclear Storage and Operations | ■ | | | ■ | | | | ■ | | |
| | Strain & Temperature Monitoring-Cables, Wind Turbine blades, Concrete, Bridges | | | | | | | | | ■ | ■ |
| | Infrastructure - LiDAR | | | | ■ | | ■ | | | | |
| Biomedical | Shape Sensing | ■ | ■ | ■ | | ■ | | | | ■ | |
| | Medical Probes - Pressure Sensing, Illumination | ■ | | ■ | ■ | | | ■ | ■ | ■ | |
| | Haptic Sensing | ■ | | ■ | ■ | | | | | ■ | |
| | Optical Coherence Tomography (OCT) | ■ | | | ■ | | | | | | |
| | Spectroscopy, Confocal Microscopy | ■ | | | ■ | | | | ■ | | |
| | DNA Sequencing, Flow Cytometry | ■ | | | ■ | | | | | | |
| Telecommunications | Erbium Doped Fiber Amplifiers (EDFAs) & Radiation tolerant EDFAs | ■ | | | | | ■ | | | ■ | |
| | High Power Amplifiers - EDFAs & Ytterbium Erbium Doped Fiber Amplifiers (YEDFAs) | ■ | | | | | ■ | ■ | ■ | ■ | |
| | OEM Amplifier GainBlock | | | | | | ■ | | | | |
| | Silicon Photonics | ■ | | | | | | | | | |
| | Fused Taper Couplers | ■ | | | | | | | | | |
| | Coherent Communications and Lyot Depolarizers | | | | ■ | | | | | | |
| | Raman Amplifiers | ■ | | | ■ | | | | | | |
| | Space Division Multiplexing (SDM) | | | ■ | | | | | | | |
| | Multimode Pumps | | | | | | | | ■ | | |
| Industrial (Process Monitoring) | Metrology | ■ | | ■ | ■ | | | | | | |
| | Condition Monitoring | ■ | | | | | | | | ■ | |
| | Temperature Sensing | ■ | ■ | ■ | | | | | ■ | ■ | ■ |
| | Faraday Effect Current Sensors | ■ | | | ■ | ■ | | | | | |
| | Embedded Sensors | ■ | ■ | ■ | ■ | | | | ■ | ■ | |
| | Chemical Sensing | ■ | ■ | | | | | | ■ | ■ | |
| | Pressure Sensing | ■ | ■ | | ■ | | | | | ■ | |
| | Lithography | ■ | | ■ | ■ | | | | | | |
| | Phase Doppler Anemometry (PDA) | ■ | | | ■ | | | | | | |
| Fiber Lasers and Amplifiers | Fiber Lasers, Amplifiers, Pre-Amplifiers, Power Delivery | | | | ■ | | ■ | ■ | ■ | | |
| Components and Devices | Couplers - Standard and PM | ■ | | ■ | ■ | | | | | | |
| | ASE Light Sources | ■ | | | | | ■ | | | | |
| | Delay Lines | ■ | | | ■ | | | | | | |
| | Lyot Depolarizers | | | | ■ | | | | | | |
| | Laser Diode Pigtails | ■ | | | | | | | ■ | | |
| | Quarter Waveplates | | | | ■ | | | | | | |
| | Modulators | ■ | | | ■ | | | | | | |
| | Pump Combiners | | | | | | | ■ | ■ | | |
| | Fiber Bragg Gratings (FBGs) | ■ | ■ | ■ | ■ | | ■ | ■ | | ■ | |
| | LiDAR | ■ | | | | | ■ | | | | |

# SM FIBER

## For Harsh Environments, Ultra Bend Insensitive, RGB and Near Infra Red





For ultraviolet, visible and near IR transmission, EDFA pigtailing, sensors and tethered platforms.

The Single-mode (SM) range of fibers has been designed to perform in a wide range of challenging applications using wavelengths between 450nm and 1650nm.

The SM-SC range of fibers both extends the range into the UV and also enables use in harsh environments. The fiber offers minimal photo-darkening and reduced susceptibility to the effects of hydrogen ingression when compared with conventional, germanosilicate cored fibers.

The SM range of fibers are offered with a range of numerical apertures from 0.10 to 0.42.

The high NA variants reduce bend-induced loss to levels dramatically below those of standard telecommunication fibers and even exceed the performance of G.657.B3 fiber. This allows them to be used in bends of 10mm diameter or smaller.

The high germania content fibers have considerably enhanced photosensitivity, making them ideal for the fabrication of fiber Bragg gratings (FBGs).

A range of harsh environment coatings are available, including carbon, polyimide and high temperature acrylate.

## RANGES OF SPECIALTY SINGLE-MODE OPTICAL FIBER

**SM Fiber for visible RGB through to near IR**
For visible and near IR transmission, EDFA pigtailing, acoustic sensors and depolarized FOGs.

**Ultra-Thin SM Fibers**
For sensing applications in extremely small spaces.

**High Temperature Acrylate Coated SM Fiber**
For medium to high temperature applications.

**Polyimide Coated SM Fiber**
For embedded and high temperature applications.

**Dual Band Carbon Coated SM Fiber**
For harsh environments with medium to high temperature applications.

**Dual Band Bend Insensitive Fiber**
Telecoms style bend insensitive fibers with specialty coatings.

**Pure Silica Core SM Fiber**
For hydrogen, radiation and UV applications.

# SM FIBER FOR VISIBLE RGB THROUGH TO NEAR IR

## 450NM TO 1650NM SINGLE-MODE TRANSMISSION

- 125/245µm fiber for SM transmission from 450nm–1650nm
- 80/170µm fiber for high reliability, small form-factor telecom components
- 50/71µm and 50/110µm fiber for applications where space is very limited
- Ultra-low & low profile, bend-insensitive fiber for de-polarized FOGs, acoustic sensors & small form-factor sensor components
- High NAs for excellent bend-insensitivity
- High Ge content offering intrinsic photosensitivity for FBG inscription without hydrogenation

## TYPICAL APPLICATIONS

- Hydrophones/ Geophones
- Telemetry
- Down-link fibers
- FBGs
- DTS/DAS/DSS
- Laser diode pigtails
- Biomedical probes
- Couplers

## SPECIFICATIONS

125µm diameter SM specialty fibers

| | SM450 | SM600 | SM750 | SM800 (5.6/125) | SM980 (3.7/125) | SM980 (4.5/125) | SM980 (5.8/125) |
|---|---|---|---|---|---|---|---|
| Operating Wavelength (nm) | 488–633 | 633–780 | 780–830 | 830–980 | 980–1550 | | |
| Cut-Off Wavelength (nm) | 350–450 | 500–600 | 610–750 | 660–800 | 870–970 | | |
| Numerical Aperture | 0.10–0.14 | | | | 0.21–0.23 | 0.17–0.19 | 0.13–0.15 |
| Mode Field Diameter (µm) | 2.8–4.1 @488nm | 3.6–5.3 @633nm | 4.4–6.5 @780nm | 4.7–6.9 @830nm | 3.4–4.0 @980nm | 4.2–4.9 @980nm | 5.3–6.4 @980nm |
| Attenuation (dB/km) | ≤50 @488nm | ≤15 @633nm | ≤5.0 @780nm | ≤5.0 @830nm | ≤2.0 @980nm | | |
| Proof Test (%) | 1, 2 or 3 (100, 200 or 300 kpsi) | | | | | | |
| Cladding Diameter (µm) | 125 ± 1 | | | | | | |
| Core Cladding Concentricity (µm) | ≤0.75 | ≤1.0 | | | ≤0.50 | | |
| Coating Diameter (µm) | 245 ± 7 | | | | | | |
| Coating Type | Dual Acrylate | | | | | | |
| Operating Temperature (°C) | -55 to +85 | | | | | | |





## SPECIFICATIONS CONTINUED

125µm diameter SM specialty fibers

| | SM1500 | | | |
|---|---|---|---|---|
| | (4.2/125) | (6.4/125) | (7.8/125) | (9/125) |
| Operating Wavelength (nm) | 1520–1650 | | | |
| Cut-Off Wavelength (nm) | 1350–1520 | | | 1300–1500 |
| Numerical Aperture | 0.29–0.31 | 0.19–0.21 | 0.15–0.17 | 0.13–0.15 |
| Mode Field Diameter (µm) | 4.0–4.5 @1550nm | 6.0–6.8 @1550nm | 7.4–8.6 @1550nm | 8.5–9.9 @1550nm |
| Attenuation (dB/km) @1550nm | ≤1.5 | ≤0.5 | ≤0.4 | ≤0.35 |
| Proof Test (%) | 1, 2 or 3 (100, 200 or 300 kpsi) | | | |
| Cladding Diameter (µm) | 125 ± 1 | | | |
| Core Cladding Concentricity (µm) | ≤0.50 | ≤0.75 | | ≤0.4 |
| Coating Diameter (µm) | 245 ± 7 | | | |
| Coating Type | Dual Acrylate | | | |
| Operating Temperature (°C) | -55 to +85 | | | |

Silicon photonic fiber

| | SM1500ES(3/125) |
|---|---|
| Operating Wavelength (nm) | 1510–1650 |
| Cut-Off Wavelength (nm) | 1400–1500 |
| Numerical Aperture | 0.38–0.42 |
| Mode Field Diameter (µm) | 3.0–3.4 @1550nm |
| Attenuation (dB/km) | ≤30 @1550nm |
| Proof Test (%) | 1 (100 kpsi) |
| Cladding Diameter (µm) | 125 ± 1 |
| Core Cladding Concentricity (µm) | ≤0.3 |
| Coating Diameter (µm) | 245 ± 7 |
| Coating Type | Dual Acrylate |
| Operating Temperature (°C) | -55 to +85 |

## SPECIFICATIONS CONTINUED

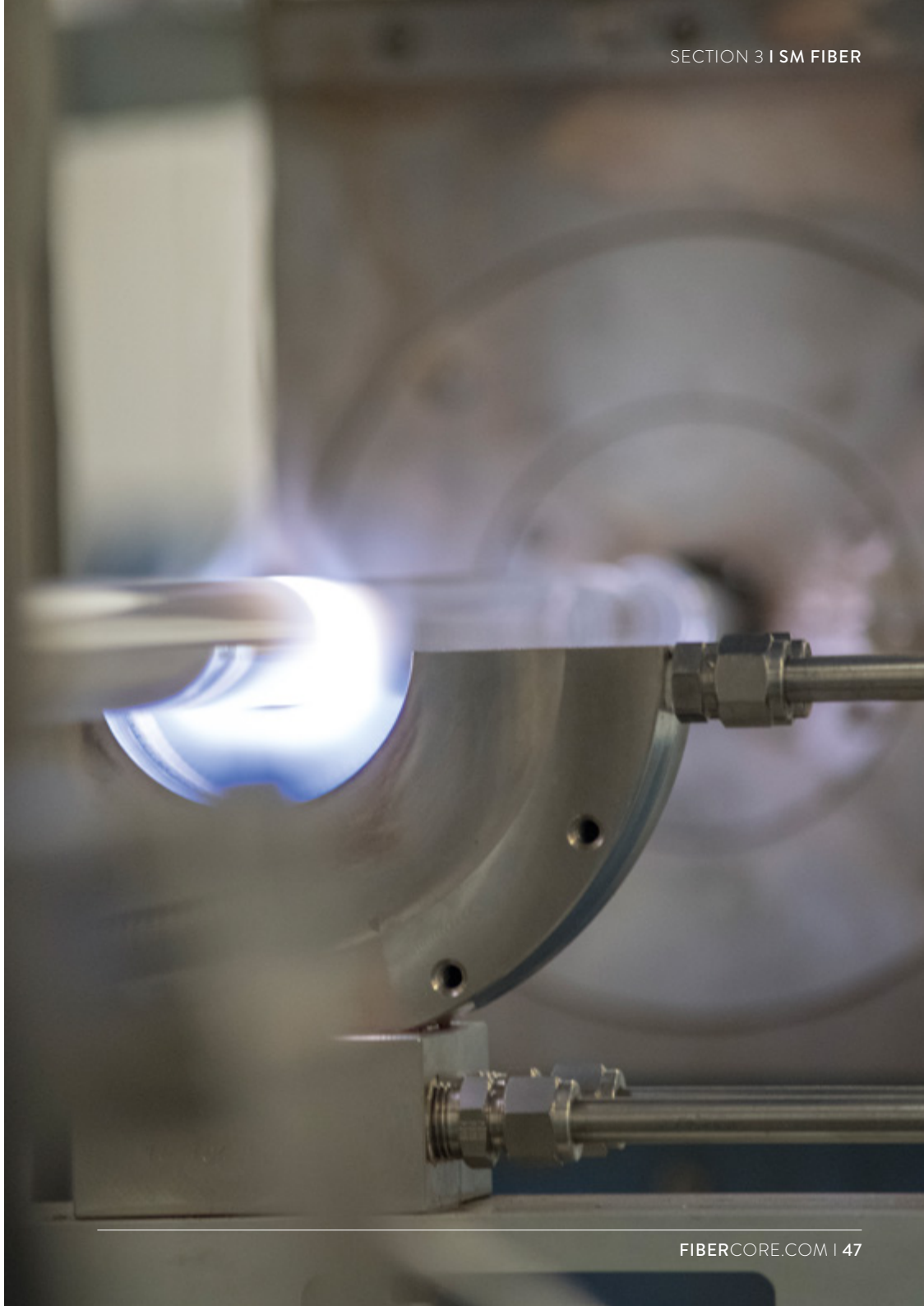
Reduced diameter SM specialty fibers

| | SM800(4.2/80) | SM980(4.5/80) | SM1250(5.4/80) | SM1250(9/80) |
|---|---|---|---|---|
| Operating Wavelength (nm) | 830–980 | 980–1550 | 1310–1550 | |
| Cut-Off Wavelength (nm) | 660–800 | 870–970 | 1150–1250 | |
| Numerical Aperture | 0.14–0.18 | 0.17–0.19 | 0.19–0.21 | 0.11–0.13 |
| Mode Field Diameter (µm) | 3.7–4.9 @830nm | 4.2–4.9 @980nm | 5.0–5.7 @1310nm | 8.2–9.9 @1310nm |
| Attenuation (dB/km) | ≤3.0 @830nm | ≤2.0 @980nm | ≤1.0 @1310nm | ≤2.0 @1310nm |
| Proof Test (%) | 1, 2 or 3 (100, 200 or 300 kpsi) | | | |
| Cladding Diameter (µm) | 80 ± 1 | | | |
| Core Cladding Concentricity (µm) | ≤0.50 | | | |
| Coating Diameter (µm) | 170 ± 5 | | | |
| Coating Type | Dual Acrylate | | | |
| Operating Temperature (°C) | -55 to +85 | | | |

| | SM1500 | | | | |
|---|---|---|---|---|---|
| | (4.2/50) | (4.2/80) | (5.3/80) | (6.4/80) | (7.8/80) |
| Operating Wavelength (nm) | 1520–1650 | | | | |
| Cut-Off Wavelength (nm) | 1350–1520 | | | | |
| Numerical Aperture | 0.29–0.31 | | 0.23–0.25 | 0.19–0.21 | 0.15–0.17 |
| Mode Field Diameter (µm) | 4.0–4.5 @1550nm | | 5.0–5.6 @1550nm | 6.0–6.8 @1550nm | 7.4–8.6 @1550nm |
| Attenuation (dB/km) @1550nm | ≤2.0 | ≤1.5 | ≤0.8 | ≤0.5 | ≤0.35 |
| Proof Test (%) | 1, 2 or 3 (100, 200 or 300 kpsi) | | | | |
| Cladding Diameter (µm) | 50 ± 1 | 80 ± 1 | | | |
| Core Cladding Concentricity (µm) | ≤0.50 | | | | |
| Coating Diameter (µm) | 110 ± 6 | 170 ± 5 | | | |
| Coating Type | Single Acrylate | Dual Acrylate | | | |
| Operating Temperature (°C) | -55 to +85 | | | | |







# ULTRA-THIN SM FIBERS
## FOR SENSING APPLICATIONS IN EXTREMELY SMALL SPACES

- Available with acrylate or polyimide coating
- Polyimide coating allows in-vivo use after autoclave sterilizing
- Excellent bend-insensitivity and reliability under tight bends or in tight coils
- Single mode operation from 1260–1650nm

## TYPICAL APPLICATIONS

- Biomedical in-vivo sensors and catheters
- Embedded sensors for structural health monitoring
- High temperature sensors (polyimide only)
- FBGs

## SPECIFICATIONS

| | SM1250(4.2/50) | SM1500(4.2/50) |
|---|---|---|
| Operating Wavelength (nm) | 1310 | 1550 |
| Cut-Off Wavelength (nm) | 1190–1290 | 1350–1500 |
| Numerical Aperture | 0.25–0.27 | 0.29–0.31 |
| Mode Field Diameter (µm) | 4.0–4.4 | 4.05–4.5 |
| Attenuation (dB/km) | Dual Acrylate: ≤5 @1310nm<br>Polyimide: ≤10 @1310nm | Dual Acrylate: ≤2 @1550nm<br>Polyimide: ≤3 @1550nm |
| Proof Test (%) | 1 (100 kpsi) | |
| Cladding Diameter (µm) | Dual Acrylate: 50 ± 1<br>Polyimide: 50 ± 2 | Dual Acrylate: 50 ± 1<br>Polyimide: 50 ± 2 |
| Core Cladding Concentricity (µm) | Dual Acrylate: ≤0.5<br>Polyimide: ≤0.5 | Dual Acrylate: ≤0.5<br>Polyimide: ≤1.0 |
| Coating Diameter (µm) | Dual Acrylate: 110 ± 5<br>Polyimide: 70 ± 5 | Dual Acrylate: 110 ± 6<br>Polyimide: 71 ± 5 |
| Coating Type | Dual Acrylate<br>Polyimide | |
| Operating Temperature (°C) | Dual Acrylate: -55 to +85<br>Polyimide: -55 to +300 | |





# HIGH TEMPERATURE ACRYLATE COATED SM FIBER

- High temperature acrylate coatings to withstand temperatures up to 150°C continuous
- Low profile, bend insensitive fibers for downhole seismic sensors, high temperature distributed pressure sensors, temperature sensors, down-links and telemetry
- Enhanced photosensitivity

## TYPICAL APPLICATIONS

- Geophones
- DTS, DAS, DSS and DPS
- Embedded sensors
- Fiber Bragg Gratings (FBGs)
- Temperature sensors

## SPECIFICATIONS

| | SM1500 (5.3/80)HT | SM1500 (6.4/80)HT | SM1500 (6.4/125)HT | SM1500 (7.8/125)HT | SM1500 (9/125)HT |
|---|---|---|---|---|---|
| Operating Wavelength (nm) | 1520–1650 | | | | |
| Cut-Off Wavelength (nm) | 1350–1520 | | | | 1300–1520 |
| Numerical Aperture | 0.23–0.24 | 0.19–0.21 | | 0.15–0.17 | 0.13–0.15 |
| Mode Field Diameter (µm) | 5.0–5.6 @1550nm | 6.0–6.8 @1550nm | | 7.3–8.3 @1550nm | 8.5–9.9 @1550nm |
| Attenuation (dB/km) @1550nm | ≤0.8 | ≤0.5 | | ≤0.4 | ≤0.35 |
| Proof Test (%) | 1, 2 or 3 (100, 200 or 300 kpsi) | | | | |
| Cladding Diameter (µm) | 80 ± 1 | | 125 ± 1 | | |
| Core Cladding Concentricity (µm) | ≤0.5 | | | ≤0.75 | ≤0.4 |
| Coating Diameter (µm) | 170 ± 5 | | 245 ± 7 | | |
| Coating Type | High Temperature Acrylate | | | | |
| Operating Temperature (°C) | -55 to +150 | | | | |

# POLYIMIDE COATED SM FIBER

## FOR EMBEDDED AND HIGH TEMPERATURE APPLICATIONS

- Polyimide coated enabling survival at temperatures up to 300°C
- Can be autoclave sterilised
- Ultra-low and low profile, bend insensitive fiber for downhole seismic geophone sensors and high temperature distributed pressure and temperature sensors
- Enhanced photosensitivity
- Maintains composite material strength when embedded

## TYPICAL APPLICATIONS

- Downhole sensors
- Geophones
- DTS, DAS, DSS and DPS
- Embedded sensors
- FBGs
- Biomedical in vivo sensors
- High temperature sensors

## SPECIFICATIONS

| | SM1250 (10.4/125)P * | SM1500 (4.2/125)P | SM1500 (6.4/125)P | SM1500 (7.8/125)P | SM1500 (9/125)P |
|---|---|---|---|---|---|
| Operating Wavelength (nm) | 1260–1650 | 1520–1650 | | | |
| Cut-Off Wavelength (nm) | 1190–1330 | 1350–1520 | | | 1300–1500 |
| Numerical Aperture | 0.11–0.14 | 0.29–0.31 | 0.19–0.21 | 0.15–0.17 | 0.13–0.15 |
| Mode Field Diameter (µm) | 9.6–11.2 @1550 | 4.0–4.5 @1550nm | 6.0–6.8 @1550nm | 7.4–8.6 @1550nm | 8.5–9.9 @1550nm |
| Attenuation (dB/km) | ≤0.7 @1310nm ≤0.6 @1550nm | ≤2.5 @1550nm | ≤0.75 @1550nm | ≤0.7 @1550nm | ≤0.6 @1550nm |
| Proof Test (%) | 1 or 2 (100 or 200 kpsi) | | | | |
| Cladding Diameter (µm) | 125 ± 2 | | | | |
| Core Cladding Concentricity (µm) | ≤0.75 | ≤0.5 | ≤0.75 | | ≤0.4 |
| Coating Diameter (µm) | 155 ± 5 | | | | |
| Coating Type | Polyimide | | | | |
| Operating Temperature (°C) | -55 to +300 | | | | |





## SPECIFICATIONS

| | SM1500 (4.2/50)P | SM1500 (4.2/80)P | SM1500 (5.3/80)P * | SM1500 (6.4/80)P * | SM1500 (7.8/80)P |
|---|---|---|---|---|---|
| Operating Wavelength (nm) | 1520–1650 | | | | |
| Cut-Off Wavelength (nm) | 1350–1520 | | | | |
| Numerical Aperture | 0.29–0.31 | | 0.23–0.25 | 0.19–0.21 | 0.15–0.17 |
| Mode Field Diameter (µm) | 4.0–4.5 @1550nm | | 5.0–5.6 @1550nm | 6.0–6.8 @1550nm | 7.4–8.6 @1550nm |
| Attenuation (dB/km) @1550nm | ≤3.0 | ≤2.5 | ≤1.5 | ≤0.75 | ≤0.7 |
| Proof Test (%) | 1 or 2 (100 or 200 kpsi) | | | | |
| Cladding Diameter (µm) | 50 ± 2 | 80 ± 2 | | | |
| Core Cladding Concentricity (µm) | ≤1.0 | ≤0.5 | | | ≤0.75 |
| Coating Diameter (µm) | 71 ± 5 | 102 ± 5 | | | |
| Coating Type | Polyimide | | | | |
| Operating Temperature (°C) | -55 to +300 | | | | |

* Special easier to strip polyimide coating available for window stripping, for applications such as FBGs.

# DUAL BAND CARBON COATED SM FIBER

- Hermetic coating
- High operating temperature, up to 150°C and 300°C
- Low attenuation
- Excellent core cladding concentricity
- Hydrogen resistant
- Improved fatigue resistance

## TYPICAL APPLICATIONS

- Distributed temperature sensors (DTS)
- Distributed acoustic sensors (DAS)
- Distributed strain sensors (DSS)

## SPECIFICATIONS

| | SM1250(10.4/125) |
|---|---|
| Operating Wavelength (nm) | 1260–1650 |
| Cut-Off Wavelength (nm) | 1190–1330 |
| Numerical Aperture | 0.11–0.14 |
| Mode Field Diameter (µm) | 9.6–11.2 |
| Attenuation (dB/km) | Carbon High Temperature: <0.6 @1310nm<br><0.4 @1550nm<br>Carbon Polyimide: <0.7 @1310nm<br><0.6 @1550nm |
| Proof Test (%) | 1 or 2 (100 or 200 kpsi) |
| Cladding Diameter (µm) | 125 ± 2 |
| Core Cladding Concentricity (µm) | ≤1.0 |
| Coating Diameter (µm) | Carbon High Temperature: 245 ± 15<br>Carbon Polyimide: 155 ± 5 |
| Coating Type | Carbon High Temperature<br>Carbon Polyimide |
| Operating Temperature (°C) | Carbon High Temperature: -55 to +150<br>Carbon Polyimide: -55 to +300 |





# DUAL BAND BEND INSENSITIVE FIBER

## TELECOMS STYLE BEND INSENSITIVE FIBERS WITH SPECIALTY COATINGS

- Low splice loss to standard telecoms fibers
- Dual band 1310nm and 1550nm transmission
- High temperature coatings for use up to 150°C and 300°C
- Low attenuation
- G.657.B3 level bend insensitivity

## TYPICAL APPLICATIONS

- Low weight/small size avionics cables
- Data center transceivers
- Oil & Gas distributed sensors
- Silicon photonics
- Well integrity monitoring
- FBGs for strain and temperature monitoring

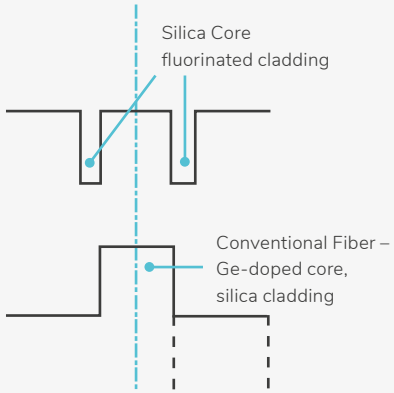
## SPECIFICATIONS

| | SM1250B3(9.3/80) | SM1250B3(9.8/125) |
|---|---|---|
| Operating Wavelength (nm) | 1310–1625 | |
| Cut-Off Wavelength (nm) | 1100–1260 | |
| Numerical Aperture | 0.13 | |
| Mode Field Diameter (µm) | 7.6–9.1@1310nm &<br>8.5–10.0@1550nm | 8.0–9.2 @1310nm &<br>9.0–10.4 @1550nm |
| Attenuation (dB/km) | ≤0.7 @1310nm & ≤0.5 @1550nm | ≤0.6 @1310nm & ≤0.4 @1550nm |
| Proof Test (%) | 2 (200 kpsi) | |
| Cladding Diameter (µm) | 80 ± 1 | Carbon High Temperature: 125 ± 2<br>Polyimide: 125 ± 1 |
| Core Cladding Concentricity (µm) | <1.0 | |
| Coating Diameter (µm) | 170 ± 5 | Carbon High Temperature: 245 ± 15<br>Polyimide: 155 ± 5 |
| Coating Type* | Dual Layer Acrylate | Carbon High Temperature<br>Polyimide |
| Operating Temperature (°C) | -55 to +85 | Carbon High Temperature: -55 to +150<br>Polyimide: -55 to +300 |
| Bend Induced Attenuation @1550nm (dB/turn) | | |
| 10mm Bend Radius | 0.03 | ≤0.03 |
| 7.5mm Bend Radius | 0.08 | ≤0.08 |
| 5mm Bend Radius | 0.10 | ≤0.15 |

* Other coating packages are available upon request

# PURE SILICA CORE SM FIBER

- Excellent hydrogen resistance
- Reduced radiation induced attenuation
- Various NAs for bend insensitivity
- Coatings for temperature use up to 150°C and 300°C
- Carbon option for hermetic sealing
- Hydrogen test data available




## TYPICAL APPLICATIONS

- DTS/DAS/DSS
- Sensing in radiation environments
- Microscopy
- Sensing using UV light
- Coiled acoustic sensors
- Biomedical probes
- Sensing in hydrogen environments

See specification details on page 55.

## COATINGS ORDER GUIDE

- Dual Layer Acrylate = No order code
- Carbon High Temperature = CHT
- Carbon Polyimide = CP
- Polyimide = P

## ORDER CODE EXAMPLE

SM1250SC(9/125) with a
Carbon High Temperature coating:
SM1250SC(9/125)CHT





## SPECIFICATIONS

| | SM300-SC | SM400-SC | SM1250SC (9/125)* | SM1500SC (7/80) | SM1500SC (7/125) |
|---|---|---|---|---|---|
| **Operating Wavelength (nm)** | 320–430 | 405–532 | 1260–1650 | 1520–1650 | |
| **Cut-Off Wavelength (nm)** | | | | | |
| Dual Layer Acrylate | ≤310 | ≤400 | 1190–1290 | 1400–1500 | |
| Polyimide (P) | - | - | 1190–1290 | 1350–1520 | |
| **Numerical Aperture** | 0.12–0.14 | | 0.13–0.15 | 0.17–0.19 | |
| **Mode Field Diameter (µm)** | 2.0–2.4 @350nm | 2.7–3.3 @480nm | 8.3–9.6 @1550nm | 6.7–7.6 @1550nm | |
| **Attenuation (dB/km)** | | | | | |
| Dual Layer Acrylate | ≤100@350nm ≤130@430nm | ≤50@430nm ≤30@532nm | ≤0.6@1310nm ≤0.4@1550nm | ≤0.4@1550nm | ≤0.7@1550nm |
| Carbon High Temperature (CHT) | - | - | ≤0.6@1310nm ≤0.4@1550nm | - | ≤0.7@1550nm |
| Carbon Polyimide (CP) | - | - | ≤0.8@1310nm ≤0.8@1550nm | - | ≤0.7@1550nm |
| Polyimide (P) | - | - | ≤0.8@1310nm ≤0.8@1550nm | ≤0.75@1550nm | ≤0.7@1550nm |
| **Proof Test (%)** | 1 or 2 (100 or 200 kpsi) | | | | |
| **Cladding Diameter (µm)** | 125 ± 1 | | 125 ± 2 | 80 ± 1 | 125 ± 2 |
| **Core Cladding Concentricity (µm)** | ≤0.75 | | | | |
| **Coating Diameter (µm)** | | | | | |
| Dual Layer Acrylate | 245 ± 7 | | | 170 ± 5 | 245 ± 7 |
| Carbon High Temperature | - | - | 245 ± 15 | - | 245 ± 15 |
| Carbon Polyimide | - | - | 155 ± 5 | - | 155 ± 5 |
| Polyimide | - | - | 155 ± 5 | 105 ± 5 | 155 ± 5 |
| **Coating Type** | Dual Layer Acrylate | | Dual Layer Acrylate, CHT, CP, P* | Dual Layer Acrylate, P | Dual Layer Acrylate, CHT, CP, P |
| **Operating Temperature (°C)** | | | | | |
| Dual Layer Acrylate | -55 to +85 | | | | |
| Carbon High Temperature | - | - | -55 to +150 | - | -55 to +150 |
| Carbon Polyimide | - | - | -55 to +300 | - | -55 to +300 |
| Polyimide | - | - | -55 to +300 | | |

* Special polyimide, for strip and recoat FBGs, available.

# PHOTOSENSITIVE FIBER

## For Temperature, Strain and Biomedical Sensors and FBGs





# HIGH PHOTOSENSITIVITY FIBERS FOR RAPID MANUFACTURE OF FBGS

Fibercore's photosensitive (PS) series of fibers have a high germania and boron co-doped core composition, enabling high reflectivity gratings to be written without the need to hydrogen-load. The mode field diameters of the boron co-doped fibers are engineered so gratings may be spliced into standard telecommunications, or pigtailing fiber with minimal excess loss.

Fibercore offers a series of high germania SM1500 single-mode fibers for distributed sensors and splice free sensor arrays. The cores of these fibers contain more than 5X the germania content of standard telecommunications fibers. This enables gratings to be written with or without hydrogen loading, whilst maintaining low attenuation around 1550nm. The addition of polyimide coated versions of these fibers extends the range, to cover high temperature harsh environment applications.

## TYPICAL APPLICATIONS

- Temperature sensors
- Strain sensors
- Biomedical sensors
- 3D shape sensing
- Pressure sensors

## THERE ARE TWO RANGES IN THIS SECTION

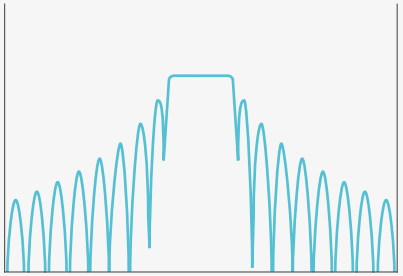
**Boron Doped Photosensitive Fiber**
Intrinsically photosensitive fibers for Bragg grating fabrication.

**Highly Germanium Doped Fiber**
High NA single-mode fibers in three different fiber diameters for writing FBGs with or without hydrogenation.

# BORON DOPED PHOTOSENSITIVE FIBER

## INTRINSICALLY PHOTOSENSITIVE FOR GRATING FABRICATION

- Rapid formation of high reflectivity FBGs – without hydrogenation
- For use 'straight from the shelf'
- Strong and consistent photosensitivity
- Compatible with standard telecommunications and pigtailing fibers
- Minimal excess loss during splicing



## TYPICAL APPLICATIONS

- FBGs
- Fiber lasers
- Temperature sensors
- Strain sensors
- Biomedical sensors

## SPECIFICATIONS

| | PS750 | PS980 | PS1250/1500 |
|---|---|---|---|
| Operating Wavelength (nm) | 780–980 | 980–1310 | 1260–1650 |
| Cut-Off Wavelength (nm) | 610–750 | 850–950 | 1100–1260 |
| Numerical Aperture | 0.12–0.14 | | |
| Mode Field Diameter (µm) | 4.4–5.9 @780nm | 5.6–6.8 @980nm | 8.8–10.6 @1550nm |
| Attenuation (dB/km) | 30 (typical) @780nm | 20 (typical) @980nm | 10 (typical) @1310nm<br>120 (typical) @1550nm |
| Proof Test (%) | 1 (100 kpsi) | | |
| Polarization Mode Dispersion (ps/m) | - | - | ≤0.006 (typical) @1310nm |
| Cladding Diameter (µm) | 125 ± 1 | | |
| Coating Diameter (µm) | 245 ± 7 | | |
| Coating Type | Dual Acrylate | | |
| Operating Temperature (°C) | -55 to +85 | | |

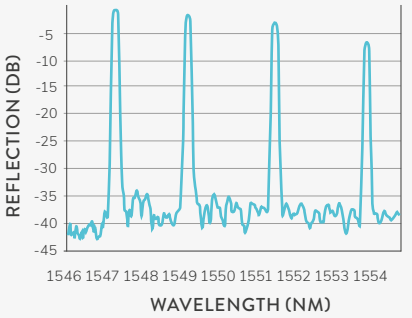




# HIGHLY GERMANIUM DOPED FIBER

## INTRINSICALLY PHOTOSENSITIVE FIBERS FOR GRATING FABRICATION IN DISTRIBUTED STRAIN AND TEMPERATURE SENSORS

- More than 5X Germania level of standard telecommunications fibers
- Suitable for inscription of long arrays with or without hydrogen loading
- High temperature polyimide coating variants available for harsh environment applications (see pg. 51 – Polyimide Coated SM Fiber)

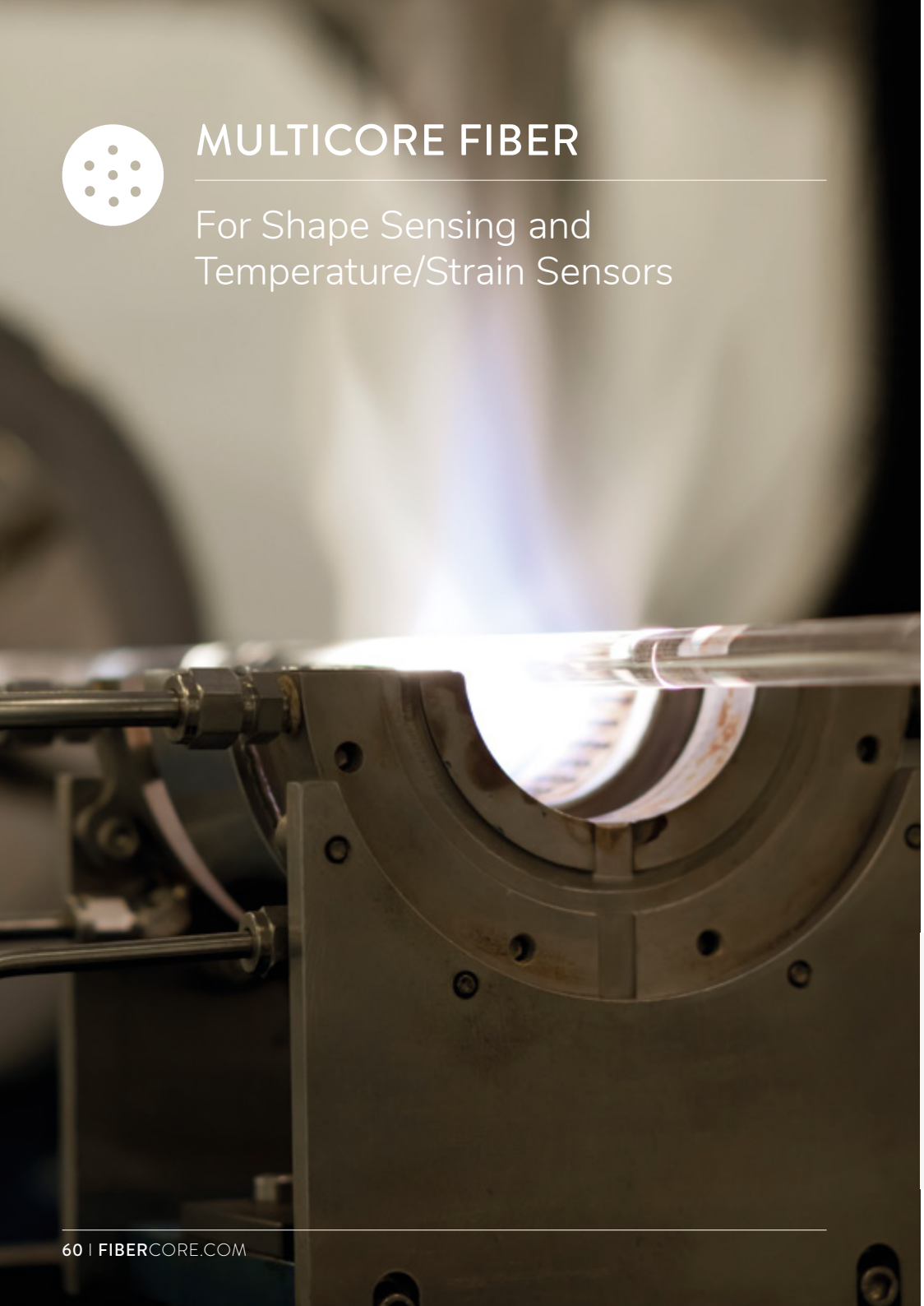



## TYPICAL APPLICATIONS

- Temperature sensors
- Strain sensors
- Biomedical sensors
- Hydrophones
- Geophones
- Fiber Bragg Gratings (FBGs)

## SPECIFICATIONS

| | SM1500(4.2/50) | SM1500(4.2/80) | SM1500(4.2/125) |
|---|---|---|---|
| Operating Wavelength (nm) | 1520–1650 | | |
| Cut-Off Wavelength (nm) | 1350–1500 | | |
| Numerical Aperture | 0.29–0.31 | | |
| Mode Field Diameter (µm) | 4.0–4.5 @1550nm | | |
| Attenuation (dB/km) | ≤2.0 @1550nm | ≤1.5 @1550nm | |
| Proof Test (%) | 1, 2 or 3 (100, 200 or 300 kpsi) | | |
| Cladding Diameter (µm) | 50 ± 1 | 80 ± 1 | 125 ± 1 |
| Core Cladding Concentricity (µm) | ≤0.5 | | |
| Coating Diameter (µm) | 110 ± 6 | 170 ± 5 | 245 ± 7 |
| Coating Type | Single Acrylate | Dual Acrylate (Single by Special Order) | |
| Operating Temperature (°C) | -55 to +85 | | |



# MULTICORE FIBER

## For Shape Sensing and Temperature/Strain Sensors





# MULTICORE FIBERS FOR SHAPE SENSING, SMALL FOOTPRINT APPLICATIONS AND MULTI-VARIABLE SENSING

Multicore fibers can be used to dramatically reduce the amount of space required for exchanges connecting to Photonic Integrated Circuits, and other applications that require precise alignment of several optical cores in a small space.

By combining multiple cores for multiple signals into a single multicore fiber with a 125 micron or 250 micron cladding, designers have a new capability not offered by single fibers. In addition, the fiber has photosensitive cores, allowing Fiber Bragg Grating (FBG) inscription into each core. While current product offerings are 4 and 7 single mode cores, Fibercore has the capability to design and manufacture other types of designs to meet specific application needs.

## TYPICAL APPLICATION SECTORS

- Biomedical
- Telecommunications
- Components
- Defence
- Industrial

## THERE ARE TWO RANGES IN THIS SECTION

### Multicore Fiber

4 and 7 core variants for 1550nm sensor and telecommunication applications.

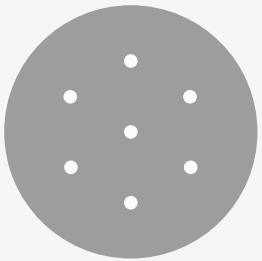
### Fan Outs

Packaged fused fiber fanout unit to breakout the signal lines of the multicore fibers.

# MULTICORE FIBER

## SINGLE FIBER WITH MULTIPLE CORES

- Simultaneous transmission of different signals down different cores
- Photosensitive core designs for FBG inscription
- Custom designs possible – more cores, mismatched cores, different core positions



### TYPICAL APPLICATIONS

- Temperature and strain sensors
- Structural Health Monitoring (SHM)
- Active Optical Cables (AOC)
- Space Division Multiplexing (SDM) transmission cables
- Silicon photonics
- Quantum Key Distribution (QKD) (non-spun)

### SPECIFICATIONS

| | SM-4C1500 (8.0/125)/001 | SM-7C1250 (5.2/125) | SM-7C1500 (6.1/125) | SSM-7C1500 (6.1/125) |
|---|---|---|---|---|
| Operating Wavelength (nm) | 1520–1650 | 1310 | 1520–1650 | |
| Cut-Off Wavelength (nm) | 1300–1500 | 1190–1310 | 1300 –1500 | |
| Numerical Aperture | 0.14–0.17 | 0.20–0.22 | | |
| Mode Field Diameter (µm) | 7.4–8.5 @1550nm | 4.8–5.6 @1310nm | 5.7–6.5 @1550nm | |
| Proof Test (%) | 1 (100 kpsi) | | | |
| Cladding Diameter (µm) | 125 ± 1 | | | |
| Core Spacing (µm) | 50 (nominal) | 35 (nominal) | | |
| Core Position Shape | Square | Hexagon plus central core | | Hexagon plus central core Spun |
| Coating Diameter (µm) | 245 ± 12 | 245 ± 7 | 245 ± 10 | 200 ± 7 |
| Coating Type | Dual Acrylate | | | |
| Operating Temperature (°C) | -55 to +85 | | | |

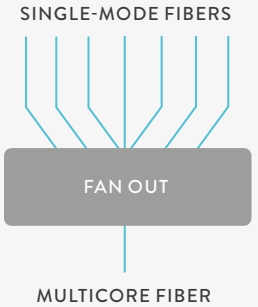




# FAN OUTS

## PLUG-AND-PLAY COMPONENT FOR MULTICORE FIBERS

- Compact package size
- High data rates

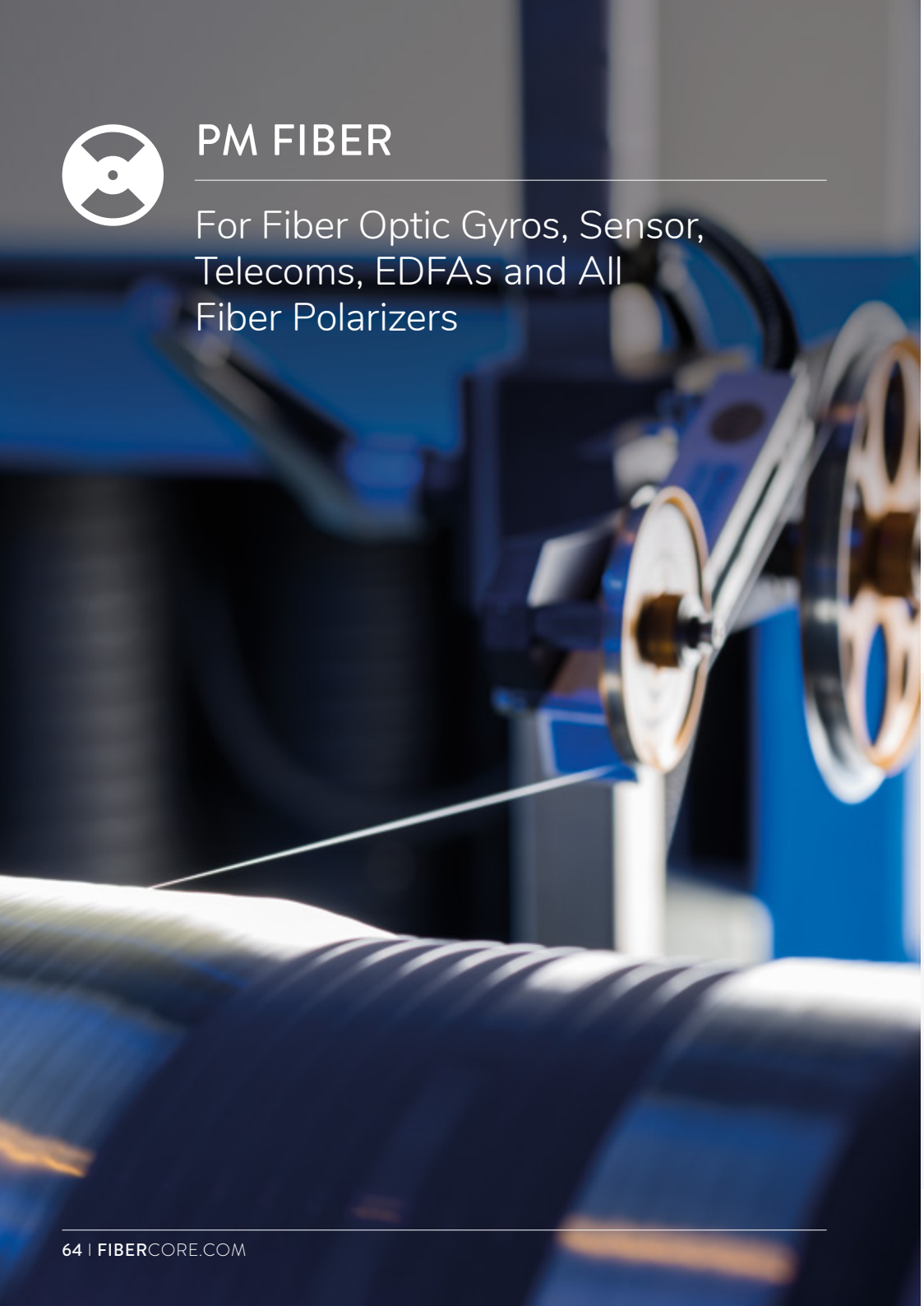



### TYPICAL APPLICATIONS

- 2D bend sensing
- Active Optical Cables (AOCs)
- Photonic Integrated Circuits
- Distributed sensing

### SPECIFICATIONS

| | FAN-4C | FAN-7C | | |
|---|---|---|---|---|
| Operating Wavelength (nm) | 1550 | 1310 | 1550 | |
| Single Core Fiber | SMF-28 or equivalent | | | |
| Multicore Fiber | SM-4C1500 (8.0/125)/001 | SM-7C1250 (5.2/125) | SM-7C1500 (6.1/125) | SSM-7C1500 (6.1/125) |
| Number of Cores | 4 | 7 | | |
| Core Configuration | Square | Hexagonal plus central core | | Spun Hexagonal plus central core |
| Insertion Loss (dB)* | 1 (typical) | 1-2 (typical) | 1 (typical) | |
| Crosstalk (dB)* | ≤-45 (typical) | | | |
| Connectorization | Single core: None, LC/PC, LC/APC, FC/PC, FC/UPC, SC/PC, SC/APC, MTP/APC and others upon request<br>Multicore: None, FC (narrow keyway), SC (all in PC or APC) and others upon request | | | |
| Operating Temperature (°C) | 0 to +85 | | | |



# PM FIBER

For Fiber Optic Gyros, Sensor, Telecoms, EDFAs and All Fiber Polarizers





## HIGHLY BIREFRINGENT (HIBI) FIBER

Designed for high-performance interferometric and polarimetric sensors, integrated optics and coherent communications.

The Bow-Tie Stress Applying Parts (SAPs) act as opposing wedges generating optimum stress distribution within the fibers, giving the very best in performance. Our Bow-Tie fibers can be customized for optimum performance for each particular application.

- 90 million meters in service worldwide
- More than 1,000,000m shipped every month

### TYPICAL APPLICATIONS

- Coherent communications
- Biomedical imaging
- Fiber optic gyroscopes

### APPLICATION SPECIFIC VARIANTS

**Standard PM Fiber**
125/245µm, bend-insensitive fibers for sensor and research applications between 488nm and 1650nm.

**Polyimide Coated PM Fiber**
125/155µm, polyimide coated fibers for high temperature embedded sensor and medical applications at 830nm, 1310nm or 1550nm.

**Telecoms PM Fiber**
125/245µm and 125/400µm fibers for telecommunications and EDFA applications at wavelengths between 980nm and 1650nm.

**PM Gyro Fiber**
80/170µm and 80/135µm broad temperature range, dual coated fibers for fiber optic gyro applications at 830nm, 1310nm or 1550nm.

**Pure Silica Core PM Fiber**
Photodarkening resistant PM fiber for UV and blue wavelengths.

**Zing™ Polarizing Fiber**
80/170µm and 125/245µm, short beat-length fibers for high performance, all-fiber polarizers.

# STANDARD PM FIBER

## HIGHLY BIREFRINGENT POLARIZATION MAINTAINING FIBERS

- Seven standard wavelengths, 488nm to 1550nm
- Maximum birefringence – Minimum stress
- Exceptional polarization maintaining ability

## TYPICAL APPLICATIONS

- Interferometric sensors
- Diode pigtails
- Coherent beam delivery
- Modulators
- Delay lines
- Spectroscopy
- Biomedical sensors
- Optical Coherence Tomography (OCT)

## SPECIFICATIONS

| | HB450 | HB600 | HB750 | HB800 | HB1000 | HB1250 | HB1500 |
|---|---|---|---|---|---|---|---|
| Operating Wavelength (nm) | 488–633 | 633–780 | 780–830 | 830–1060 | 1060–1300 | 1300–1550 | 1520–1650 |
| Cut-Off Wavelength (nm) | 350–470 | 500–600 | 610–750 | 600–800 | 840–1020 | 1030–1270 | 1230–1520 |
| Numerical Aperture | 0.10–0.13 | 0.14–0.18 | | | | | |
| Mode Field Diameter (µm) | 3.0–4.1 @488nm | 2.8–3.7 @633nm | 3.5–4.6 @780nm | 3.7–4.9 @830nm | 4.8–6.3 @1060nm | 5.8–7.9 @1310nm | 7.0–9.2 @1550nm |
| Attenuation (dB/km) | ≤100 @488nm | ≤15 @633nm | ≤8 @780nm | ≤5 @830nm | ≤3 @1060nm | ≤2 @1310nm | ≤2 @1550nm |
| Beat-Length (mm) @633nm | ≤2.0 | | | | | | |
| Proof Test (%) | 1 (100 kpsi) | | | | | | |
| Cladding Diameter (µm) | 125 ± 1 | | | | | | |
| Core Cladding Concentricity (µm) | ≤0.75 | ≤1.0 | | | | | |
| Coating Diameter (µm) | 245 ± 7 | | | | | | |
| Coating Type | Dual Layer Acrylate | | | | | | |
| Operating Temperature (°C) | -55 to +85 | | | | | | |





# POLYIMIDE COATED PM FIBER

## POLARIZATION MAINTAINING FIBER FOR HIGH TEMPERATURE APPLICATIONS

- Survives composite embedding temperatures up to 300°C
- Photosensitive core for FBG inscriptions
- Suitable for autoclave sterilization temperatures

## TYPICAL APPLICATIONS

- High temperature sensors
- Downhole sensors
- Interferometric sensors
- Medical probes
- Embedded sensors

## SPECIFICATIONS

| | HB800P | HB1250P | HB1500P |
|---|---|---|---|
| Operating Wavelength (nm) | 830–1200 | 1300–1550 | 1520–1650 |
| Cut-Off Wavelength (nm) | 600–800 | 1030–1270 | 1230–1520 |
| Numerical Aperture | 0.14–0.18 | | |
| Mode Field Diameter (µm) | 3.7–5.0 @830nm | 5.8–7.8 @1310nm | 7.0–9.2 @1550nm |
| Attenuation (dB/km) | ≤5 @830nm | ≤2 @1310nm | ≤2 @1550nm |
| Beat-Length (mm) @633nm | ≤2.0 | | |
| Proof Test (%) | 1 (100 kpsi) | | |
| Cladding Diameter (µm) | 125 ± 2 | | |
| Core Cladding Concentricity (µm) | ≤1.0 | | |
| Coating Diameter (µm) | 155 ± 5 | | |
| Coating Type | Polyimide | | |
| Operating Temperature (°C) | -55 to +300 | | |

# TELECOMS PM FIBER

## FOR EDFA PUMPS, RAMAN PUMP LYOT DEPOLARIZERS AND TELECOMMUNICATIONS APPLICATIONS

- Splice compatible with both standard SM fibers and other PM fibers
- Tested in accordance with Telecordia GR-20-CORE
- Excellent geometry for splicing
- Available in both 245µm and 400µm coating diameters

## TYPICAL APPLICATIONS

- Pump diode pigtails
- Erbium Doped Fiber Amplifier (EDFA)
- Cable Television (CATV)
- Interferometric sensors
- Lyot depolarizers

## SPECIFICATIONS

| | HB980T | HB1250T (245) | HB1250T (400) | HB1500T (245) | HB1500T (400) |
|---|---|---|---|---|---|
| Operating Wavelength (nm) | 980– 1310 | 1300–1480 | | 1520–1650 | |
| Cut-Off Wavelength (nm) | 870–970 | 1100–1290 | | 1290–1520 | |
| Numerical Aperture | 0.13– 0.15 | 0.11–0.13 | | | |
| Mode Field Diameter (µm) | 5.3–6.4 @980nm | 8.1–9.9 @1310nm | | 9.6–11.7 @1550nm | |
| Attenuation (dB/km) | ≤3 @980nm | ≤2 @1310nm | | ≤2 @1550nm | |
| Beat-Length (mm) @633nm | ≤2.0 | | | | |
| Proof Test (%) | 1 or 2 (100 or 200 kpsi) | | | | |
| Cladding Diameter (µm) | 125 ± 1 | | | | |
| Core Cladding Concentricity (µm) | ≤0.6 | | | | |
| Coating Diameter (µm) | 245 ± 7 | | 400 ± 20 | 245 ± 7 | 400 ± 20 |
| Coating Type | Dual Layer Acrylate | | | | |
| Operating Temperature (°C) | -55 to +85 | | | | |





## SPECIFICATIONS CONTINUED

Short beat-length

| | HB980T(6.6/125) | HB1250T(9/125) | HB14XXT |
|---|---|---|---|
| Operating Wavelength (nm) | 980–1310 | 1260–1650 | 1300–1650 |
| Cut-Off Wavelength (nm) | 870–970 | 1100–1250 | 1100–1290 |
| Numerical Aperture | 0.11–0.13 | | |
| Mode Field Diameter (µm) | 6.1–7.1 @980nm | 8.1–9.9 @1310nm | 9.5–11.5 @1465nm |
| Attenuation (dB/km) | ≤2 @980 | ≤2 @1310nm | ≤2 @1480nm |
| Beat-Length (mm) @633nm | ≤1.2 | | |
| Proof Test (%) | 1 or 2 (100 or 200 kpsi) | | |
| Cladding Diameter (µm) | 125 ± 1 | | |
| Core Cladding Concentricity (µm) | ≤0.4 | | ≤0.6 |
| Coating Diameter (µm) | 245 ± 7 | | |
| Coating Type | Dual Layer Acrylate | | |
| Operating Temperature (°C) | -55 to +85 | | |

# PM GYRO FIBER

## THE NO.1 FIBER FOR FIBER OPTIC GYROSCOPES

- High polarization extinction in coiled applications
- -55°C to +85°C in-coil operating range
- Tight coating diameter tolerance for high accuracy coil winding
- 80µm OD saves space and enhances lifetime
- Radiation tolerant variants for space applications
- High reliability in coiled applications
- High temperature coating variant available for downhole FOGs

## TYPICAL APPLICATIONS

- FOGs
- Current sensors
- Delay lines

## SPECIFICATIONS

Short beat-length fiber

| | HB800G-SB | HB1500G-SB (6.5/80/135) | HB1500G-SB (6.5/80/155) |
|---|---|---|---|
| Operating Wavelength (nm) | 810–1000 | 1520–1650 | |
| Cut-Off Wavelength (nm) | 660–800 | 1360–1520 | |
| Numerical Aperture | 0.14–0.18 | 0.19–0.21 | |
| Mode Field Diameter (µm) | 3.7–5.0 @830nm | 6.0–6.85 @1550nm | |
| Attenuation (dB/km) | ≤5 @830nm | 1.5 @1550nm | |
| Beat-Length (mm) @633nm | ≤1.0 | | |
| Proof Test (%) | 1 or 2 (100 or 200 kpsi) or greater upon request | | |
| Cladding Diameter (µm) | 80 ± 1 | | |
| Core Cladding Concentricity (µm) | ≤1.0 | | |
| Coating Diameter (µm) | 165 ± 5 | 135 ± 2 | 155 ± 5 |
| Coating Type | Dual Layer Acrylate | | |
| Operating Temperature (°C) | -55 to +85 | | |

**SB** – Short Beat-Length





## SPECIFICATIONS CONTINUED

Standard gyro fiber

| | HB800G | HB1250G | HB1500G | HB1500G-HI |
|---|---|---|---|---|
| Operating Wavelength (nm) | 810–1000 | 1280–1520 | 1520–1650 | |
| Cut-Off Wavelength (nm) | 660–800 | 1030–1270 | 1230–1520 | 1360–1520 |
| Numerical Aperture | 0.14–0.18 | | | 0.19–0.21 |
| Mode Field Diameter (µm) | 3.7–4.9 @830nm | 5.8–7.8@1310nm | 6.9–9.3 @1550nm | 6.0–6.9 @1550nm |
| Attenuation (dB/km) | ≤5 @830nm | ≤2 @1310nm | ≤2 @1550nm | ≤3 @1550nm |
| Beat-Length (mm) @633nm | ≤1.5 | | | |
| Proof Test (%) | 1 or 2 (100 or 200 kpsi) or greater upon request | | | |
| Cladding Diameter (µm) | 80 ± 1 | | | |
| Core Cladding Concentricity (µm) | ≤1.0 | | | |
| Coating Diameter (µm) | 165 ± 5 | 170 ± 5 | | 155 ± 5 |
| Coating Type | Dual Layer Acrylate | | | |
| Operating Temperature (°C) | -55 to +85 | | | |

**HI** – High Index

Radiation tolerant fiber

| | HB1500G-RT | HB1500G-RT-SB | HB1500G-SB (6/60/100) |
|---|---|---|---|
| Operating Wavelength (nm) | 1520–1650 | | |
| Cut-Off Wavelength (nm) | 1230–1520 | 1360–1520 | 1260 - 1520 |
| Numerical Aperture | 0.14–0.18 | 0.19–0.21 | 0.20 - 0.22 |
| Mode Field Diameter (µm) | 6.9–9.3 @1550nm | 6.0–7.0 @1550nm | 5.6-6.5 @1550nm |
| Attenuation (dB/km) | ≤2 @1550nm | | ≤2.5 @1550nm |
| Beat-Length (mm) @633nm | ≤1.5 | ≤1.15 | ≤1.0 |
| Proof Test (%) | 1 or 2 (100 or 200 kpsi) or greater upon request | | 1 (100 kpsi) or greater upon request |
| Cladding Diameter (µm) | 80 ± 1 | | 60 ± 2.5 |
| Core Cladding Concentricity (µm) | ≤1.0 | | |
| Coating Diameter (µm) | 170 ± 5 | 165 ± 5 | 100 ± 5 |
| Coating Type | Dual Layer Acrylate | | |
| Operating Temperature (°C) | -55 to +85 | | |

**SB** – Short Beat-Length **RT** – Radiation Tolerant

For other coating packages/smaller diameter fibers call Fibercore.

# PURE SILICA CORE PM FIBER

## PHOTODARKENING AND RADIATION RESISTANT PM FIBER FOR UV AND BLUE WAVELENGTHS

- Germanium-free pure silica core, designed to minimise photodarkening effects
- Polarization maintaining design for short wavelength lasers and sensors
- Single-mode down to 430nm
- Compatible with MM125 coreless end-cap fiber
- Other wavelengths available upon request

## TYPICAL APPLICATIONS

- Confocal microscopy
- Environmental monitoring
- DNA sequencing
- Flow cytometry

## SPECIFICATIONS

| | HB450-SC |
|---|---|
| Operating Wavelength (nm) | 430–650 |
| Cut-Off Wavelength (nm) | 350–420 |
| Numerical Aperture | 0.11–0.13 |
| Mode Field Diameter (µm) | 3.0–3.6 @488nm |
| Attenuation (dB/km) | ≤30 @488nm |
| Beat-Length (mm) @633nm | ≤2.5 |
| Proof Test (%) | 1 (100 kpsi) |
| Cladding Diameter (µm) | 125 ± 1 |
| Coating Diameter (µm) | 245 ± 7 |
| Core Concentricity (µm) | ≤0.75 |
| Coating Type | Dual Layer Acrylate |
| Operating Temperature (°C) | -55 to +85 |





# ZING™ POLARIZING FIBER

## BOW-TIE SINGLE POLARIZATION FIBERS FOR ALL-FIBER POLARIZERS

- Wide and stable polarizing window with a range of deployment conditions
- Consistently low loss and high PER of 30dB+
- Extreme birefringence with excellent handling characteristics
- Functional tunability

## TYPICAL APPLICATIONS

- Fiber lasers
- Laser diodes
- Fiber Optic Gyroscopes (FOGs)
- Current sensors
- Interferometric sensors

## SPECIFICATIONS

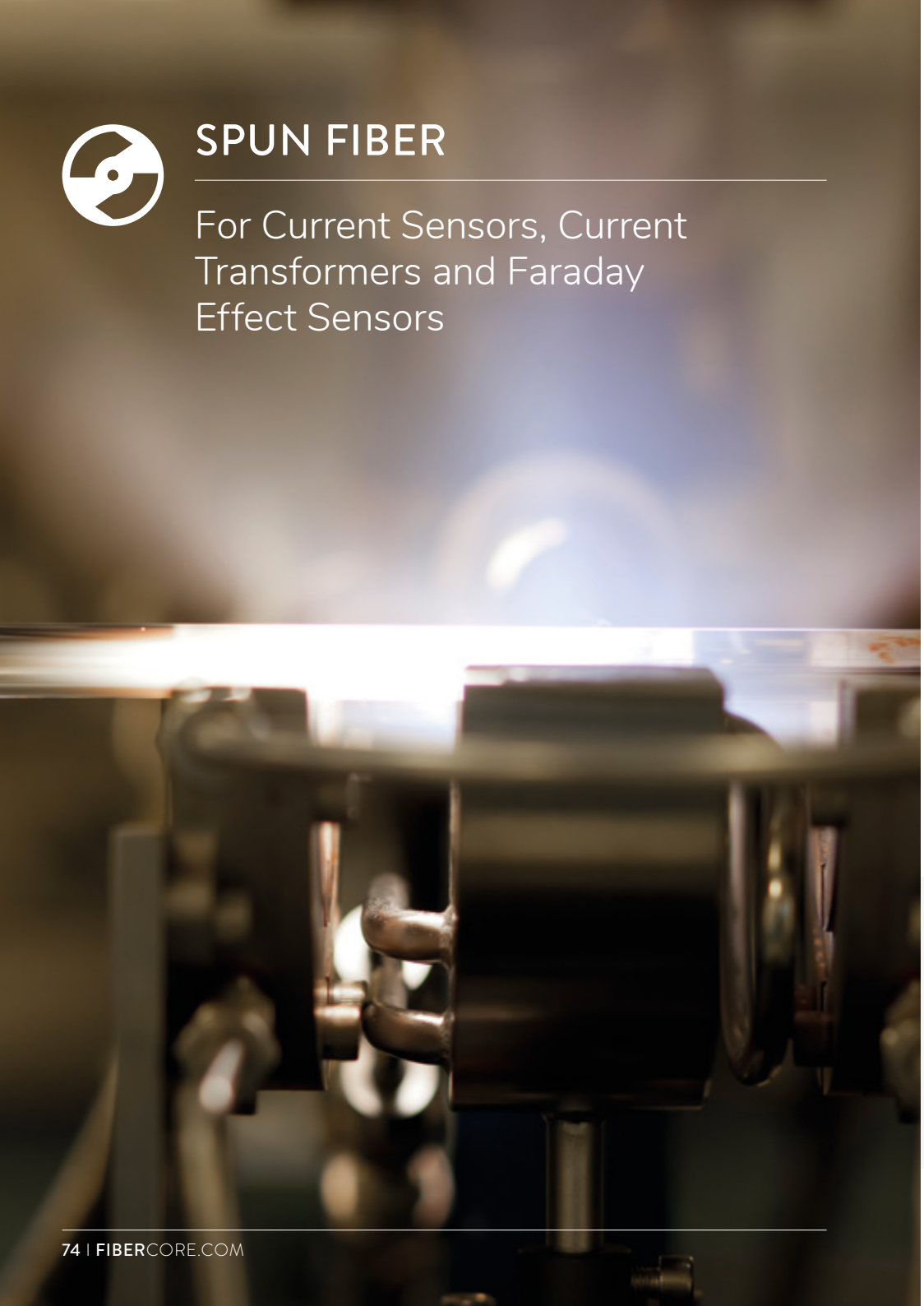
| | HB830Z (5/80) | HB1060Z (7/125) | HB1310Z (9/80) | HB1550Z (11/80) | HB1550Z (11/80)–50mm ** | HB1550Z (11/125) |
|---|---|---|---|---|---|---|
| Operating Wavelength (nm) | 830 | 1064 | 1310 | 1550 | | |
| 20dB Fast Edge* (nm) | ≤790 | ≤1015 | ≤1270 | ≤1500 | | |
| 3dB Slow Edge* (nm) | ≥860 | ≥1105 | ≥1370 | ≥1600 | | |
| Polarization Extinction Ratio* (dB) | ≥30 | | | | | |
| Mode Field Diameter (µm) | 4.1–7.7 @830nm | 6.0–8.0 @1064nm | 7.0–10.3 @1310nm | 8.5–13.5 @1550nm | | 10.0–12.5 @1550nm |
| Attenuation (dB/km) | ≤20 | | | | | |
| Proof Test (%) | 1 (100 kpsi) | | | | | |
| Cladding Diameter (µm) | 80 ± 1 | 125 ± 1 | 80 ± 1 | | | 125 ± 1 |
| Core Concentricity (µm) | ≤1.0 | | | | | |
| Coating Diameter (µm) | 170 ± 5 | 245 ± 7 | 170 ± 5 | | | 245 ± 7 |
| Coating Type | Dual Layer Acrylate | | | | | |
| Operating Temperature (°C) | -55 to +85 | | | | | |

* Typical polarizing performance with deployment conditions of 5m length in a coil.

** Zing™ fibers are designed to provide the polarizing window in a 90mm coil diameter.

Variants with an ** are designed for smaller diameters of 50mm.

To tune the fiber for your application, changing the length of the fiber and/or the coil diameter, can alter the central wavelength and operating bandwidth. For more information and to discuss your precise requirements, contact us at sales@fibercore.com



# SPUN FIBER

## For Current Sensors, Current Transformers and Faraday Effect Sensors





Fibercore's spun fiber is primarily designed for fiber optic Faraday effect current transformers where high stability fiber design is critical to enable high accuracy current sensing.

The spun fiber allows highly sensitive and accurate current sensing over a wide range of environmental conditions including temperature variation and vibration, making it suitable for current transformers deployed outdoors in real life applications. When used in conjunction with Fibercore's PM fiber for delay lines and Zing™ for depolarizers, world-class current sensors can be achieved.

## BOW-TIE SPUN FIBER FOR FARADAY EFFECT CURRENT SENSORS

- Circularly birefringent
- Supported by full range of complementary fibers
- Higher Verdet constant at 1310nm than at 1550nm

## TYPICAL APPLICATIONS

- Current sensors
- Current transformers
- Faraday effect sensors

## PRODUCTS IN THIS RANGE

Spun Fiber:

- Circularly birefringent
- Thermally stable
- Vibrationally stable
- Highest accuracies possible

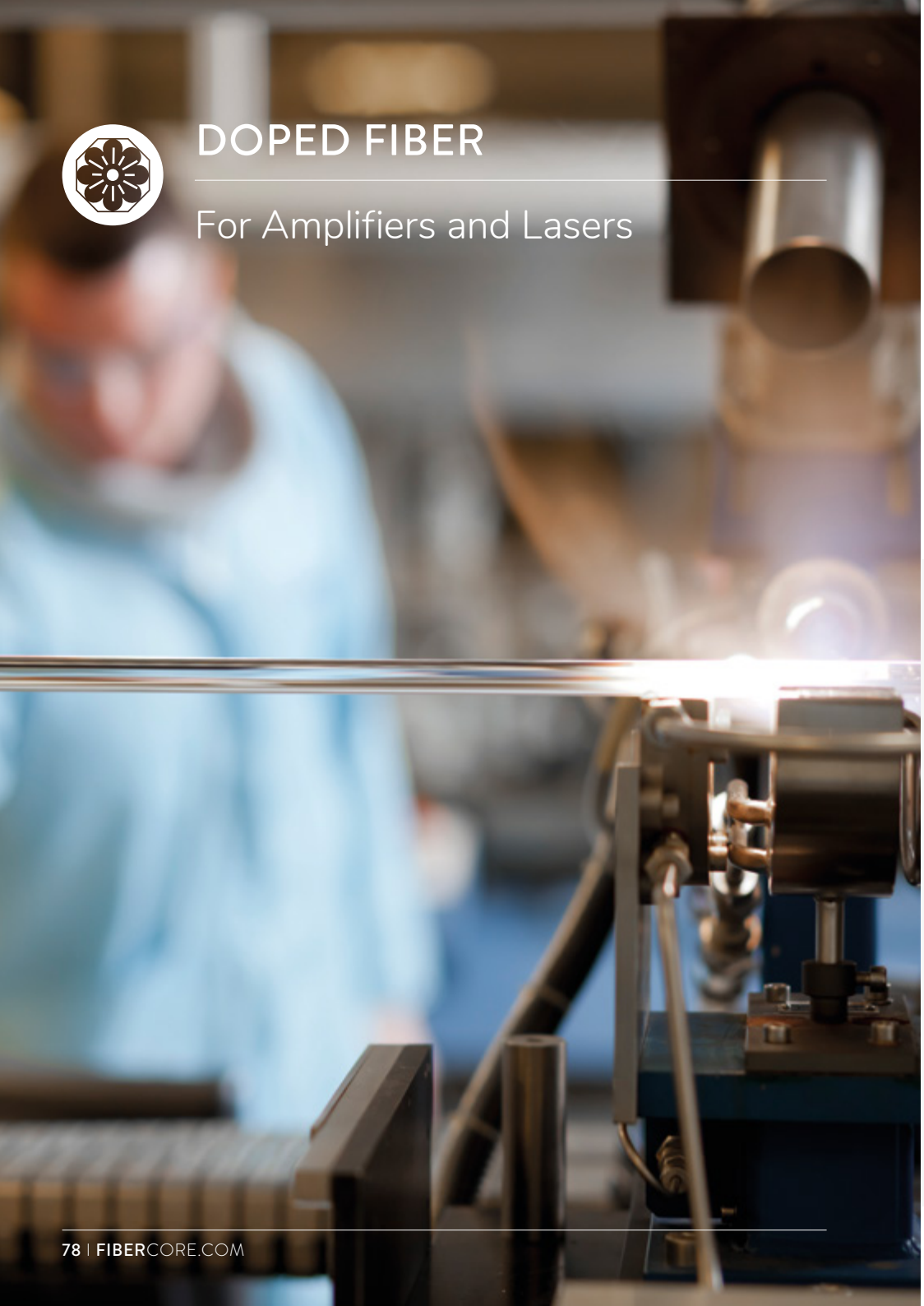
## SPECIFICATIONS

Spun HiBi

| | SHB1250 (7.3/80)–2.5mm | SHB1250 (7.3/80) | SHB1250 (7.3/125) | SHB1500 (8.9/125) |
|---|---|---|---|---|
| Operating Wavelength (nm) | 1260–1510 | | | 1510–1650 |
| Cut-Off Wavelength (nm) | 1100–1250 | | | 1360–1500 |
| Numerical Aperture | 0.14–0.17 | | | 0.13–0.16 |
| Mode Field Diameter (µm) | 6.2–7.8 @1310nm | | | 7.9–9.9 @1550nm |
| Attenuation (dB/km) | ≤5 @1310nm | | | ≤3 @1550nm |
| Circular Beat-Length (mm) | 63–135 @1310nm | 63–110 @1310nm | | 86–160 @1550nm |
| Spin Pitch (mm) Nominal | 2.5 | 4.0 | | |
| Proof Test (%) | 1 (100 kpsi) | | | |
| Cladding Diameter (µm) | 80 ± 1.5 | | 125 ± 2 | |
| Core Cladding Concentricity (µm) | ≤1.0 | | | |
| Coating Diameter (µm) | 165 ± 5 | | 245 ± 7 | |
| Coating Type | Dual Layer Acrylate | | | |
| Operating Temperature (°C) | -55 to +85 | | | |







# DOPED FIBER

## For Amplifiers and Lasers





Fibercore offers a number of different doped fibers including erbium doped fiber for various ‘C’ and ‘L’ amplifier configurations and ASE applications, all supported by our GainMaster™ simulation software to help you design even the most complex EDFAs.

## TYPICAL APPLICATIONS

- DWDM systems
- ‘Metro’ EDFA’s
- Low power fiber lasers
- CATV systems

## PRODUCTS IN THIS RANGE

### Erbium Doped Fiber IsoGain™ Multichannel

Erbium doped fibers for high channel-count DWDM systems.

### Erbium Doped Fiber AstroGain™

Space grade erbium doped fibers.

### PM Erbium Doped Fiber

Polarization maintaining erbium doped fiber.

### Triple-Clad Doped Fiber

Triple-clad doped fiber for high power amplifiers for telecom and CATV.

### Dual Clad Erbium/Ytterbium Doped Fiber

All-glass erbium/ytterbium co-doped dual clad fiber. Field-proven in commercial CATV systems.

### Isolating Wavelength Division Multiplexer CP-IWDM

Designed for cladding pump applications with double clad erbium/ytterbium doped fiber.

### Other Doped Fibers

Pump ranges at 780nm to 830nm and 900nm to 1064nm. Output ranges at around 1088nm and 1075nm to 1100nm. Ideal for student lab classes, low power fiber lasers and single channel amplifiers and fiber lasers.

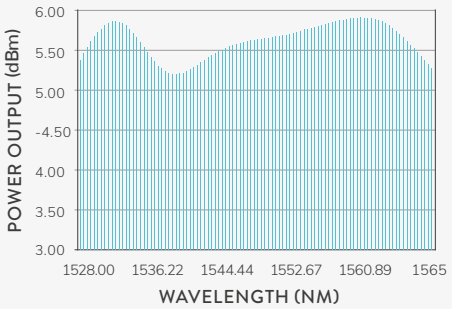
### OEM Amplifier GainBlock

Packaged passive optical unit for integration into amplifiers and fiber lasers.

# ERBIUM DOPED FIBER ISOGAIN™

## ERBIUM DOPED FIBERS FOR HIGH CHANNEL-COUNT DWDM SYSTEMS

- Optimized core composition for high channel- count DWDM systems' EDFAs
- World-class leading conversion efficiency
- Suitable for C and L-band amplifiers




## TYPICAL APPLICATIONS

- EDFAs/telecoms
- Fiber lasers
- Biomedical illumination
- Optical Coherence Tomography (OCT)
- LiDAR
- ASE light sources
- Gyros
- Current sensors
- Distributed sensor systems

## SPECIFICATIONS

High Efficiency C-Band Erbium Doped Fibers

| | I-4(980/125) | I-4(980/125)HC | I-4(980/125)HP | I-6(980/125) |
|---|---|---|---|---|
| Cut-Off Wavelength (nm) | 870–970 | 1050–1320 | 1100–1320 | 870–970 |
| Numerical Aperture | 0.22–0.24 | | 0.19–0.22 | 0.22–0.24 |
| Mode Field Diameter (µm) | 5.5–6.6 @1550nm | 5.2–5.8 @1550nm | 5.7–6.6 @1550nm | 5.5–6.3 @1550nm |
| Absorption (dB/m) @1531nm | 5.0–6.7 | 7.7–9.4 | | 7.2–8.4 |
| Proof Test (%) | 1 (100 kpsi) | | | |
| Attenuation (dB/km) @1200nm | ≤10 | | | |
| Polarization Mode Dispersion (ps/m) | ≤0.005 | | | |
| Cladding Diameter (µm) | 125 ± 1 | | | |
| Core Concentricity (µm) | ≤0.3 | | | |
| Coating Diameter (µm) | 245 ± 7 | | | |
| Coating Type | Dual Layer Acrylate | | | |
| Operating Temperature (°C) | -55 to +85 | | | |





## SPECIFICATIONS CONTINUED

L-Band and C-Band Erbium Doped Fibers

| | I-12(980/125) | I-12(980/125)HC | I-15(980/125)HC | I-25(980/125) |
|---|---|---|---|---|
| Cut-Off Wavelength (nm) | 900–970 | 1200–1320 | | 900–970 |
| Numerical Aperture | 0.21–0.23 | 0.23–0.26 | | |
| Mode Field Diameter (µm) | 5.7–6.6 @1550nm | 5.0–5.5 @1550nm | 4.8–5.4 @1550nm | 5.3–6.3 @1550nm |
| Absorption (dB/m) | 14–21 @1531nm | 17–21 @1531nm | 27–33 @1531nm | 35–45 @1531nm |
| Proof Test (%) | 1 (100 kpsi) | | | |
| Attenuation (dB/km) @1200nm | ≤10 | | | |
| Polarization Mode Dispersion (ps/m) | ≤0.005 | | | |
| Cladding Diameter (µm) | 125 ± 1 | | | |
| Core Concentricity (µm) | ≤0.3 | | | ≤0.5 |
| Coating Diameter (µm) | 245 ± 7 | | | |
| Coating Type | Dual Layer Acrylate | | | |
| Operating Temperature (°C) | -55 to +85 | | | |

Reduced Cladding Erbium Doped Fiber for Mini and Micro EDFAs

| | I-15(980/80)HC | I-25H(1480/80) |
|---|---|---|
| Cut-Off Wavelength (nm) | 1200–1320 | 900–1075 |
| Numerical Aperture | 0.24–0.26 | ≥0.30 |
| Mode Field Diameter (µm) | 4.8–5.4 @1550nm | 3.8–4.7 @1550nm |
| Absorption (dB/m) | 27–33 @1531nm | 23–27 @1531nm |
| Proof Test (%) | 2 (200 kpsi) | 1 (100 kpsi) |
| Attenuation (dB/km) @1200nm | ≤15 | ≤30 |
| Polarization Mode Dispersion (ps/m) | ≤0.005 | |
| Cladding Diameter (µm) | 80 ± 1 | |
| Core Concentricity (µm) | ≤0.3 | ≤0.5 |
| Coating Diameter (µm) | 170 ± 5 | 160 ± 5 |
| Coating Type | Dual Layer Acrylate | |
| Operating Temperature (°C) | -55 to +85 | |

EDFA simulation software, **GainMaster™** is available on fibercore.com

# ERBIUM DOPED FIBER ASTROGAIN™

## SPACE GRADE ERBIUM DOPED FIBERS

- AG980H for high duty cycle space applications
- AG980L for low duty cycle space applications
- Optimized trivalent core matrix for space operation
- High efficiency designs for maximum electrical-to-optical power conversion
- High reliability mechanical design

## TYPICAL APPLICATIONS

- Amplifiers for inter-satellite communications
- Light sources for earth observation missions
- Light sources and amplifiers for large scale sensing missions

## SPECIFICATIONS

| | AG980H | AG980L |
|---|---|---|
| Cut-Off Wavelength (nm) | 900–970 | |
| Numerical Aperture | 0.22–0.24 | |
| Mode Field Diameter (µm) | 5.5–6.3 @1550nm | |
| Absorption (dB/m) | 5.0–7.1 @1531nm | |
| Duty Cycle | High | Low |
| Proof Test (%) | 1 (100 kpsi) | |
| Attenuation (dB/km) | ≤10 @1200nm | |
| Polarization Mode Dispersion (ps/m) | ≤0.005 | |
| Cladding Diameter (µm) | 125 ± 1 | |
| Core Cladding Concentricity (µm) | ≤0.3 | |
| Coating Diameter (µm) | 245 ± 7 | |
| Coating Type | Dual Layer Acrylate | |
| Operating Temperature (°C) | -55 to +85 | |

EDFA simulation software, **GainMaster™** is available on fibercore.com

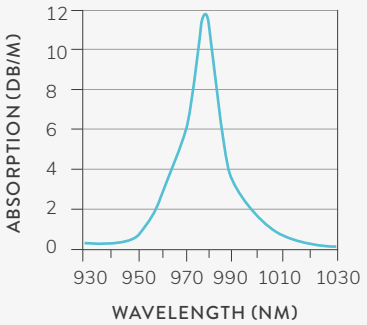




# PM ERBIUM DOPED FIBER

## POLARIZATION MAINTAINING ERBIUM DOPED FIBER

- DHB1500 matched to IsoGain™ I-12(980/125)
- DHB1500-LA designed with lower absorption for higher efficiencies
- Polarization extinction levels of up to -30db over typical gain lengths of 8–14 meters
- Designed for 980nm pumping




## TYPICAL APPLICATIONS

- EDFAs
- Coherent communications
- Amplified Spontaneous Emission (ASE) light source
- Fiber lasers

## SPECIFICATIONS

| | DHB1500 | DHB1500-LA |
|---|---|---|
| Cut-Off Wavelength (nm) | 860–960 | |
| Numerical Aperture | 0.22–0.26 | 0.22–0.24 |
| Mode Field Diameter (µm) | 5.1–6.7 @1550nm | 5.5–6.7 @1550nm |
| Absorption (dB/m) | 12–27 @1531nm | 3.0–5.5 @1531nm |
| Beat-Length (mm) @633 | ≤4.0 | |
| Proof Test (%) | 1 (100 kpsi) | |
| Attenuation (dB/km) | ≤20 @1200nm | ≤15 @1200nm |
| Cladding Diameter (µm) | 125 ± 1 | |
| Core Cladding Concentricity (µm) | ≤1.0 | |
| Coating Diameter (µm) | 245 ± 7 | |
| Coating Type | Dual Layer Acrylate | |
| Operating Temperature (°C) | -55 to +85 | |

**LA** – Low absorption

EDFA simulation software, **GainMaster™** is available on fibercore.com

# TRIPLE-CLAD DOPED FIBER

- Circular outer cladding for high splice repeatability
- Easy to strip, cleave and splice
- Octagonal inner structure optimizes pump conversion effectively
- High reliability

## TYPICAL APPLICATIONS

- Fiber lasers
- LiDAR
- CATV

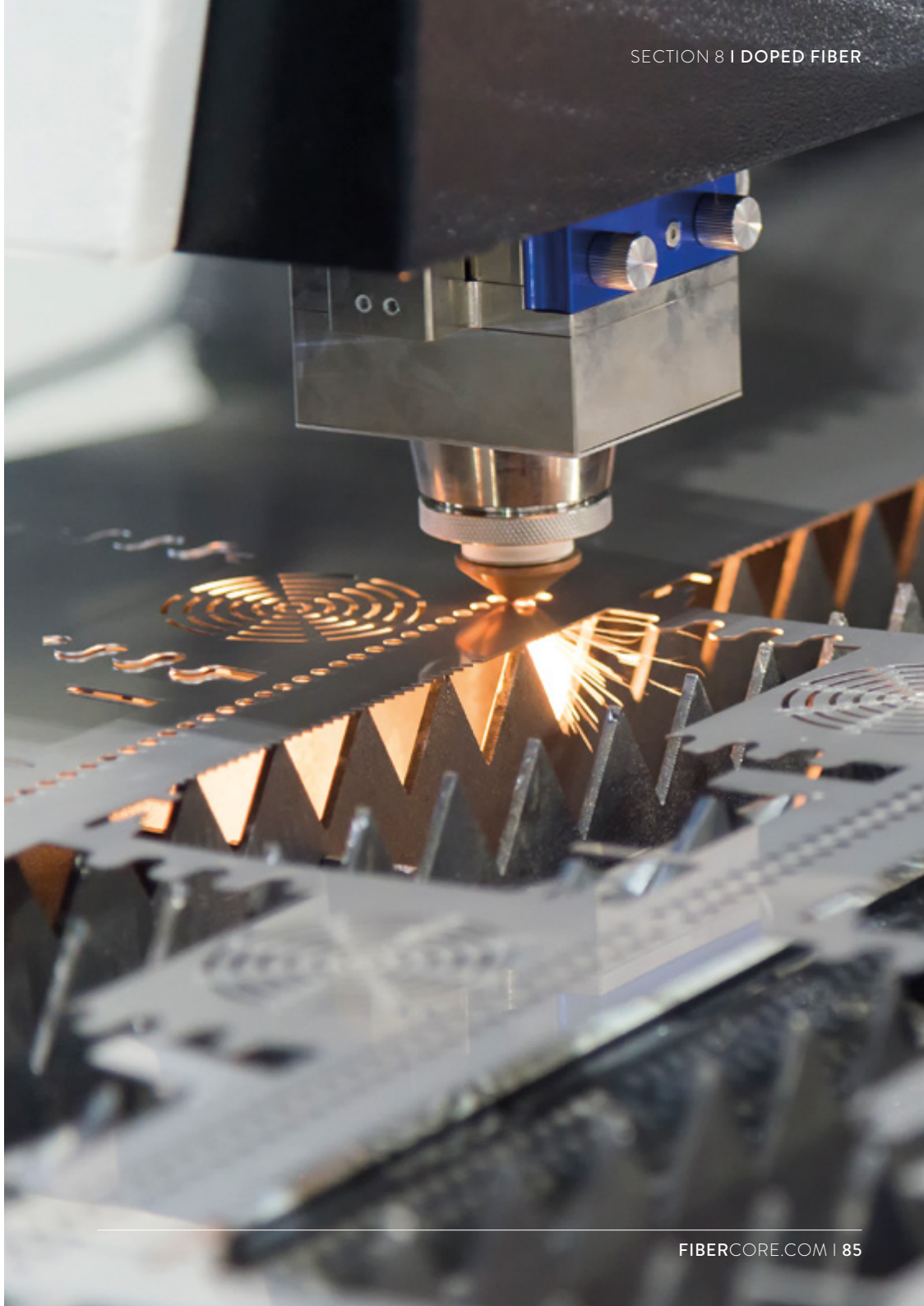
## SPECIFICATIONS

| | TC1060Y (10/125)0.08HD * | TC1500Y (6/125)HD | TC1500Y (11/125)HD |
|---|---|---|---|
| **Laser Core** | | | |
| Composition | Ytterbium | Erbium and Ytterbium | |
| Operating Wavelength (nm) | 1060 | 1520–1570 | |
| Numerical Aperture | 0.07–0.08 | 0.20–0.23 | 0.10–0.13 |
| Mode Field Diameter (µm) | - | 5.6–7.2 @1550nm | 9.6–12 @1550nm |
| Single-Mode Core Diameter (µm) | 10–12 | - | - |
| Cut-Off Wavelength (nm) | - | 1290–1510 | |
| Peak Core Absorption (dB/m) | - | 75 ± 20 @1535nm | |
| **Pump Guide** | | | |
| Composition | Pure silica with F-doped silica cladding | | |
| Mean Core Diameter (µm) | 105–115 | | |
| Absorption (dB/m) | 1.1–1.5 @915nm | 0.6–0.9 @915nm | 2.5–4.5 @915nm |
| Numerical Aperture of low index coating w.r.t. silica | 0.45 (Nominal) | | |
| **General** | | | |
| Proof Test (%) | 1 (100 kpsi) | | |
| Coating Type | Low index acrylate | | |
| Cladding Diameter (µm) | 125 ± 1 | | |
| Coating Diameter (µm) | 245 ± 15 | | |

*Passive DC variant available







# DUAL CLAD ERBIUM/YTTERBIUM DOPED FIBER

- PM and non-PM erbium/ytterbium co-doped dual clad fiber
- Optimized for efficient energy transfer
- All-silica pump waveguides and low index acrylate pump waveguides available

## TYPICAL APPLICATIONS

- High power Erbium Doped Fiber Amplifiers (EDFAs)
- Ytterbium/Erbium Doped Fiber Amplifier (YEDFA)
- Fiber lasers
- Light Radar (LiDAR)
- Cable Television (CATV)

## SPECIFICATIONS

| | CP1500Y | CP1500Y (9/125) | PMCP1500Y (6.0/125)0.2 | PMDC1500Y (12/125)HD |
|---|---|---|---|---|
| **Laser Core** | | | | |
| Composition | Phosphosilicate with erbium and ytterbium | | | |
| Operating Wavelength (nm) | 1520–1570 | | | |
| Numerical Aperture | 0.20–0.22 | 0.125–0.155 | 0.20–0.22 | 0.18–0.22 |
| Mode Field Diameter (µm) | 5.6–6.5 @1550nm | 8.1–10.3 @1550nm | 5.7–6.5 @1550nm | - |
| Core Diameter (µm) | 4.5–5.8 | 6.3-9.3 | 4.5–5.8 | 10.5–13.5 |
| Cut-Off Wavelength (nm) | 1290–1510 | | | - |
| Absorption (dB/m) | 19 (nominal) @1550nm | 55-95 @1535nm | 19 (nominal) @1550nm | 55–95 @1535nm |
| **Pump Guide** | | | | |
| Composition | Pure silica with F-doped silica cladding | | | Pure silica cladding |
| Numerical Aperture | 0.24–0.28 | 0.22-0.24 | 0.20–0.22 | ≥0.45 |
| Mean Pump Guide Diameter (µm) | 80–104 | 105-120 | 105 | 125 |
| Absorption (dB/m) | 1 (nominal) @940nm | 2-4 @915nm | 1 (nominal) @940nm | 2.5–4.5 @915nm |
| **General** | | | | |
| Proof Test (%) | 1 (100 kpsi) | | | |
| Coating Type | Dual Layer Acrylate * | | | Low Index Acrylate |
| Cladding Diameter (µm) | 125 ± 1 | | | |
| Coating Diameter (µm) | 245 ± 7 | 245 ± 12 | 250 ± 10 | 245 ± 13 |
| Operating Temperature (°C) | -55 to +85 | | | |

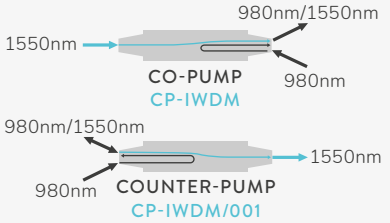
* High temperature acrylate variant available upon request





# ISOLATING WAVELENGTH DIVISION MULTIPLEXER CP-IWDM

- Combines a high-power multimode pump and a single-mode signal to a single SMM900 dual clad pump-signal fiber output
- Designed for cladding-pump applications with CP1500Y
- Provides multiplexing and isolation in one small package




## TYPICAL APPLICATIONS

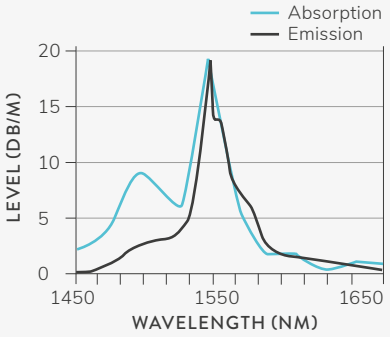
- High power Erbium Doped Fiber Amplifiers (EDFAs)
- Fiber lasers
- WDM systems
- Cable Television (CATV)

## SPECIFICATIONS

| | | |
|---|---|---|
| **General Mechanical** | Package Size (mm) | 5.5 x 54 |
| | Operating Temperature (°C) | 0 to +70 |
| | Storage Temperature (°C) | -40 to +85 |
| **General Optical** | Directivity (dB) | ≥40 |
| | Polarization Mode Dispersion (ps) | ≥0.25 |
| | Polarization Dependant Loss (dB) | ≥0.1 |
| | Isolation @23°C (dB) | ≥31 |
| | Signal Wavelength Isolation (dB) (1 to 3) | ≥12 |
| **S Single-Mode Fiber** | Cladding Diameter (µm) | 125 |
| | Operating Wavelength (nm) | 1550 |
| | Numerical Aperture nominal | 0.12 |
| | Max Input @1550nm (mW) | 300 |
| **P Multimode Input** | Cladding Diameter (µm) | 125 |
| | Pump Guide Diameter (µm) nominal | 105 |
| | Numerical Aperture nominal | 0.22 |
| | Max Input @970nm (mW) | 5000 |
| **C Dual Clad Fiber** | Cladding Diameter (µm) | 125 |
| | Single-Mode Cut-Off Wavelength (nm) | 870–970 |
| | Single-Mode NA | 0.18–0.20 |
| | Pump Guide Diameter (µm) nominal | 105 |
| | Pump Guide NA nominal | 0.22 |

# OTHER DOPED FIBERS

- Core pumped designs
- Emission at 1060, 1085 and 1550nm
- Splice compatible with fused taper couplers
- Low pump threshold designs




## TYPICAL APPLICATIONS

- Fiber lasers
- Amplified Spontaneous Emission (ASE) light source
- Erbium Doped Fiber Amplifier (EDFA)
- Cable Television (CATV) Educational kits

## SPECIFICATIONS

| | DF1000 | DF1100 | DF1500Y |
|---|---|---|---|
| Operating Wavelength (nm) | 1085 | 1030–1100 | 1550 |
| Cut-Off Wavelength (nm) | 875–1025 | 800–900 | 950–1050 |
| Numerical Aperture | 0.18–0.22 | 0.14–0.17 | 0.20–0.24 |
| Mode Field Diameter (µm) | 3.9–5.0 @1085nm | 5.1–6.3 @1085nm | 5.3–6.8 @1550nm |
| Absorption (dB/m) | 4.5 (nominal) @780nm<br>8.5 (nominal) @810nm<br>3.5 (nominal) @830nm | 1500 (nominal) @977nm | 1000 (nominal) @975nm<br>10–15 @1047nm<br>20 (nominal) @1532nm |
| Attenuation (dB/km) | ≤20 @1085nm | ≤50 @1200nm | ≤200 @1200nm |
| Proof Test (%) | 1 (100 kpsi) | | |
| Cladding Diameter (µm) | 125 ± 1 | | |
| Core Cladding Concentricity (µm) | ≤0.5 | | |
| Coating Diameter (µm) | 245 ± 7 | | |
| Coating Type | Dual Layer Acrylate | | |
| Operating Temperature (°C) | -55 to +85 | | |
| Dopants | Neodymium (Nd) | Ytterbium (Yb) | Erbium/Ytterbium (Er/Yb) |

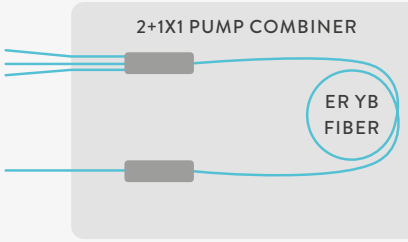




# OEM AMPLIFIER GAINBLOCK

## PACKAGED PASSIVE OPTICAL UNIT FOR INTEGRATION INTO AMPLIFIERS AND FIBER LASER

- Compact package (121 x 83 x 13mm)
- Optional output power ranges
- Simplifies engineering requirements for high power amplifier development

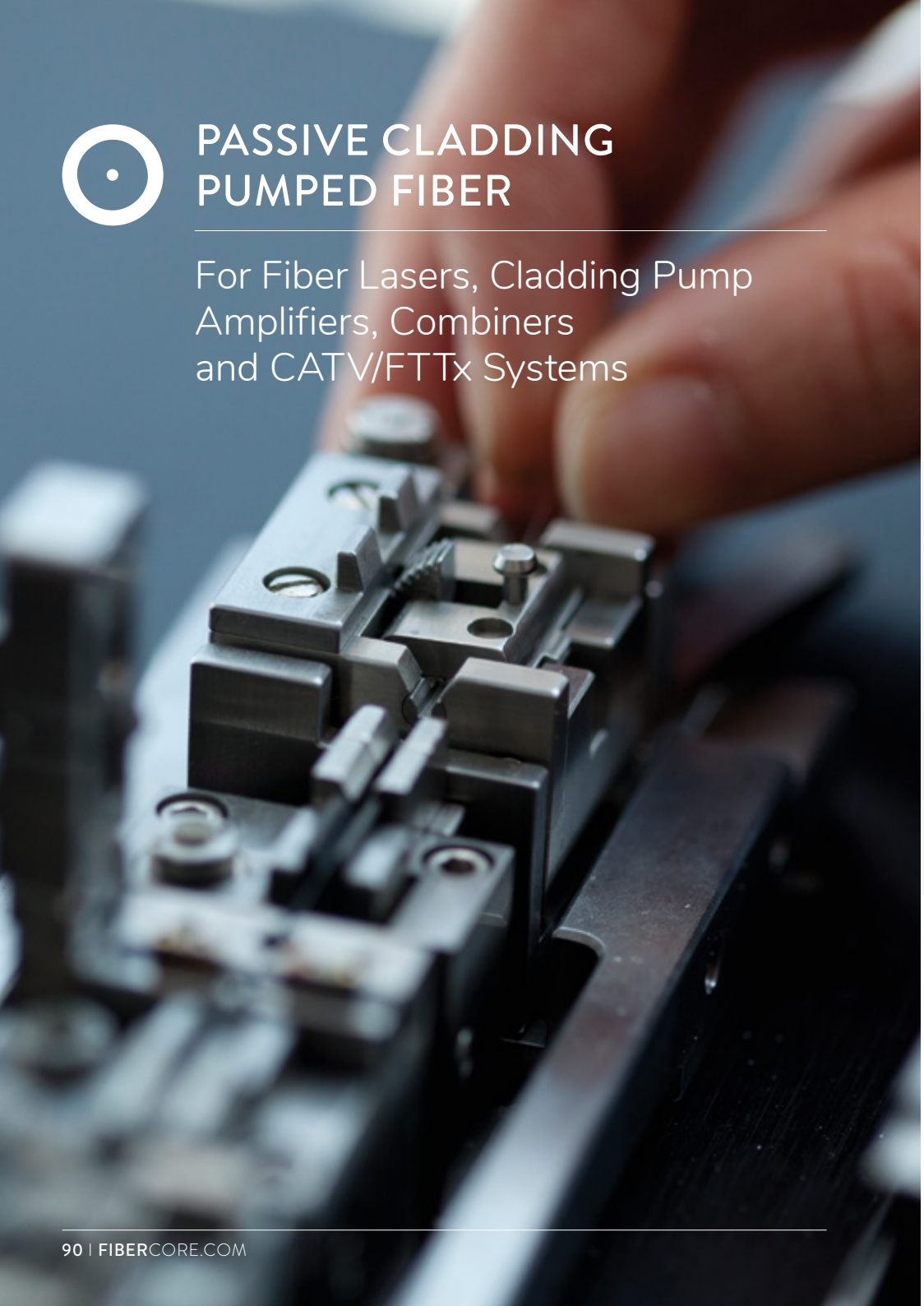



## TYPICAL APPLICATIONS

- CATV amplifiers
- LiDAR
- Fiber lasers

## SPECIFICATIONS

| | GB1550-3W |
|---|---|
| Operating Wavelength (nm) | 1543–1565 |
| Output Power (W) | ≥3 |
| Input Power (mW) | ≥17 |
| Pump Power to reach 3W @940nm (W) | 9 typical |
| Pump Ports | MM 105/125 0.22 NA |
| Input Signal Port | G652 type SM fiber |
| Output Signal Port | G652 type SM fiber |



# PASSIVE CLADDING PUMPED FIBER

## For Fiber Lasers, Cladding Pump Amplifiers, Combiners and CATV/FTTx Systems





Fibercore offers two ranges of double clad fiber: low index polymer coated double clad fibers and an all silica double clad fiber.

## TYPICAL APPLICATIONS

- CATV & FTTx systems
- Cladding pump amplifiers
- Fiber lasers

## PRODUCTS IN THIS RANGE

### Low Index Double Clad Passive Fiber

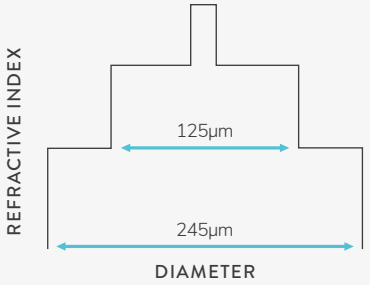
The low index coated double clad passive fibers are designed for high power amplifiers and fiber lasers at 1060nm and 1550nm where stable management of high power optical powers is crucial.

### All Silica Double Clad Fiber

The all silica double clad fiber gives the benefit of not requiring low index recoating at the strip point. The fiber can be stripped, cleaved and spliced like any standard optical fiber.

# LOW INDEX DOUBLE CLAD PASSIVE FIBER

- High power handling capability
- 1060nm and 1550nm variants
- Splice compatible with Fibercore doped fibers
- Range of core NAs available




## TYPICAL APPLICATIONS

- High power amplifiers
- Fiber lasers
- LiDAR
- Biomedical probes
- Beam delivery
- Pump combiners

## SPECIFICATIONS

| | DC1060(10/125) 0.08HD | DC1500(11/125) 0.12HD | DC1500(6/125) 0.21HD | DCSC (135/155/320)HD |
|---|---|---|---|---|
| **Single-Mode Core** | | | | |
| Mode Field Diameter (µm) | - | 9.5–11.5 @1550nm | 5.6–6.5 @1550nm | - |
| Core Numerical Aperture | 0.07–0.09 | 0.11–0.13 | 0.20–0.22 | 0.21–0.23 |
| Cut-Off Wavelength (nm) | 960–1040 | 1360–1520 | 1290–1520 | - |
| Core Attenuation (dB/km) | ≤20 @1060nm | ≤1 @1550nm | | - |
| Core Concentricity (µm) | ≤0.5 | | | ≤3 |
| Core Diameter (µm) | 9–11 | 9 (nominal) | 5 (nominal) | 133–137 |
| **Pump Guide** | | | | |
| Cladding Attenuation (dB/km) | ≤15 @1095nm | | | - |
| Cladding Numerical Aperture | 0.45 (nominal) | | | |
| Cladding Diameter (µm) | 125 ± 1 | | | 155 ± 1.5 |
| **General** | | | | |
| Operating Wavelength (nm) | 1060 | 1550 | | 800–1600 |
| Coating Diameter (µm) | 245 ± 7 | | | 320 ± 20 |
| Proof Test (%) | 1 (100 kpsi) | | | |
| Coating Type | Low index fluoroacrylate | | | |
| Operating Temperature (°C) | -55 to +85 | | | |

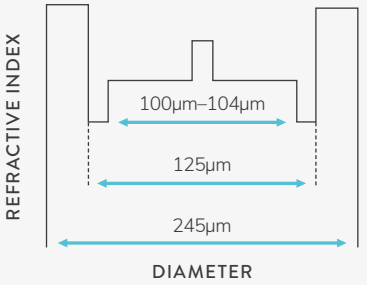




# ALL SILICA DOUBLE CLAD FIBER

## DOUBLE CLAD COMPONENT FIBER

- Designed for use with CP1500Y
- Combines both single-mode and multimode characteristics
- Compatible with SM980(4.5/125) and other 900/1500nm dual wavelength fibers




## TYPICAL APPLICATIONS

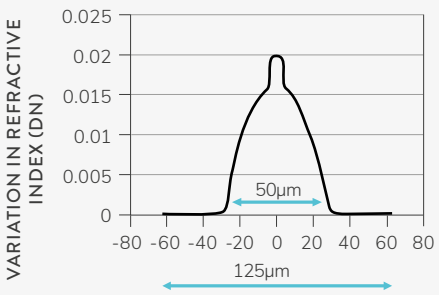
- Pump combiners
- High power amplifiers (EDFA/YEDFA)
- Cable Television (CATV)
- Fiber lasers
- Biomedical probes

## SPECIFICATIONS

| | SMM900 | SMM1500(6/125)HT | SMM1500(9/125)HD |
|---|---|---|---|
| **Single-Mode Core** | | | |
| Mode Field Diameter (µm) | 6.5–8.2 @1550nm | 5.6–6.5 @1550nm | 8.1-10.3 @1550nm |
| Numerical Aperture | 0.18–0.20 | 0.20–0.22 | 0.125-0.155 |
| Cut-Off Wavelength (nm) | 870–970 | 1290-1510 | 1290-1510 |
| Attenuation (dB/km) | 4 (nominal) @1550nm | ≤4 @1550nm | ≤1 @1550nm |
| Core Concentricity (µm) | ≤0.75 | ≤0.5 | ≤0.8 |
| **Pump Guide** | | | |
| Diameter (µm) | 100–104 | 100–106 | 102–106 |
| Numerical Aperture | 0.24–0.28 | 0.22–0.24 | ≥0.45 |
| **General** | | | |
| Cladding Diameter (µm) | 125 ± 1 | | |
| Proof Test (%) | 1 (100 kpsi) | | |
| Coating Diameter (µm) | 245 ± 7 | 245 ± 10 | 245 ± 10 |
| Coating Type | Dual Layer Acrylate | | Low Index Acrylate |
| Operating Temperature (°C) | -55 to +85 | | |

# DUAL CLAD GRADED INDEX FIBER

- Single fiber for simultaneous SM and MM applications
- GRIN region for long range MM transmission
- Standard telecoms SM core compatible




## TYPICAL APPLICATIONS

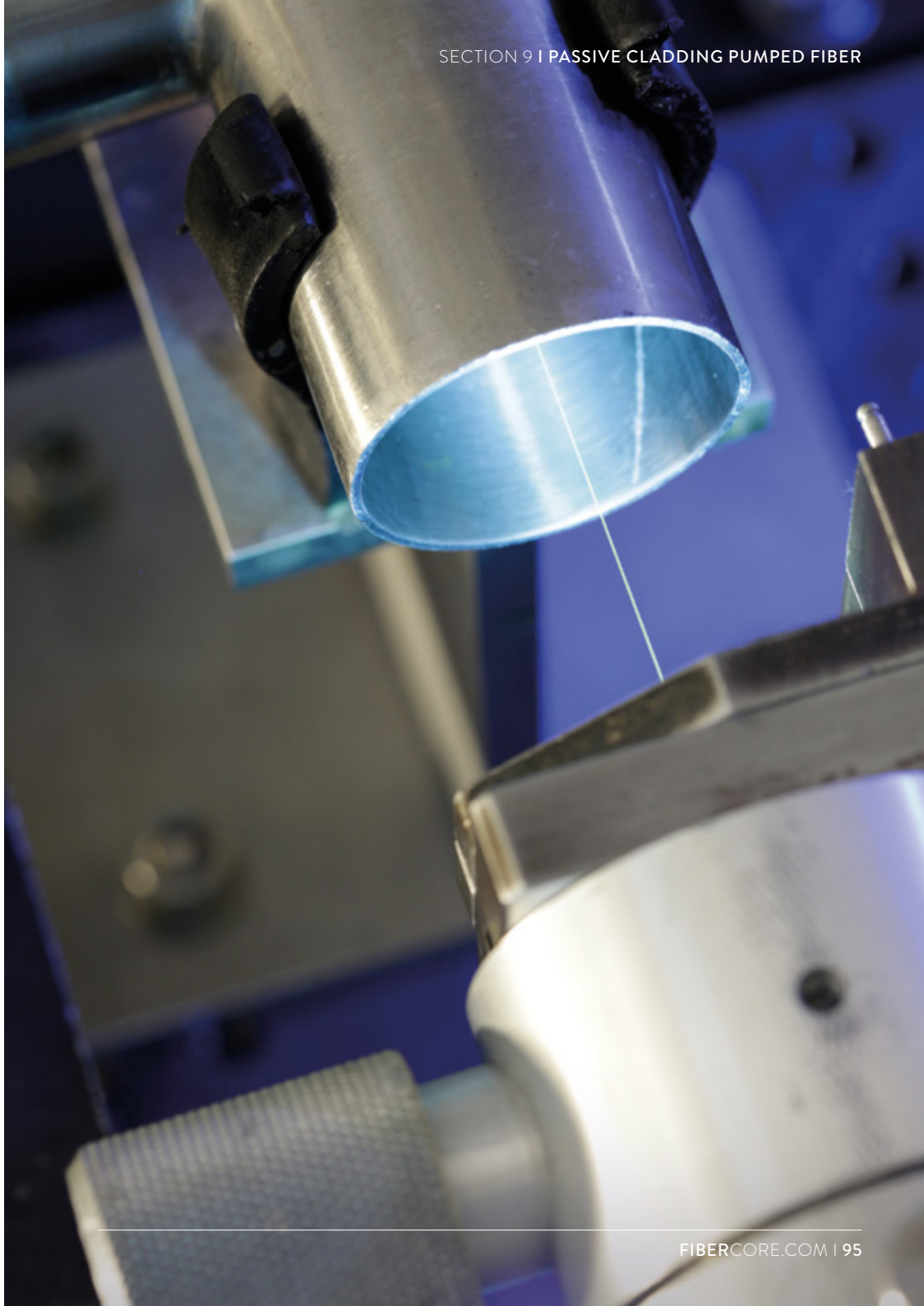
- Distributed Acoustic Sensing (DAS)
- Distributed Temperature Sensing (DTS)
- Power over Fiber (PoF) with communication

## SPECIFICATIONS

| | DCGI1500(10.4/50/125) |
|---|---|
| **Single-Mode Core** | |
| Mode Field Diameter (µm) | 9.6–11.4 @1550nm |
| Cut-Off Wavelength (nm) | 1160–1500 |
| Core Concentricity (µm) | ≤1 |
| **Pump Guide** | |
| Diameter (µm) | 45–55 |
| Numerical Aperture | 0.18-0.22 (Max GRIN) |
| **General** | |
| Cladding Diameter (µm) | 123–127 |
| Proof Test (%) | 1 (100 kpsi) |
| Coating Diameter (µm) | Dual Layer Acrylate, High Temperature & Carbon High Temperature: 245±15<br>Polyimide & Carbon Polyimide: 155±5 |
| Coating Type | Dual Layer Acrylate, High Temperature, Carbon High Temperature,<br>Polyimide & Carbon Polyimide (upon request) |



SECTION 9 I PASSIVE CLADDING PUMPED FIBER



# MM FIBERS

## For Harsh Environments





# MULTIMODE FIBERS

Multimode fibers for sensing and telecommunications with specialized coatings for harsh environment.

The multimode (MM) fibers are available in Graded Index (GRIN) variants with 50µm and 62.5µm germanium doped cores. In addition to these germanium doped cores, Fibercore offers pure silica core GRIN fibers specifically designed for long term-use in downhole hydrogen environments as experienced in the Oil & Gas industry and applications where resistance to radiation effects is required.

## PRODUCTS IN THIS RANGE

**Graded Index Multimode Fiber**
For high bandwidth sensing up to 150°C and 300°C.

**Graded Index Multimode Pure Silica Core Fiber**
For high bandwidth terrestrial sensing in hydrogen and/or radiation environments.

**Large Core Fiber**
Designed for pump power delivery.

# GRADED INDEX MULTIMODE FIBER

- High bandwidth
- Carbon coating options for reduced hydrogen sensitivity
- High temperature coatings for 150°C and 300°C
- 50µm and 62.5µm variants

## TYPICAL APPLICATIONS

- DTS
- Telemetry
- Downhole monitoring

## SPECIFICATIONS

| | GIMM(50/125) * | | GIMMBI(50/125) * | | GIMM(62.5/125) | |
|---|---|---|---|---|---|---|
| **Operating Wavelength (nm)** | 800–1750 | | | | | |
| **Numerical Aperture** | 0.18–0.22 | | | | 0.25–0.30 | |
| **Attenuation (dB/km)** | @850nm | @1300nm | @850 | @1310 | @850nm | @1300nm |
| High Temperature | ≤3.2 | ≤1.0 | <3.5 | <1.5 | ≤3.2 | ≤1.0 |
| Carbon High Temperature | ≤3.2 | ≤1.0 | <3.5 | <1.5 | ≤3.2 | ≤1.0 |
| Polyimide | ≤4.0 | ≤2.0 | <3.5 | <1.5 | ≤4.0 | ≤2.0 |
| Carbon Polyimide | ≤4.0 | ≤2.0 | <3.5 | <1.5 | ≤4.0 | ≤2.0 |
| **Proof Test (%)** | 1 or 2 (100 or 200 kpsi) | | | | | |
| **Bandwidth (MHz.km)** | 400/400 @850/1300nm | | 500/500 @850/1300nm | | 160/160 @850/1300nm | |
| **Cladding Diameter (µm)** | High Temperature & Polyimide: 125 ± 1<br>Carbon High Temperature & Carbon Polyimide: 125 ± 2 | | | | | |
| **Core Cladding Concentricity (µm)** | ≤2.0 | | | | | |
| **Coating Diameter (µm)** | High Temperature & Carbon High Temperature: 245 ± 15<br>Polyimide & Carbon Polyimide: 155 ± 5 | | | | | |
| **Core Diameter (µm) (nominal)** | 50 | | | | 62.5 | |
| **Coating Type** | High Temperature, Carbon High Temperature, Polyimide & Carbon Polyimide | | | | | |
| **Operating Temperature (°C)** | High Temperature & Carbon High Temperature: -50 to +150<br>Polyimide & Carbon Polyimide: -50 to +300 | | | | | |

* Special easier to strip polyimide coating available for window stripping, for applications such as FBGs.
For Coatings Order Guide see pg. 54





# GRADED INDEX MULTIMODE PURE SILICA CORE FIBER

- Coatings available for 150°C and 300°C
- Graded Index profile
- High bandwidth
- Hermetic coating option
- Hydrogen resistance

## TYPICAL APPLICATIONS

- Distributed temperature sensing
- Pipeline monitoring
- Fire detection systems
- Production/injection monitoring
- DTS in hydrogen
- DTS in radiation

## SPECIFICATIONS

| | GIMMSC(50/125) |
|---|---|
| **Operating Wavelength (nm)** | 600–1750 |
| **Numerical Aperture** | 0.18–0.22 |
| **Attenuation (dB/km)** | ≤3.0 @850nm<br>≤1.2 @1300nm |
| **Proof Test (%)** | 1 or 2 (100 or 200 kpsi) |
| **Bandwidth (MHz.km)** | 300/300 @850/1300nm |
| **Cladding Diameter (µm)** | High Temperature & Polyimide: 125 ± 1<br>Carbon High Temperature & Carbon Polyimide: 125 ± 2 |
| **Core Cladding Concentricity (µm)** | ≤2.0 |
| **Core Diameter (µm) (nominal)** | 50 |
| **Coating Diameter (µm)** | High Temperature & Carbon High Temperature: 245 ± 7<br>Polyimide & Carbon Polyimide: 155 ± 5 |
| **Coating Type** | High Temperature, Carbon High Temperature, Polyimide & Carbon Polyimide |
| **Operating Temperature (°C)** | High Temperature & Carbon High Temperature: -50 to +150<br>Polyimide & Carbon Polyimide: -50 to +300 |

# LARGE CORE FIBER

- Wide range of coatings available
- High and low OH variants available, optimized for UV or visible/NIR applications
- Broad selection of core diameters for high power applications
- Highly customizable designs, alternative designs available by request
- ETFE and Nylon buffers available on request

## TYPICAL APPLICATIONS

- Fiber laser beam delivery fiber
- Biomedical devices including optical power delivery within catheters
- Endoscopes
- Spectroscopy
- Pump diode pigtails





## SPECIFICATIONS

| | MMSC(105/125)0.22 |
|---|---|
| Operating Wavelength (nm) | 500–1600 |
| OH Level | Low (High OH for UV wavelengths also available) |
| Numerical Aperture | 0.20–0.24 |
| Core Diameter (µm) | 105 ± 2 |
| Core Composition | Silica |
| Proof Test (%) | 1 (100 kpsi) |
| Cladding Composition | Fluorosilicate |
| Cladding Diameter (µm) | 125 ± 1 |
| Coating Diameter (µm) | 245 ± 7 |
| Coating Type | Acrylate |
| Operating Temperature (°C) | -50 to +85 |

| | MMSC (200/220)0.22 | MMSC (300/330)0.22 | MMSC (400/440)0.22 | MMSC (600/660)0.22 |
|---|---|---|---|---|
| Operating Wavelength (nm) | 500–1600 | | | |
| OH Level | Low (High OH for UV wavelengths also available) | | | |
| Numerical Aperture | 0.20–0.24 | | | |
| Core Diameter (µm) | 200 ± 4 | 300 ± 7 | 400 ± 9 | 600 ± 10 |
| Core Composition | Silica | | | |
| Proof Test (%) | 1 (100 kpsi) | 0.7 (70 kpsi) | | |
| Cladding Composition | Fluorosilicate | | | |
| Cladding Diameter (µm) | 220 ± 4 | 330 ± 6 | 440 ± 8 | 660 ± 10 |
| Coating Diameter (µm) | Acrylate: 330<br>Polyimide: 240 | Acrylate: 450<br>Polyimide: 370 | Acrylate: 560<br>Polyimide: 480 | Acrylate: 840<br>Polyimide: 700 |
| Coating Type | Acrylate<br>Polyimide | | | |
| Operating Temperature (°C) | Acrylate: -55 to +150<br>Polyimide: -55 to +300 | | | |

Graded Index available upon request.

Polyimide is rated to cryogenic and high temperatures – contact Fibercore for further information.

# FIBER BRAGG GRATINGS (FBG)





Fibercore offers two types of FBGs:

- Femtosecond laser written FBGs for high mechanical strength and reduced hydrogen, radiation and UV photodarkening effects, suitable for use in harsh environments.
- Standard UV written FBGs for spectrally demanding applications, suitable for use in standard sensor and telecommunications environments.

The femtosecond laser written FBGs are written through the coating, without the need to strip and recoat. This maintains the inherently high mechanical strength of the fiber, making femto FBGs ideal for high strain and high reliability applications. Due to the way that the femtosecond inscription method works, FBGs are resistant to temperatures up to 700°C and can be written into non-photosensitive glass, allowing inscription into pure silica core fibers that have reduced attenuation sensitivity to hydrogen, radiation and UV light. This allows the FBGs to be used in harsh environments that might be experienced in the Oil & Gas industry, nuclear environments and UV laser applications.

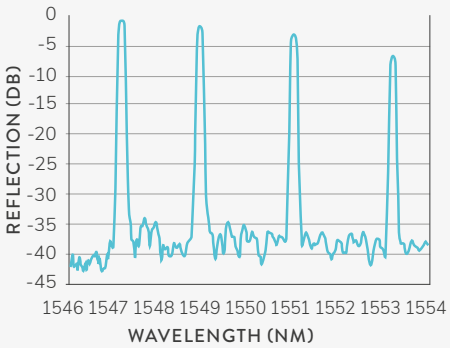
Standard UV written FBGs are available using the strip-and-recoat method. These FBGs offer a higher level of FBG specification with a greater flexibility on the spectral design, ideal for spectrally demanding applications in the sensing and telecommunications industries.

## TYPICAL APPLICATIONS

- Temperature sensing
- Strain sensing
- Hydrophone and geophone acoustic sensing
- Laser wavelength locking
- Wavelength division multiplexing

# FIBER BRAGG GRATINGS (FBGS)

- Ultra high temperature femto FBGs
- High mechanical strength FBGs
- Hydrogen darkening resistant variants
- Radiation induced attenuation resistant variants
- UV photodarkening resistant variants




## TYPICAL APPLICATIONS

- Temperature sensing
- Strain sensing
- Hydrophone and geophone acoustic sensing
- Laser wavelength locking
- Wavelength division multiplexing
- End tip force sensing

## SPECIFICATIONS

| | Femtosecond FBG | UV Written FBG |
|---|---|---|
| Central Wavelength (nm) | 790–850<br>1500–1600 | 970–1620 |
| Wavelength Tolerance (nm) | ±0.3 (standard)<br>±0.1 (optional) | ±0.5 (standard)<br>±0.25 (optional) |
| Reflectivity (%) | <1–>80 | 1–99 |
| FWHM Bandwidth (nm) | 0.3–1 | 0.1–3 |
| FBG Length (mm) | ≤150 | 1–25 |
| FBG Profile | Uniform or Apodized | |
| Chirp | No | Not chirped (standard)<br>Chirped (optional) |
| FBG Arrays | Optional | |
| Fiber Type | SM, MM | SM, PM |
| Fiber Cladding Diameters (µm) | 125, 80 | 125, 80, 60, 50 |
| Fiber Core Composition | Germanium Doped<br>Pure Silica | Germanium Doped |

Please note: Each parameter is inherently linked, therefore not all values are independently achievable.





# ENHANCED DISTRIBUTED ACOUSTIC SENSING FIBER (eDAS™)

- Enhanced SNR for distributed sensing techniques
- Thermally stable to 300°C
- Compatible with pure silica core fiber

## TYPICAL APPLICATIONS

- Distributed acoustic sensing (DAS)
- Oil and gas sensing
- Pipeline monitoring
- Structural health monitoring (SHM)

## SPECIFICATIONS

| | Low Temperature eDAS | Mid Temperature eDAS | High Temperature eDAS |
|---|---|---|---|
| Enhancement (dB)<br>[above Rayleigh scatter level] | 3-15 | | |
| Fiber Types | G.652 / G.657<br>(others on request) | SM1250(10.4/124)HT<br>SM1250SC(9/125)HT<br>(others on request) | SM1250SC(9/125)P<br>(others on request) |
| Reflector Spacing (m) | 0.5, 1, 5<br>(others on request) | | |
| Cladding Diameter (µm) | 125<br>(80µm on request) | | |
| Coating Diameter (µm) | 245 | | 155 |
| Coating Type | Acrylate | High Temperature Acrylate | Polyimide |
| Max Operating Temperature (°C) | 85 | 150 | 300 |

# COMPLEMENTARY PRODUCTS





At Fibercore, we understand you may require additional complementary products.

With this in mind, we have put together a range of products to enhance the specialty optical fibers we offer. Should you need something else, simply ask and we will see what we can do.

## THERE ARE FIVE RANGES OF COMPLEMENTARY PRODUCTS

### Fiber Optic Cables

High performance cables engineered for harsh environments including Oil & Gas, Subsea and Avionics applications.

- Downhole Fiber Optic Cable
- Slickline Fiber Optic Cable
- Wireline Fiber Optic Cable
- Fiber In Metal Tube
- Wire Armored Metal Tube

### Ruggedized Sleeving and Buffering

A range of sleeving options to ruggedize our specialty fibers for use in different environments.

### Pigtails and Patchcords

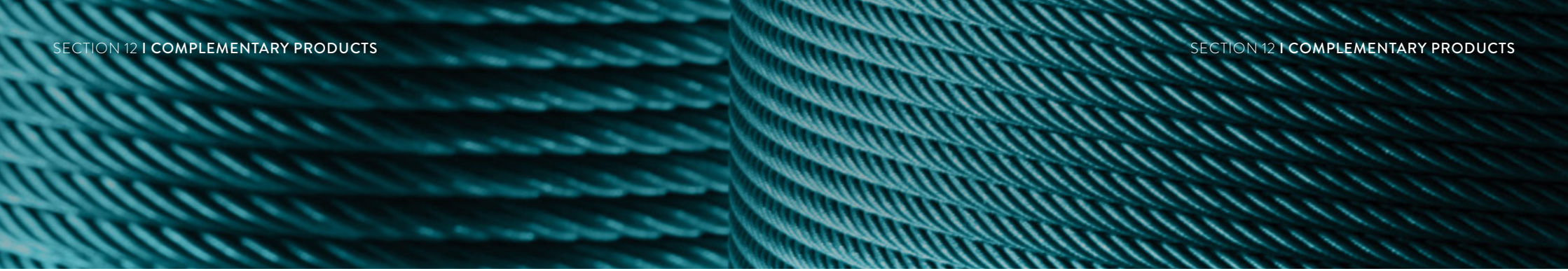
All our fibers are available ruggedized and connectorized if required. Whether you wish to use SM, PM or MM fiber, we can supply them as patchcords or pigtails to your specified length.

### Coreless Fiber

For beam expanding and hermetic sealing.

### Quarter Wave Plate Fiber

For manufacturing all-fiber quarter wave plates.



SECTION 12 I COMPLEMENTARY PRODUCTS

# FIBER OPTIC CABLES

Specialty high performance cables engineered for harsh environments.

In many applications, the optical fiber must be contained within a cable structure to ensure it survives the environment in which it is designed to be deployed. The best fiber in the World cannot overcome an improperly designed or manufactured cable. Fibercore brings over 25 years of cable design knowledge and manufacturing expertise to create cable designs that are customized to the rigors of specific environments. Fibercore specializes in the harshest of environments, ranging from cryogenic applications to the some of the hottest enhanced oil recovery wells. Fibercore extends to a network of manufacturing facilities, each with a particular strength and are not limited to in-house capabilities. For the most challenging applications, Fibercore delivers the best solution.

## CABLE APPLICATIONS

### Oil & Gas

Fiber optics are used for measuring a variety of attributes in an oil or gas well including: distributed temperature, distributed acoustic energy, and strain. This is also used alongside telemetry for fiber optic point sensors, such as pressure sensors and fiber Bragg gratings (FBGs). The types of cables used in the industry include: permanently installed fiber optic cables, logging cables (both wireline and slickline) and surface cables. With the information these types of cables can yield, the reservoir engineer can optimize the production from the oil or gas field thus improving the return on investment.

### Industrial Sensing

There are many environments where knowledge of the temperature, strain, acoustic energy or other attributes is beneficial to the user. Applications such as pipelines, LNG facilities, waterways, industrial facilities, power cables, dams, power generation facilities like nuclear, coal or gas have used fiber optics successfully to gain insight into their operation. Each of these applications would use slightly different cable structures to provide not only the robustness necessary for long term use, but also to optimize the measurement of the attribute desired.

## GOALS IN DESIGNING FIBER OPTIC CABLES

- Enable deployment of optical fiber
- Preserving optical transmission characteristics
- Optimizing the attribute to be measured
- Protecting from ecological/mechanical stress
- Providing reliable transmission throughout design life of cable

## PRODUCTS IN THIS RANGE

- Downhole Fiber Optic Cable
- Slickline Fiber Optic Cable
- Wireline Fiber Optic Cable
- Fiber In Metal Tube
- Wire Armored Metal Tube

# DOWNHOLE FIBER OPTIC CABLE

Fibercore offers a range of designs for downhole fiber optic cable to meet the specific requirements of your oil or gas well.

These types of cables are permanently installed either cemented in behind the casing or strapped to the production tubing. The optical fibers can be used to sense temperature and listen to well bore activities along the entire length of the cable and can be used for telemetry to point fiber optic sensors, such as pressure sensors and strain sensors. This information provides key data to the reservoir engineer to better manage both the well and the reservoir. Design variables include type and number of optical fibers, metal types to deal with different corrosive environments, thicknesses of metal tubes to handle different pressure requirements and outer encapsulations for improved handling and abrasion resistance.

## TYPICAL CABLE CROSS SECTIONS

Bare Downhole Cable

11mm Round Encapsulated Downhole Cable

11x11mm Square Encapsulated Downhole Cable

## SPECIFICATIONS

Available options

| | |
|---|---|
| Temperature Ratings (°C) | 85<br><150<br><300<br>(Higher temperature ratings available upon request) |
| Outer Encapsulation Options (11mm round and 11x11mm square) | Polypropylene, Nylon, Santoprene, PVDF, ETFE, ECTFE, FEP |

| Tube Material | Outer Diameter (mm) | Inner Diameter (mm) | Wall Thickness (mm) |
|---|---|---|---|
| 316L Stainless Steel | 6.35 (0.250") | 4.57 (0.180") | 0.89 (0.035") |
| | 6.35 (0.250") | 3.86 (0.152") | 1.245 (0.049") |
| Incoloy 825 | 6.35 (0.250") | 4.57 (0.180") | 0.89 (0.035") |
| | 6.35 (0.250") | 3.86 (0.152") | 1.245 (0.049") |





# SLICKLINE FIBER OPTIC CABLE

Fibercore offers a range of slickline fiber optic cables suitable for logging wells directly or to be incorporated into a coiled tube.

The portfolio utilizes a fiber in metal tube to house and protect the optical fibers and to ensure that the excess fiber length is controlled appropriately. As with the permanent downhole fiber optic cables, these fibers can be used to sense temperature and listen to well bore activities along the entire length of the cable and can be used for telemetry to point fiber optic sensors, such as pressure sensors and strain sensors that are incorporated into a tool. This information provides key information to the reservoir engineer to better manage the well and the reservoir. Design variables include: type and number of optical fibers, metal types to deal with different corrosive environments and thicknesses of metal tubes to handle different pressure requirements.

## TYPICAL CABLE CROSS SECTIONS

Single Outer Tube Slickline

Multilayer Slickline

## SPECIFICATIONS

Available options

| | |
|---|---|
| Temperature Ratings (°C) | 85<br><150<br><300 |

| Tube Material | Outer Diameter (mm) | Inner Diameter (mm) | Wall Thickness (mm) |
|---|---|---|---|
| 316L Stainless Steel | 3.175 (0.125") | 1.96 (0.077") | 0.60 (0.024") |
| | 4.000 (0.157") | 2.50 (0.098") | 0.75 (0.030") |
| Incoloy 825 | 3.175 (0.125") | 1.96 (0.077") | 0.60 (0.024") |
| | 4.000 (0.157") | 2.50 (0.098") | 0.75 (0.030") |

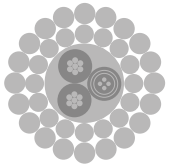
# WIRELINE FIBER OPTIC CABLE

Fibercore, in conjunction with selected partners, offer wireline logging cables that utilize Fibercore's hydrogen resistant, high temperature fibers.

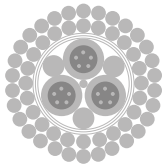
The optical fibers are protected in a hermetic metal tube to provide the necessary protection for incorporation into the wireline cable. By working closely with our partners, Fibercore ensures that our designs meet the rigorous requirements of wireline logging cables in regards to temperature, corrosion resistance and strength.

Optical fibers that are incorporated within these cables are used for telemetry to the tool, but can also be monitored for distributed temperature and acoustics, providing additional information for management of the well. In addition to the optical fibers, these cables can include insulated copper elements that can be used to power a tractor, components in the tool or for other sensors.

## TYPICAL CABLE CROSS SECTIONS



Electro-Optic Wireline



All Optical Wireline

## SPECIFICATIONS

Available options

| | |
|---|---|
| Temperature Ratings (°C) | 85<br><150<br><300<br>(Higher temperatures may be available upon request depending on application specifics) |





# FIBER IN METAL TUBE

Fibercore provides fiber in metal tubes (FIMTs) in different sizes, wall thickness and metal types.

FIMTs are used in a variety of applications due to the hermeticity of the tube, strength, crush resistance, corrosion resistance and fiber density. Some of these applications include downhole fiber optic cables, logging cables, power cables, cryogenic applications, industrial monitoring, subsea cables and many more.

## TYPICAL CABLE CROSS SECTIONS

0.84mm 2.4mm 3.2mm 4.0mm 6.35mm

## SPECIFICATIONS

Available options

| | |
|---|---|
| Temperature Ratings (°C) | 85<br><150<br><300<br>(Higher temperature ratings available upon request) |
| Outer Tube Materials | 304 Stainless Steel<br>316 Stainless Steel<br>Incoloy 825<br>Inconel 625<br>(Other materials may be available upon request) |
| Diameter Range | 0.84mm to 6.35mm (0.033" to 0.250")<br>(Diameters are available in 0.1mm increments) |
| Wall Thickness Range | 0.127mm to 0.3mm (0.005" to 0.12") |

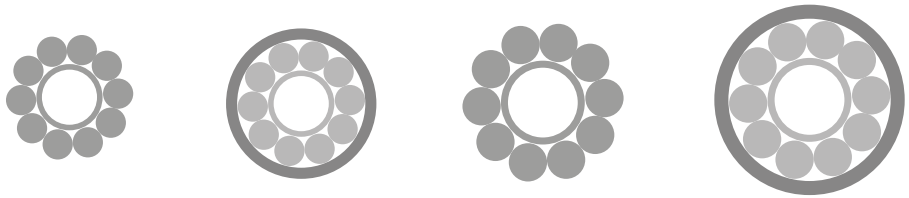
Outer buffering over the FIMT is available upon request.

# WIRE ARMORED METAL TUBE

Fibercore provides fiber in wire armored metal tubes, enabling further robustness to the FIMT.

FIMTs are prone to kinking and crushing, so are typically not used as a standalone product. With the addition of a high strength stranded wire layer over the FIMT, the handling characteristics improve tremendously along with crush performance and tensile strength. The tube construction incorporates stainless steel components to provide improved corrosion resistance and an optional outer polymer jacket is also available upon request. Typical applications for wire armored metal tubes are for tactical applications (deploy/re-deploy), hydrological studies, industrial sensing, power cable monitoring and more applications.

## TYPICAL CABLE CROSS SECTIONS



2.1mm | 2.1mm Jacketed | 2.8mm | 2.8mm Jacketed

## SPECIFICATIONS

Available options

| | |
|---|---|
| Temperature Ratings (°C) | 85<br><150<br><300<br>(Higher temperature ratings available upon request) |
| Construction | 316L Stainless Steel tube<br>316L Stainless Steel wires<br>Optional outer sheath (polyamide, polyethylene and other types upon request)<br>Up to 8 optical fibers |
| Diameter Range | 2.1mm to 4.8mm |
| Weight Range | 18kg to 46kg |
| Maximum Operational Tension | 750N to 2600N |
| Minimum Bend Radius | 20xDiameter |





# RUGGEDIZED SLEEVING AND BUFFERING

## PROTECTS VALUABLE FIBER

- Options available from 900µm tight or loose buffer to 3mm aramid reinforced cable
- Available in blue (for PM fiber), orange (MM fiber) and yellow (for other fiber), or other colours by request
- Provide essential protection for indoor and outdoor applications
- Fully compatible with the Fibercore range of connectors

Enables rapid fabrication of short custom cables.

- Furcation cable option
- Available without the fiber or connectors
- Nylon pull-cord allows ruggedization of virtually any fiber

## TYPICAL APPLICATIONS

- Sensor cables
- Medical probes
- Beam delivery

## SPECIFICATIONS

| | 900µm Hytrel® | LT3 (0.5/0.9) | LT3 (1.0/1.8) |
|---|---|---|---|
| Sheath Outer Coating (mm) | 0.9 | 2.8 | |
| Sheath Material | Hytrel® | PVC (blue) | |
| Loose Tube Outer Diameter (mm) | - | 0.9 | 1.8 |
| Loose Tube Inner Diameter (mm) | - | 0.5 | 1.0 |
| Loose Tube Material | - | Hytrel® (with fiber) | |
| Reinforcement | - | Aramid Yarn | |
| Pull Cord | No | Yes (Nylon filament) | |

# PIGTAILS AND PATCHCORDS

## FOR SPECIALTY SINGLE-MODE, MULTIMODE, MULTICORE OR POLARIZATION MAINTAINING FIBER

- Reliable, demountable connection for ease of fiber use
- Choice of Generic or Premium for optimum PM Fiber performance

## TYPICAL APPLICATIONS

- Fiber laser beam delivery
- Oil & Gas sensor cables
- Medical probes
- High bit rate data transmission

## CONNECTOR SPECIFICATIONS

| Type | Single-Mode Connectors | | Polarization Maintaining Connectors | |
|---|---|---|---|---|
| End Face Angle | 0° | 8° | 0° | 8° |
| Insertion Loss (dB) * | 0.2 Typical (0.4 Max) | | 0.4 Typical (0.5 Max) | |
| Return Loss (dB) | 50 | 65 | 50 | 65 |
| Repeatability (dB) | ±0.2 | | | |
| Service Life (Cycles) | 500 | | | |
| Extinction Ratio (dB) | Not applicable | | ≥25 | |
| Keyway Size | 2.00 ± 0.02mm | | | |
| Temperature Range (°C) | -40 to +80 | | | |
| Connector Types | Din UPC, E2000 APC, E2000 UPC, FC UPC, FC APC, LC APC, LC UPC, SC UPC, SMA, ST UPC | | | |

* Numbers provided are for ~10µm core size on 125µm clad fibers. Actual results will vary with different core sizes and wavelengths. Please contact Fibercore for further details.

Contact Fibercore for options and characteristics for Multicore Fiber connectors.

For sleeving options and selection guide see data sheet
fibercore.com/product/pigtails-and-patchcords

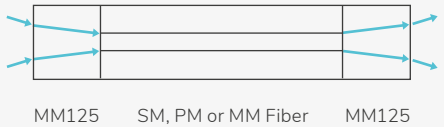




# CORELESS FIBER

## FOR BEAM EXPANDING AND HERMETIC SEALING

- Allows beam expansion at the end face of a small core fiber
- Larger MFD reduces end face power density
- Reduces power density related end effects reduces Fresnel back reflection coupling efficiency
- Hermetically seals Photonic Crystal Fibers (PCF) and holey fibers




## TYPICAL APPLICATIONS

- Fiber lasers
- Laser diodes
- Microscopy
- Distributed acoustic sensors (DAS)

## SPECIFICATIONS

| | MM125 |
|---|---|
| Cladding Diameter (µm) | 125 ± 1 |
| Coating Diameter (µm) | 245 ± 15 |
| Proof Test (%) | 1 (100 kpsi) |
| Coating Type | Acrylate<br>High Temperature Acrylate |
| Temperature Range (°C) | Acrylate: -55 to +85<br>High Temperature Acrylate: -55 to +150 |

# QUARTER WAVE PLATE FIBER

## FOR MANUFACTURING ALL-FIBER QUARTER WAVE PLATES

- Capable of converting linear polarization to circular polarization
- Designed for optical compatibility with Spun HiBi current sensor fibers
- High splice compatibility with Fibercore sensor fibers

## TYPICAL APPLICATIONS:

- Current sensors
- Polarimetric systems
- Quarter wave plates

## SPECIFICATIONS

| | HB1250(7.3/125)QW | HB1500(8.9/125)QW |
|---|---|---|
| Operating Wavelength (nm) | 1310 | 1550 |
| Cut-Off Wavelength (nm) | ≤1270 | 1200–1500 |
| Numerical Aperture | 0.13–0.17 | |
| Mode Field Diameter (µm) | 6.2–8.4 @1310nm | 7.9–9.9 @1550nm |
| Attenuation (dB/km) | ≤5 @1310nm | ≤5 @1550nm |
| Beat-Length (mm) @633nm | 3.0–4.3 | |
| Proof Test (%) | 1 (100 kpsi) | |
| Cladding Diameter (µm) | 125 ± 1 | |
| Coating Diameter (µm) | 245 ± 15 | |
| Core Concentricity (µm) | ≤1 | |

# ADDITIONAL SERVICES





## TEST, MEASUREMENT AND OTHER LABORATORY SERVICES

As a leading manufacturer of specialty fiber, Fibercore maintains a state-of-the-art test and measurement laboratory.

Fibercore have combined over 40 years' experience in the industry with an unsurpassed reputation for technical expertise and service. The facility enables Fibercore to provide a variety of services.

## WE OFFER MULTIPLE OPTIONS IN THIS GROUP

### Hydrogen Testing
Custom built facility to fully evaluate the performance of optical fibers.

### Qualification and Reliability Testing
Full testing facilities available from our highly skilled team of experts using our dedicated T&M laboratory.

### Fiber Test and Measurement
Detailed test facilities in accordance with BS EN ISO9001(2015) Quality System, undertaken by our team of experts.

### Fusion Splicing
For PM and rare-earth doped fibers.

### Development Projects and Custom Fiber
If the success of your project relies on the availability of a custom single-mode optical fiber, provided that it is based on silica-glass. Fibercore has the capability to develop that fiber on your behalf.

### Custom and Multifiber Cables
Fibercore can supply its range of specialty optical fibers, custom-cabled to suit highly complex deployments and demanding environments.

# FIBERCORE'S COMMITMENT TO...

## QUALITY: ISO 9001:2015

Fibercore is dedicated to supplying customers with exceptional quality products, service, and support. Accredited to ISO9001, Fibercore maintains traceability to all critical elements and materials in the fiber that is manufactured. The unique identification of every length of fiber ensures that all test and manufacturing data can be easily accessed.

Fully documented procedures and instructions provide consistency and uniformity of products. Controlled test plans implemented through calibrated equipment guarantees the fiber is matched to your application.

## ENVIRONMENT: ISO 14001:2015

Fibercore is committed to reducing its environmental impact, be this through the prevention of pollution or the reduction of resource and energy use.

An ISO14001 certified management system was installed by in-house staff to manage all aspects of Fibercore's environmental management including the permit under which Fibercore operates.

## HEALTH & SAFETY: ISO 45001:2018

Fibercore continues its commitment to quality by the addition of an Occupational Health & Safety Management System to our procedures.

## ROHS 3 AND REACH

Our products all comply with RoHS 3 requirements and with REACH.

## CONFLICT MINERALS

Fibercore is committed to ensuring that neither its products or the processes involved in their manufacture contain or utilize minerals sourced from Conflict Regions. Fibercore will continue to review its position under Section 1502 of the US Dodd-Frank Wall Street Reform and Consumer Protection Act.

Copies of these certificates, as well as our policies can be downloaded from our website at www.fibercore.com or contact us at info@fibercore.com





# A–Z OF ACRONYMS

| | |
|---|---|
| AOC | Active Optical Cable |
| ASE | Amplified Spontaneous Emission |
| C | Carbon and Acrylate |
| CATV | Cable Television |
| CHT | Carbon High Temperature |
| CP | Carbon Polyimide |
| DAS | Distributed Acoustic Sensing |
| dB | Decibel |
| DPS | Distributed Pressure Sensing |
| DSS | Distributed Strain Sensing |
| DTS | Distributed Temperature Sensing |
| DWDM | Dense Wavelength Division Multiplexing |
| EDFA | Erbium Doped Fiber Amplifier |
| EFL | Excess Fiber Length |
| EMI | Electromagnetic Interference |
| FBG | Fiber Bragg Grating |
| FC/APC | Ferrule Connector/Angled Physical Contact |
| FIMT | Fiber In Metal Tube |
| FOG | Fiber Optic Gyroscope |
| FTTx | Fiber To The x |
| Ge | Germanium |
| GRIN | Graded Index |
| HI | High Index |
| HiBi | High Birefringence |
| HT | High Temperature Acrylate |
| IR | Infrared |
| IWDM | Isolating Wavelength Division Multiplexer |
| LCT | Laser Communications Terminals |
| LDA | Laser Doppler Anemometer |
| LiDAR | Light Detection and Ranging |
| MFD | Mode Field Diameter |
| MM | Multimode |
| NA | Numerical Aperture |
| nm | Nanometer |
| OBS | Ocean Bottom Seismic |
| OCT | Optical Coherence Tomography |
| OD | Outer Diameter |
| OEM | Original Equipment Manufacturer |
| P | Polyimide |
| PCF | Photonic Crystal Fibers |
| PER | Polarization Extinction Ratio |
| PM | Polarization Maintaining |
| PS | Photosensitive |
| RIA | Radiation Induced Attenuation |
| RIP | Refractive Index Profile |
| RLG | Ring Laser Gyroscope |
| RT | Radiation Tolerant |
| SAGD | Steam Assisted Gravity Drainage |
| SAP | Stress Applying Part |
| SB | Short Beat-Length |
| SC | Silica Core |
| SDM | Space Division Multiplexing |
| SHM | Structural Health Monitoring |
| SM | Single-Mode |
| SMF | Single-Mode Fiber |
| SM-SC | Single-Mode Pure Silica Core |
| µm | Micron |
| UV | Ultraviolet |
| VSP | Vertical Seismic Profiling |
| WDM | Wavelength Division Multiplexer |
| YEDFA | Ytterbium Erbium Doped Fiber Amplifier |

Visit fibercore.com/fiberpaedia for our encyclopedia of industry terms/knowledge base.

# EQUATIONS

## NA, Cut-Off and MFD

$$NA = 2.405\left(\frac{\lambda_C}{\pi \times MFD}\right)\left[0.65 + \left(\frac{1.619}{\left[2.405 \times \frac{\lambda_C}{\lambda_{op}}\right]^{3/2}}\right) + \left(\frac{2.879}{\left[2.405 \times \frac{\lambda_C}{\lambda_{op}}\right]^{6}}\right)\right]$$

$$\lambda_c = \frac{2\pi a \times NA}{2.405}$$

$$MFD = 2a\left[0.65 + \left(\frac{1.619}{\left[2.405 \times \frac{\lambda_C}{\lambda_{op}}\right]^{3/2}}\right) + \left(\frac{2.879}{\left[2.405 \times \frac{\lambda_C}{\lambda_{op}}\right]^{6}}\right)\right]$$

### Key

- $a$ = core radius
- $B$ = birefringence
- $\lambda_c$ = 2nd order cut-off wavelength
- $\lambda_{op}$ = operating wavelength
- $n$ = refractive index
- $L_p$ = beat-length
- $P$ = power
- $V$ = V-value

## Refractive Index and NA

$$\Delta n = n_{core} - n_{clad} \qquad NA = \sqrt{n_{core}^2 - n_{clad}^2}$$

## Birefringence and Beat-Length

$$B = n_{slow} - n_{fast} \qquad B = \frac{\lambda}{L_p}$$

## V-value

$$V = \frac{2\pi a \times NA}{\lambda_{op}} \qquad V = 2.405\ \frac{\lambda_c}{\lambda_{op}}$$

## Scale–mW vs. dBmW

$$ratio\ [dB] = 10 \times \log_{10}\left(\frac{P_A}{P_B}\right) \qquad P\ [dBmW] = 10 \times \log_{10}\left(P\ [mW]\right)$$



# REPRESENTATIVES

We have representatives in the following regions. The most up-to-date information including contact details can be found on our website: **fibercore.com/representatives**

CHINA
GERMANY
INDIA
ISRAEL
JAPAN
RUSSIA
SINGAPORE
SOUTH KOREA
TAIWAN

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