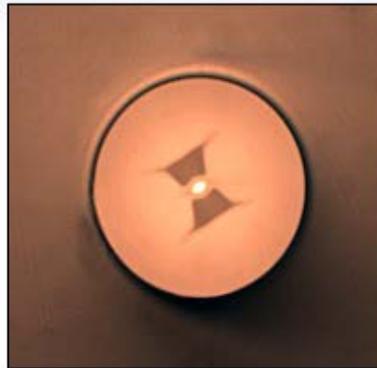


PM14XX-HP - October 4, 2019

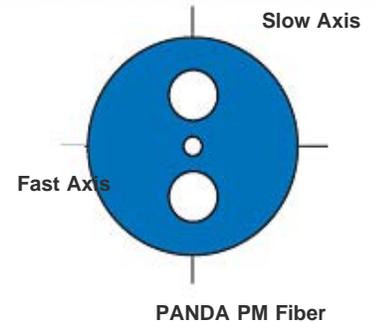
Item # PM14XX-HP was discontinued on October 4, 2019. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

POLARIZATION-MAINTAINING SINGLE MODE OPTICAL FIBER

- ▶ 350 nm to 2200 nm Operating Wavelengths
- ▶ Fibers with Ø80 µm or Ø125 µm Cladding
- ▶ Bow-Tie or PANDA Stress Rod Configurations



Bow-Tie PM Fiber



PANDA PM Fiber

[Hide Overview](#)

OVERVIEW

Features

| Available PM Fiber Types | | <ul style="list-style-type: none"> • Maintain Polarization State of Input PANDA or Bow-Tie Fiber • Specialized Photosensitive, Dispersion-Compensating, and Bend/Temperature-Insensitive Fibers Available <p>Thorlabs offers both PANDA and Bow-Tie Single Mode Polarization-Maintaining (PM) fiber. These two fibers are named based on the stress rods used. Stress rods run parallel to the fiber's core and apply stress that creates birefringence in the fiber's core,</p> |
|--------------------------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PANDA | Pure Silica Core | |
| | Standard | |
| | Photosensitive | |
| Bow-Tie | Dispersion Compensating | |
| | Standard | |
| | Bend- and Temperature-Insensitive | |

| Stock Patch Cables Available with these Fibers | | |
|------------------------------------------------|-----------------------------------------|----------------------------------------------------------------------------------|
| Type | Fibers Available | |
| Standard | FC/PC | PM-S405-XP, PM460-HP, PM630-HP, PM780-HP, PM980-XP, PM1300-XP, PM1550-XP, PM2000 |
| | FC/APC | |
| | Hybrid | |
| AR-Coated | PM630-HP, PM780-HP, PM980-XP, PM1550-XP | |
| Reflective-Coated | PM980-XP | |

allowing polarization-maintaining operation. PANDA stress rods are cylindrical, while bow-tie uses trapezoidal prism stress rods, as shown in the images above. For the average user, these two fiber types are interchangeable. PANDA fibers have historically been used in telecom applications, as it is easier to maintain uniformity in their cylindrical stress rods over very long lengths when manufacturing.

We also offer specialized PM fibers. Our photosensitive fiber can be exposed to UV light to create a Fiber Bragg Grating, our dispersion-compensating fiber corrects for chromatic dispersion, and our bend- and temperature-insensitive PM fiber is ideal for use in fiber optic gyroscopes (FOG).

S P E C S

PANDA Fibers, Pure Silica Core, 350 - 680 nm

| Item # | Wavelength Range | MFD ^a | NA ^b | Cut-Off Wavelength | Attenuation | Beat Length | Birefringence | Minimum Bend Radius ^c | Core Index | Cladding Index |
|------------|------------------|------------------------------------------------|-----------------|--------------------|----------------------------------------------|-----------------|------------------------|----------------------------------|-------------------|-------------------|
| PM-S350-HP | 350 - 460 nm | 2.3 μm @ 350 nm | 0.12 | ≤340 nm | - | 1.5 mm @ 350 nm | 2.5 x 10 ⁻⁴ | 13 mm | Call ^d | Call ^d |
| PM-S405-XP | 400 - 680 nm | 3.3 ± 0.5 μm @ 405 nm 4.6 ± 0.5 μm @ 630 nm | | 380 ± 20 nm | ≤30.0 dB/km @ 488 nm ≤30.0 dB/km @ 630 nm | 2.0 mm @ 405 nm | 2.5 x 10 ⁻⁴ | | | |

- Mode Field Diameter (MFD) is specified as a nominal value. It is the beam diameter at the 1/e² power level in the near field.
- Numerical Aperture (NA) is specified as a nominal value.
- Minimum bend radius for mechanical reliability.
- Please contact our Tech Support to learn more about the refractive index of this fiber, as we are not permitted to publish this information on our website.

| Item # | Core Diameter | Cladding Diameter | Coating Diameter | Core-Clad Offset | Coating Concentricity | Coating Material | Core Type | Operating Temperature Range | Proof Test Level | Strip Tool |
|------------|---------------|-------------------|------------------|------------------|-----------------------|------------------------|-------------|-----------------------------|------------------------------------|------------|
| PM-S350-HP | 2.5 μm | 125 ± 2 μm | 245 ± 15 μm | ≤0.5 μm | <5 μm | UV Cured Dual Acrylate | Pure Silica | -40 to 85 °C | ≥200 kpsi (1.4 GN/m ²) | T06S13 |
| PM-S405-XP | 3.0 μm | | | | | | | -60 to 85 °C | | |

PANDA Fibers, 460 - 2200 nm

| Item # | Wavelength Range | MFD ^a | NA ^b | Core Index | Cladding Index | Cut-Off Wavelength | Attenuation | Beat Length | Birefringence | Normalized Cross Talk | Minimum Bend Radius ^c |
|-----------|------------------|-------------------------|-----------------|-------------------|-------------------|--------------------|----------------------|-------------------|------------------------|---------------------------|----------------------------------|
| PM460-HP | 460 - 700 nm | 3.3 ± 0.5 μm @ 515 nm | 0.12 | Call ^d | Call ^d | 410 ± 40 nm | ≤100 dB/km @ 488 nm | 1.3 mm @ 460 nm | 3.5 x 10 ⁻⁴ | - | 13 mm |
| PM630-HP | 620 - 850 nm | 4.5 ± 0.5 μm @ 630 nm | | Call ^d | Call ^d | 570 ± 50 nm | ≤15 dB/km @ 630 nm | 1.8 mm @ 630 nm | | - | |
| PM780-HP | 770 - 1100 nm | 5.3 ± 1.0 μm @ 850 nm | | Call ^d | Call ^d | 710 ± 60 nm | ≤4 dB/km @ 850 nm | 2.4 mm @ 850 nm | | ≤-40 dB @ 4 m @ 850 nm | |
| PM980-XP | 970 - 1550 nm | 6.6 ± 0.5 μm @ 980 nm | | Call ^d | Call ^d | 920 ± 50 nm | ≤2.5 dB/km @ 980 nm | ≤2.7 mm @ 980 nm | - | ≤-40 dB @ 4 m | |
| PM1300-XP | 1270 - 1625 nm | 9.3 ± 0.5 μm @ 1300 nm | | Call ^d | Call ^d | 1210 ± 60 nm | ≤1.0 dB/km @ 1300 nm | ≤4.0 mm @ 1300 nm | - | ≤-30 dB @ 100 m (nominal) | |
| PM14XX-HP | 1390 - 1625 nm | 9.8 ± 0.8 μm @ 1450 nm | 0.13 | Call ^d | Call ^d | 1320 ± 60 nm | <1.0 dB/km @ 1450 nm | ≤4.7 mm @ 1450 nm | - | | |
| PM1550-XP | 1440 - 1625 nm | 10.1 ± 0.4 μm @ 1550 nm | 0.125 | Call ^d | Call ^d | 1380 ± 60 nm | <1.0 dB/km @ 1550 nm | ≤5.0 mm @ 1550 nm | - | ≤-40 dB @ 4 m @ 1550 nm | |

| | | | | | | | | | | |
|--------|----------------|-----------------------------|------|-------------------|-------------------|------------------|------------------------------------------------|------------------|---|---|
| PM2000 | 1850 - 2200 nm | 8.0 μm @ 1950 nm | 0.20 | Call ^d | Call ^d | 1720 \pm 80 nm | <11.5 dB/km @ 1950 nm <22.5 dB/km @ 2000 nm | 5.2 mm @ 1950 nm | - | - |
|--------|----------------|-----------------------------|------|-------------------|-------------------|------------------|------------------------------------------------|------------------|---|---|

- Mode Field Diameter (MFD) is specified as a nominal value. It is the beam diameter at the $1/e^2$ power level in the near field.
- Numerical Aperture (NA) is specified as a nominal value.
- Minimum bend radius for mechanical reliability.
- Please contact our Tech Support to learn more about the refractive index of this fiber, as we are not permitted to publish this information on our website.

| Item # | Core Diameter | Cladding Diameter | Coating Diameter | Core-Clad Offset | Coating Concentricity | Coating Material | Operating Temperature Range | Proof Test Level | Strip Tool |
|-----------|-------------------|---------------------------|----------------------------|--------------------------|-----------------------|------------------------|-----------------------------|------------------------------------------|------------|
| PM460-HP | 3.0 μm | 125 \pm 2 μm | 245 \pm 15 μm | \leq 0.5 μm | <5 μm | UV-Cured Dual Acrylate | -40 to 85 °C | \geq 200 kpsi (1.4 GN/m ²) | T06S13 |
| PM630-HP | 3.5 μm | | | | | | | | |
| PM780-HP | 4.5 μm | | | | | | | | |
| PM980-XP | 5.5 μm | | | | | | | | |
| PM1300-XP | 8.0 μm | | | | | | | | |
| PM14XX-HP | - | | | | | | | | |
| PM1550-XP | 8.5 μm | | | | | | | | |
| PM2000 | 7.0 μm | | | | | | | | |

Photosensitive PANDA Fiber, 980 nm

| Item # | Operating Wavelength | MFD | NA | Core Index | Cladding Index | Cut-Off Wavelength | Attenuation | Beat Length | Normalized Cross Talk |
|----------|----------------------|--------------------------------------|------|-------------------|-------------------|--------------------|---------------------------|------------------------|--------------------------------------------------------|
| PS-PM980 | 970 - 1550 nm | 6.6 \pm 1.0 μm @ 980 nm | 0.12 | Call ^a | Call ^a | 900 \pm 70 nm | \leq 3.0 dB/km @ 980 nm | \leq 3.5 mm @ 980 nm | \leq -40 dB @ 4 m \leq -25 dB @ 100 m (nominal) |

- Please contact our Tech Support to learn more about the refractive index of this fiber, as we are not permitted to publish this information on our website.

| Item # | Core Diameter | Cladding Diameter | Coating Diameter | Core-Clad Concentricity | Coating-Clad Offset | Coating Material | Operating Temperature Range | Proof Test Level | Strip Tool |
|----------|-------------------|-----------------------------|----------------------------|-------------------------|------------------------|------------------------|-----------------------------|------------------------------------------|------------|
| PS-PM980 | 6.0 μm | 125 \pm 1.0 μm | 245 \pm 15 μm | <0.5 μm | \leq 5 μm | UV Cured Dual Acrylate | -40 to 85 °C | \geq 100 kpsi (0.7 GN/m ²) | T06S13 |

PANDA, Dispersion-Compensating Fiber, 1510 - 1620 nm

| Item # | Operating Wavelength | MFD | NA | Core Index | Cladding Index | Cut-Off Wavelength, Slow-Axis | Attenuation | Beat Length ^a | Core Diameter |
|--------|----------------------|---------------------------|--------------------------|-------------------|-------------------|-------------------------------|--------------------------------------------------------------|--------------------------|--------------------------|
| PMDCF | 1510 - 1620 nm | 5 μm @ 1550 nm | Proprietary ^b | Call ^c | Call ^c | 1400 nm | 0.40 dB/km (Typical) @ 1550 nm 0.45 dB/km (Max) @ 1550 nm | 5 mm | Proprietary ^d |

- Typical Values at 1550 nm
- We regret that we cannot provide this proprietary information.
- Please contact our Tech Support to learn more about the refractive index of this fiber, as we are not permitted to publish this information on our website.

- We regret that we cannot provide this proprietary information.

| Item # | Cladding Diameter ^a | Coating Diameter ^a | Effective Area ^b | Differential | Splicing Loss, Direct ^{b,c} | Dispersion ^d | Dispersion Slope ^d | Relative Dispersion Slope ^d | Group Velocity Dispersion ^d | β_3/β_2^d | Strip Tool |
|--------|--------------------------------|-------------------------------|-----------------------------|--------------------------|--------------------------------------|-------------------------|--------------------------------|----------------------------------------|--------------------------------------------|---------------------|------------|
| | | | | Group Delay ^b | | | | | | | |
| PMDCF | 125 ± 1.5 μm | 250 ± 10 μm | 20 μm^2 | 2 ps/m | 1 dB | -100 ± 10 ps/(nm•km) | -0.34 ps/(nm ² •km) | 0.0034 ± 0.0004 nm ⁻¹ | 1.275 x 10 ⁵ fs ² /m | -25 fs | T06S13 |

- Typical Values
- Typical Values at 1550 nm
- Between PM1550-XP and PMDCF Optical Fibers
- Typical values along the slow axis at 1550 nm.

Bow-Tie Fibers, 980 - 1550 nm

| Item # | Design Wavelength ^a | MFD ^b | NA | Core Index ^c | Cladding Index ^c | Cut-Off Wavelength | Attenuation | Beat Length ^d |
|---------|--------------------------------|--------------------------|-------------|-------------------------------|-------------------------------|--------------------|-------------|--------------------------|
| HB980T | 980 nm | 5.3 - 6.4 μm | 0.13 - 0.15 | 980 nm: 1.45647 ^e | 980 nm: 1.45068 ^e | 870 - 970 nm | ≤3 dB/km | ≤2 mm |
| HB1250T | 1310 nm | 8.1 - 9.9 μm | 0.11 - 0.13 | 1310 nm: 1.45094 ^f | 1310 nm: 1.44680 ^f | 1100 - 1290 nm | <2 dB/km | <2 mm |
| HB1500T | 1550 nm | 9.6 - 11.7 μm | 0.11 - 0.13 | 1550 nm: 1.44813 ^f | 1550 nm: 1.44399 ^f | 1290 - 1520 nm | <2 dB/km | ≤2 mm |

- The Design Wavelength is the wavelength (or wavelengths) at which the fiber is typically used. In practice, the fiber will transmit the TEM₀₀ mode at wavelengths of up to approximately 200 nm longer than the cut-off wavelength.
- Mode Field Diameter (MFD) is specified as a nominal value. It is the beam diameter at the 1/e² power level in the near field.
- The index provided is nominal, at nominal operating wavelength.
- The Beat Length is measured at 633 nm for all HB fiber types. To a first approximation, beat length scales directly with operating wavelength.
- The index provided is for an NA of 0.13.
- The index provided is for an NA of 0.11.

| Item # | Cladding Diameter | Coating Diameter | Core-Clad Concentricity | Coating Material | Proof Test Level | Strip Tool |
|---------|-----------------------|------------------------|-------------------------|---------------------|------------------------------------------------------------------|------------|
| HB980T | 125 ± 1 μm | 245 ± 15 μm | ≤0.6 μm | Dual-Layer Acrylate | 100 or 200 kpsi (0.7 or 1.4 GN/m ²) (1% or 2%) | T06S13 |
| HB1250T | | 400 μm ± 5% | | | | - |
| HB1500T | | | | | | - |

Bend- and Temperature-Insensitive Bow-Tie Fiber, 800 - 1000 nm

| Item # | Design Wavelength ^a | MFD ^b | NA | Core Index ^c | Cladding Index ^c | Cut-Off Wavelength | Attenuation | Beat Length ^d |
|--------|--------------------------------|-------------------------|-------------|------------------------------|------------------------------|--------------------|-------------|--------------------------|
| HB800G | 830 nm | 3.7 - 4.9 μm | 0.14 - 0.18 | 830 nm: 1.45954 ^e | 830 nm: 1.45282 ^e | 660 - 800 nm | ≤5 dB/km | ≤1.5 mm |

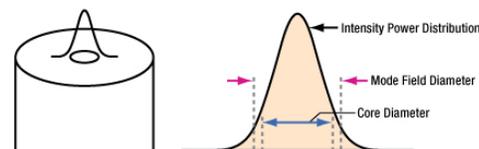
- The fiber will transmit the TEM₀₀ mode at wavelengths up to approximately 200 nm longer than the cutoff wavelength.
- Mode Field Diameter (MFD) is specified as a nominal value. It is the beam diameter at the 1/e² power level in the near field.
- The index provided is nominal, at nominal operating wavelength.
- The Beat Length is measured at 633 nm for all HB fiber types. To a first approximation, beat length scales directly with operating wavelength.
- The index provided is for an NA of 0.14

| Item # | Cladding Diameter | Coating Diameter | Core-Clad Concentricity | Coating Material | Proof Test Level | Strip Tool |
|--------|----------------------|-----------------------|-------------------------|------------------|---------------------------------------------------------------|------------|
| HB800G | 80 ± 1 μm | 165 ±10 μm | ≤1 μm | Dual Acrylate | 100 or 200 kpsi (0.7 or 1.4 GN/m ²) (1% or 2%) | T04S10 |

MFD DEFINITION

Definition of the Mode Field Diameter

The mode field diameter (MFD) is one measure of the beam width of light propagating in a single mode fiber. It is a function of wavelength, core radius, and the refractive indices of the core and cladding. While much of the light in an optical fiber is trapped within the fiber core, a small fraction propagates in the cladding. The light can be approximated as a Gaussian power distribution as shown to the right, where the MFD is the diameter at which the optical power is reduced to $1/e^2$ from its peak level.



[Click to Enlarge](#)

The left image shows the intensity profile of the beam propagated through the fiber overlaid on the fiber itself. The right image shows the standard intensity profile of the beam propagated through the fiber with the MFD and core diameter called out.

Measurement of MFD

The measurement of MFD is accomplished by the Variable Aperture Method in the Far Field (VAMFF). An aperture is placed in the far field of the fiber output, and the intensity is measured. As successively smaller apertures are placed in the beam, the intensity levels are measured for each aperture; the data can then be plotted as power vs. the sine of the aperture half-angle (or the numerical aperture for an SM fiber).

The MFD is then determined using Petermann's second definition, which is a mathematical model that does not assume a specific shape of power distribution. The MFD in the near field can be determined from this far-field measurement using the Hankel Transform.

[Hide Damage Threshold](#)

DAMAGE THRESHOLD

Laser-Induced Damage in Silica Optical Fibers

The following tutorial details damage mechanisms relevant to unterminated (bare) fiber, terminated optical fiber, and other fiber components from laser light sources. These mechanisms include damage that occurs at the air / glass interface (when free-space coupling or when using connectors) and in the optical fiber itself. A fiber component, such as a bare fiber, patch cable, or fused coupler, may have multiple potential avenues for damage (e.g., connectors, fiber end faces, and the device itself). The maximum power that a fiber can handle will always be limited by the lowest limit of any of these damage mechanisms.

While the damage threshold can be estimated using scaling relations and general rules, absolute damage thresholds in optical fibers are very application dependent and user specific. Users can use this guide to estimate a safe power level that minimizes the risk of damage. Following all appropriate preparation and handling guidelines, users should be able to operate a fiber component up to the specified maximum power level; if no maximum is specified for a component, users should abide by the "practical safe level" described below for safe operation of the component. Factors that can reduce power handling and cause damage to a fiber component include, but are not limited to, misalignment during fiber coupling, contamination of the fiber end face, or imperfections in the fiber itself. For further discussion about an optical fiber's power handling abilities for a specific application, please contact Thorlabs' Tech Support.

Damage at the Air / Glass Interface

There are several potential damage mechanisms that can occur at the air / glass interface. Light is incident on this interface when free-space coupling or when two fibers are mated using optical connectors. High-intensity light can damage the end face leading to reduced power handling and permanent damage to the fiber. For fibers terminated with optical connectors where the connectors are fixed to the fiber ends using epoxy, the heat generated by high-intensity light can burn the epoxy and leave residues on the fiber facet directly in the beam path.



[Click to Enlarge Damaged Fiber End](#)



[Click to Enlarge Undamaged Fiber End](#)

Damage Mechanisms on the Bare Fiber End Face

Damage mechanisms on a fiber end face can be modeled similarly to bulk optics, and industry-standard damage thresholds for UV Fused Silica substrates can be applied to silica-based fiber. However, unlike bulk optics, the relevant surface areas and beam diameters involved at the air / glass interface of an optical fiber are very small, particularly for coupling into single mode (SM) fiber. therefore, for a given power density, the power incident on the fiber needs to be lower for a smaller beam diameter.

Estimated Optical Power Densities on Air / Glass Interface^a

| Type | Theoretical Damage Threshold ^b | Practical Safe Level ^c |
|---------------------------|-------------------------------------------|-----------------------------------|
| CW (Average Power) | ~1 MW/cm ² | ~250 kW/cm ² |
| 10 ns Pulsed (Peak Power) | ~5 GW/cm ² | ~1 GW/cm ² |

- All values are specified for unterminated (bare) silica fiber and apply for free space coupling into a clean fiber end face.

The table to the right lists two thresholds for optical power densities: a theoretical damage threshold and a "practical safe level". In general, the theoretical damage threshold represents the estimated maximum power density that can be incident on the fiber end face without risking damage with very good fiber end face and coupling conditions. The "practical safe level" power density represents minimal risk of fiber damage. Operating a fiber or component beyond the practical safe level is possible, but users must follow the appropriate handling instructions and verify performance at low powers prior to use.

- This is an estimated maximum power density that can be incident on a fiber end face without risking damage. Verification of the performance and reliability of fiber components in the system before operating at high power must be done by the user, as it is highly system dependent.
- This is the estimated safe optical power density that can be incident on a fiber end face without damaging the fiber under most operating conditions.

Calculating the Effective Area for Single Mode and Multimode Fibers

The effective area for single mode (SM) fiber is defined by the mode field diameter (MFD), which is the cross-sectional area through which light propagates in the fiber; this area includes the fiber core and also a portion of the cladding. To achieve good efficiency when coupling into a single mode fiber, the diameter of the input beam must match the MFD of the fiber.

As an example, SM400 single mode fiber has a mode field diameter (MFD) of $\sim\text{Ø}3\ \mu\text{m}$ operating at 400 nm, while the MFD for SMF-28 Ultra single mode fiber operating at 1550 nm is $\text{Ø}10.5\ \mu\text{m}$. The effective area for these fibers can be calculated as follows:

$$\text{SM400 Fiber: Area} = \pi \times (\text{MFD}/2)^2 = \pi \times (1.5\ \mu\text{m})^2 = 7.07\ \mu\text{m}^2 = 7.07 \times 10^{-8}\ \text{cm}^2$$

$$\text{SMF-28 Ultra Fiber: Area} = \pi \times (\text{MFD}/2)^2 = \pi \times (5.25\ \mu\text{m})^2 = 86.6\ \mu\text{m}^2 = 8.66 \times 10^{-7}\ \text{cm}^2$$

To estimate the power level that a fiber facet can handle, the power density is multiplied by the effective area. Please note that this calculation assumes a uniform intensity profile, but most laser beams exhibit a Gaussian-like shape within single mode fiber, resulting in a higher power density at the center of the beam compared to the edges. Therefore, these calculations will slightly overestimate the power corresponding to the damage threshold or the practical safe level. Using the estimated power densities assuming a CW light source, we can determine the corresponding power levels as:

$$\text{SM400 Fiber: } 7.07 \times 10^{-8}\ \text{cm}^2 \times 1\ \text{MW/cm}^2 = 7.1 \times 10^{-8}\ \text{MW} = 71\ \text{mW (Theoretical Damage Threshold)}$$

$$7.07 \times 10^{-8}\ \text{cm}^2 \times 250\ \text{kW/cm}^2 = 1.8 \times 10^{-5}\ \text{kW} = 18\ \text{mW (Practical Safe Level)}$$

$$\text{SMF-28 Ultra Fiber: } 8.66 \times 10^{-7}\ \text{cm}^2 \times 1\ \text{MW/cm}^2 = 8.7 \times 10^{-7}\ \text{MW} = 870\ \text{mW (Theoretical Damage Threshold)}$$

$$8.66 \times 10^{-7}\ \text{cm}^2 \times 250\ \text{kW/cm}^2 = 2.1 \times 10^{-4}\ \text{kW} = 210\ \text{mW (Practical Safe Level)}$$

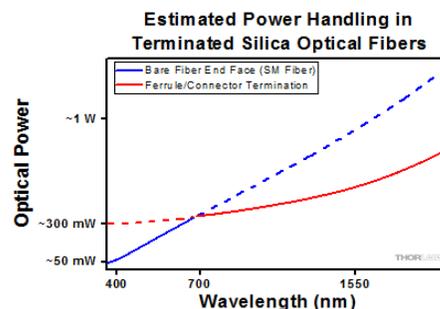
The effective area of a multimode (MM) fiber is defined by the core diameter, which is typically far larger than the MFD of an SM fiber. For optimal coupling, Thorlabs recommends focusing a beam to a spot roughly 70 - 80% of the core diameter. The larger effective area of MM fibers lowers the power density on the fiber end face, allowing higher optical powers (typically on the order of kilowatts) to be coupled into multimode fiber without damage.

Damage Mechanisms Related to Ferrule / Connector Termination

Fibers terminated with optical connectors have additional power handling considerations. Fiber is typically terminated using epoxy to bond the fiber to a ceramic or steel ferrule. When light is coupled into the fiber through a connector, light that does not enter the core and propagate down the fiber is scattered into the outer layers of the fiber, into the ferrule, and the epoxy used to hold the fiber in the ferrule. If the light is intense enough, it can burn the epoxy, causing it to vaporize and deposit a residue on the face of the connector. This results in localized absorption sites on the fiber end face that reduce coupling efficiency and increase scattering, causing further damage.

For several reasons, epoxy-related damage is dependent on the wavelength. In general, light scatters more strongly at short wavelengths than at longer wavelengths. Misalignment when coupling is also more likely due to the small MFD of short-wavelength SM fiber that also produces more scattered light.

To minimize the risk of burning the epoxy, fiber connectors can be constructed to have an epoxy-free air gap between the optical fiber and ferrule near the fiber end face. Our high-power multimode fiber patch cables use connectors with this design feature.



Click to Enlarge
Plot showing approximate input power that can be incident on a single mode silica optical fiber with a termination. Each line shows the estimated power level due to a specific damage mechanism. The maximum power handling is limited by the lowest power level from all relevant damage mechanisms (indicated by a solid line).

Determining Power Handling with Multiple Damage Mechanisms

When fiber cables or components have multiple avenues for damage (e.g., fiber patch cables), the maximum power handling is always limited by the lowest damage threshold that is relevant to the fiber component. In general, this represents the highest input power that can be incident on the patch cable end face and not the coupled output power.

As an illustrative example, the graph to the right shows an estimate of the power handling limitations of a single mode fiber patch cable due to damage to the fiber end face and damage via an optical connector. The total input power handling of a terminated fiber at a given wavelength is limited by the lower of the two limitations at any given wavelength (indicated by the solid lines). A single mode fiber operating at around 488 nm is primarily limited by damage to the fiber end face (blue solid line), but fibers operating at 1550 nm are limited by damage to the optical connector (red solid line).

In the case of a multimode fiber, the effective mode area is defined by the core diameter, which is larger than the effective mode area for SM fiber. This results in a lower power density on the fiber end face and allows higher optical powers (on the order of kilowatts) to be coupled into the fiber without damage (not shown in graph). However, the damage limit of the ferrule / connector termination remains unchanged and as a result, the maximum power handling for a multimode fiber is limited by the ferrule and connector termination.

Please note that these are rough estimates of power levels where damage is very unlikely with proper handling and alignment procedures. It is worth noting that optical fibers are frequently used at power levels above those described here. However, these applications typically require expert users and testing at lower powers first to minimize risk of damage. Even still, optical fiber components should be considered a consumable lab supply if used at high power levels.

Intrinsic Damage Threshold

In addition to damage mechanisms at the air / glass interface, optical fibers also display power handling limitations due to damage mechanisms within the optical fiber itself. These limitations will affect all fiber components as they are intrinsic to the fiber itself. Two categories of damage within the fiber are damage from bend losses and damage from photodarkening.

Bend Losses

Bend losses occur when a fiber is bent to a point where light traveling in the core is incident on the core/cladding interface at an angle higher than the critical angle, making total internal reflection impossible. Under these circumstances, light escapes the fiber, often in a localized area. The light escaping the fiber typically has a high power density, which burns the fiber coating as well as any surrounding furcation tubing.

A special category of optical fiber, called double-clad fiber, can reduce the risk of bend-loss damage by allowing the fiber's cladding (2nd layer) to also function as a waveguide in addition to the core. By making the critical angle of the cladding/coating interface higher than the critical angle of the core/clad interface, light that escapes the core is loosely confined within the cladding. It will then leak out over a distance of centimeters or meters instead of at one localized spot within the fiber, minimizing the risk of damage. Thorlabs manufactures and sells 0.22 NA double-clad multimode fiber, which boasts very high, megawatt range power handling.

Photodarkening

A second damage mechanism, called photodarkening or solarization, can occur in fibers used with ultraviolet or short-wavelength visible light, particularly those with germanium-doped cores. Fibers used at these wavelengths will experience increased attenuation over time. The mechanism that causes photodarkening is largely unknown, but several fiber designs have been developed to mitigate it. For example, fibers with a very low hydroxyl ion (OH) content have been found to resist photodarkening and using other dopants, such as fluorine, can also reduce photodarkening.

Even with the above strategies in place, all fibers eventually experience photodarkening when used with UV or short-wavelength light, and thus, fibers used at these wavelengths should be considered consumables.

Preparation and Handling of Optical Fibers

General Cleaning and Operation Guidelines

These general cleaning and operation guidelines are recommended for all fiber optic products. Users should still follow specific guidelines for an individual product as outlined in the support documentation or manual. Damage threshold calculations only apply when all appropriate cleaning and handling procedures are followed.

1. All light sources should be turned off prior to installing or integrating optical fibers (terminated or bare). This ensures that focused beams of light are not incident on fragile parts of the connector or fiber, which can possibly cause damage.
2. The power-handling capability of an optical fiber is directly linked to the quality of the fiber/connector end face. Always inspect the fiber end prior to connecting the fiber to an optical system. The fiber end face should be clean and clear of dirt and other contaminants that can cause scattering of coupled light. Bare fiber should be cleaved prior to use and users should inspect the fiber end to ensure a good quality cleave is achieved.
3. If an optical fiber is to be spliced into the optical system, users should first verify that the splice is of good quality at a low optical power prior to high-

power use. Poor splice quality may increase light scattering at the splice interface, which can be a source of fiber damage.

- Users should use low power when aligning the system and optimizing coupling; this minimizes exposure of other parts of the fiber (other than the core) to light. Damage from scattered light can occur if a high power beam is focused on the cladding, coating, or connector.

Tips for Using Fiber at Higher Optical Power

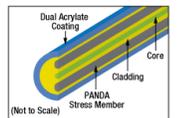
Optical fibers and fiber components should generally be operated within safe power level limits, but under ideal conditions (very good optical alignment and very clean optical end faces), the power handling of a fiber component may be increased. Users must verify the performance and stability of a fiber component within their system prior to increasing input or output power and follow all necessary safety and operation instructions. The tips below are useful suggestions when considering increasing optical power in an optical fiber or component.

- Splicing a fiber component into a system using a fiber splicer can increase power handling as it minimizes possibility of air/fiber interface damage. Users should follow all appropriate guidelines to prepare and make a high-quality fiber splice. Poor splices can lead to scattering or regions of highly localized heat at the splice interface that can damage the fiber.
- After connecting the fiber or component, the system should be tested and aligned using a light source at low power. The system power can be ramped up slowly to the desired output power while periodically verifying all components are properly aligned and that coupling efficiency is not changing with respect to optical launch power.
- Bend losses that result from sharply bending a fiber can cause light to leak from the fiber in the stressed area. When operating at high power, the localized heating that can occur when a large amount of light escapes a small localized area (the stressed region) can damage the fiber. Avoid disturbing or accidentally bending fibers during operation to minimize bend losses.
- Users should always choose the appropriate optical fiber for a given application. For example, large-mode-area fibers are a good alternative to standard single mode fibers in high-power applications as they provide good beam quality with a larger MFD, decreasing the power density on the air/fiber interface.
- Step-index silica single mode fibers are normally not used for ultraviolet light or high-peak-power pulsed applications due to the high spatial power densities associated with these applications.

[Hide PANDA, PM Fiber, Pure Silica Core, 350 - 680 nm](#)

PANDA, PM Fiber, Pure Silica Core, 350 - 680 nm

- ▶ Pure Silica Core for Resistance to Photodarkening
- ▶ PANDA Stress Members
- ▶ Operating Wavelength Ranges Span from 350 to 680 nm



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PANDA PM Fiber Cross
Section](#)

These pure silica core polarization-maintaining fibers are designed for wavelengths from 350 to 680 nm. Their pure silica core provides protection from photodarkening, which makes them ideal for use at short wavelengths. These fibers use PANDA-type stress rods for polarization-maintaining operation.

| Item # | Wavelength Range | MFD ^a | NA ^b | Core Index | Cladding Index | Cut-Off | Attenuation | Beat Length | Cladding Diameter | Coating Diameter | Minimum Bend Radius ^c | Strip Tool |
|------------|------------------|------------------------------------------------|-----------------|-------------------|-------------------|-------------|----------------------------------------------|-----------------|-------------------|------------------|----------------------------------|------------|
| PM-S350-HP | 350 - 460 nm | 2.3 μm @ 350 nm | 0.12 | Call ^d | Call ^d | ≤340 nm | - | 1.5 mm @ 350 nm | 125 ± 2 μm | 245 ± 15 μm | 13 mm | T06S13 |
| PM-S405-XP | 400 - 680 nm | 3.3 ± 0.5 μm @ 405 nm 4.6 ± 0.5 μm @ 630 nm | | | | 380 ± 20 nm | ≤30.0 dB/km @ 488 nm ≤30.0 dB/km @ 630 nm | 2.0 mm @ 405 nm | | | | |

- Mode Field Diameter (MFD) is specified as a nominal value. It is the beam diameter at the 1/e² power level in the near field. See the *MFD Definition* for more information.
- Numerical Aperture (NA) is specified as a nominal value.
- Minimum bend radius for mechanical reliability.

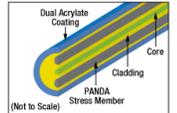
- Please contact our Tech Support to learn more about the refractive index of this fiber, as we are not permitted to publish this information on our website.

| Part Number | Description | Price | Availability |
|-------------|------------------------------------------------------------------|--------------------------------------------------|--------------|
| PM-S350-HP | 350 - 460 nm PM Fiber w/ Pure Silica Core, 2.3 μ m MFD | \$36.52 Per Meter Volume Pricing Available | Today |
| PM-S405-XP | 400 - 680 nm PM Fiber w/ Pure Silica Core, 3.5 - 4.6 μ m MFD | \$33.28 Volume Pricing Available | Today |

[Hide PANDA, PM Fiber, 460 - 2200 nm](#)

PANDA, PM Fiber, 460 - 2200 nm

- ▶ Operating Wavelength Ranges Span from 460 to 2200 nm
- ▶ PANDA Stress Members



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PANDA PM Fiber Cross
Section

These polarization-maintaining fibers are designed for single-mode transmission in the visible, NIR, and telecom wavelength ranges. They have PANDA-type stress rods for polarization-maintaining operation.

| Item # | Wavelength Range | MFD ^a | NA ^b | Core Index | Cladding Index | Cut-Off | Attenuation | Beat Length | Cladding Diameter | Coating Diameter | Minimum Bend Radius ^c | Strip Tool |
|-----------|------------------|-------------------------------------|-----------------|-------------------|------------------------------------------------------------------|---------------------|-------------------------------|----------------------------|---------------------|----------------------|----------------------------------|------------|
| PM460-HP | 460 - 700 nm | 3.3 \pm 0.5 μ m @ 515 nm | 0.12 | Call ^d | Call ^d | 410 \pm 40 nm | \leq 100 dB/km @ 488 nm | 1.3 mm @ 460 nm | 125 \pm 2 μ m | 245 \pm 15 μ m | 13 mm | T06S13 |
| PM630-HP | 620 - 850 nm | 4.5 \pm 0.5 μ m @ 630 nm | | | | 570 \pm 50 nm | \leq 15 dB/km @ 630 nm | 1.8 mm @ 630 nm | | | | |
| PM780-HP | 770 - 1100 nm | 5.3 \pm 1.0 μ m @ 850 nm | | | | 710 \pm 60 nm | \leq 4 dB/km @ 850 nm | 2.4 mm @ 850 nm | | | | |
| PM980-XP | 970 - 1550 nm | 6.6 \pm 0.5 μ m @ 980 nm | | | | 920 \pm 50 nm | \leq 2.5 dB/km @ 980 nm | \leq 2.7 mm @ 980 nm | | | | |
| PM1300-XP | 1270 - 1625 nm | 9.3 \pm 0.5 μ m @ 1300 nm | 0.13 | | | 1210 \pm 60 nm | \leq 1.0 dB/km @ 1300 nm | \leq 4.0 mm @ 1300 nm | | | | |
| PM14XX-HP | 1390 - 1625 nm | 9.8 \pm 0.8 μ m @ 1450 nm | | | | 1320 \pm 60 nm | $<$ 1.0 dB/km @ 1450 nm | \leq 4.7 mm @ 1450 nm | | | | |
| PM1550-XP | 1440 - 1625 nm | 10.1 \pm 0.4 μ m @ 1550 nm | 0.125 | | | 1380 \pm 60 nm | $<$ 1.0 dB/km @ 1550 nm | \leq 5.0 mm @ 1550 nm | | | | |
| PM2000 | 1850 - 2200 nm | 8.0 μ m @ 1950 nm | 0.20 | 1720 \pm 80 nm | \leq 11.5 dB/km @ 1950 nm \leq 22.5 dB/km @ 2000 nm | 5.2 mm @ 1950 nm | | | | | | |

- Mode Field Diameter (MFD) is specified as a nominal value. It is the beam diameter at the $1/e^2$ power level in the near field. See the *MFD Definition* for more information.
- Numerical Aperture (NA) is specified as a nominal value.
- Minimum bend radius for mechanical reliability.
- Please contact our Tech Support to learn more about the refractive index of this fiber, as we are not permitted to publish this information on our website.

| Part Number | Description | Price | Availability |
|-------------|----------------------------------------|--------------------------------------------------|--------------|
| PM460-HP | 460 - 700 nm PM Fiber, 3.3 μ m MFD | \$30.30 Per Meter Volume Pricing Available | Today |
| | | \$21.64 | |

| | | | |
|-----------|-------------------------------------------------------------|--------------------------------------------------|-----------|
| PM630-HP | 620 - 850 nm PM Fiber, 4.5 μm MFD | Per Meter Volume Pricing Available | Today |
| PM780-HP | 770 - 1100 nm PM Fiber, 5.3 μm MFD | \$21.64 Per Meter Volume Pricing Available | 5-8 Days |
| PM980-XP | 970 - 1550 nm PM Fiber, 6.6 μm MFD | \$27.06 Per Meter Volume Pricing Available | Today |
| PM1300-XP | 1270 - 1625 nm PM Fiber, 9.3 μm MFD | \$27.06 Per Meter Volume Pricing Available | Today |
| PM14XX-HP | 1390 - 1625 nm PM Fiber, 9.8 μm MFD | \$21.21 Per Meter | Lead Time |
| PM1550-XP | 1440 - 1625 nm PM Fiber, 10.1 μm MFD | \$27.06 Per Meter Volume Pricing Available | Today |
| PM2000 | Customer Inspired! 1850 - 2200 nm PM Fiber, 8.0 μm MFD | \$46.27 Per Meter Volume Pricing Available | Today |

[Hide PANDA, Photosensitive PM Fiber, 970 - 1550 nm](#)

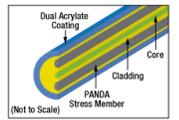
PANDA, Photosensitive PM Fiber, 970 - 1550 nm

Features

- ▶ Typical PM Fiber Performance with Added Photosensitivity
- ▶ PANDA Stress Members
- ▶ High Photosensitivity
- ▶ High Lot-to-Lot Uniformity

Applications

- ▶ Grating-Based Pump Diode Pigtailed
- ▶ Sensors
- ▶ Multiplexers



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PANDA PM Fiber Cross Section

PS-PM980 photosensitive 970 - 1550 nm polarization maintaining fiber is designed to perform all functions of a 980 nm PM fiber but with enhanced photosensitivity for fabrication of gratings. Portions of this fiber that are exposed to UV light will have their refractive index changed, thus allowing the construction of a Fiber Bragg Grating or other types of devices with periodic changes in refractive index.

This fiber is designed for use in 980 nm pump diodes, couplers and multiplexers. Using one fiber that provides excellent photosensitivity, as well as polarization maintaining attributes, substantially reduces writing time thus lowering costs.

| Item # | Operating Wavelength | MFD | NA | Core Index | Cladding Index | Cut-Off Wavelength | Attenuation | Cladding Diameter | Coating Diameter | Strip Tool |
|----------|----------------------|-----------------------|------|-------------------|-------------------|--------------------|---------------------|-------------------|------------------|------------|
| PS-PM980 | 970 - 1550 nm | 6.6 ± 1.0 μm @ 980 nm | 0.12 | Call ^a | Call ^a | 900 ± 70 nm | ≤3.0 dB/km @ 980 nm | 125 ± 1.0 μm | 245 ± 15 μm | T06S13 |

- Please contact our Tech Support to learn more about the refractive index of this fiber, as we are not permitted to publish this information on our website.

| Part Number | Description | Price | Availability |
|-------------|---------------------------------------------------|--------------------------------------------------|--------------|
| PS-PM980 | 970 - 1550 nm PM Photosensitive Fiber, 6.6 μm MFD | \$34.08 Per Meter Volume Pricing Available | Today |

[Hide PANDA, PM Dispersion-Compensating Fiber, 1510 - 1620 nm](#)

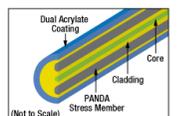
PANDA, PM Dispersion-Compensating Fiber, 1510 - 1620 nm

Features

- ▶ -100 ± 10 ps/(nm·km) Dispersion at 1550 nm
- ▶ -0.34 ps/(nm²·km) Dispersion Slope at 1550 nm



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- ▶ Dispersion and Dispersion Slope Matched to Standard PM 1550 nm Fibers
- ▶ Optimized for Slow-Axis Light Propagation

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PANDA PM Fiber Cross
Section

Applications

- ▶ Pulse-Stretching or Pulse-Compression Fiber
- ▶ Optical Timing Distribution Systems
- ▶ Telecommunications

Thorlab's PMDCF Dispersion-Compensating fibers (DCF) corrects for both the chromatic dispersion and dispersion slope of standard PM optical fiber in the 1510 to 1620 nm wavelength range. Sub-picosecond pulses are transmitted with low loss and no pulse broadening caused by chromatic dispersion, all while maintaining linear polarization. The fiber has PANDA stress rod supports that run parallel to the fiber's core and apply stress that creates a birefringence in the fiber's core which enables polarization-maintaining operation, and is specially designed for slow-axis light propagation.

| Item # | Operating Wavelength | MFD | NA | Core Index | Cladding Index | Cut-Off Wavelength, Slow-Axis | Attenuation | Cladding Diameter | Coating Diameter | Strip Tool |
|--------|----------------------|---------------------------|--------------------------|-------------------|-------------------|-------------------------------|---------------------------------------------------------|-----------------------------|----------------------------|------------|
| PMDCF | 1510 - 1620 nm | 5 μm @ 1550 nm | Proprietary ^a | Call ^b | Call ^b | 1400 nm | 0.40 dB/km (Typ.) @1550 nm 0.45 dB/km (Max) @1550 nm | 125 \pm 1.5 μm | 250 \pm 10 μm | T06S13 |

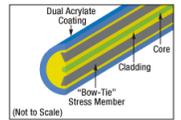
- We regret that we cannot provide this proprietary information.
- Please contact our Tech Support to learn more about the refractive index of this fiber, as we are not permitted to publish this information on our website.

| Part Number | Description | Price | Availability |
|-------------|----------------------------------------------------------------------|--------------------|--------------|
| PMDCF | 1510 - 1620 nm PM Dispersion-Compensating Fiber, 5 μm MFD | \$350.10 Per Meter | Today |

[Hide Bow-Tie, PM Fiber, 980 - 1550 nm](#)

Bow-Tie, PM Fiber, 980 - 1550 nm

- ▶ Operating Wavelength Ranges Span from 980 to 1550 nm
- ▶ Bow-Tie Stress Members



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Bow-Tie PM Fiber Cross
Section

These polarization-maintaining fibers use bow-tie stress members. They are commonly used for sensor applications, polarization multiplexing of EDFA lasers, and laser pigtailing.

| Item # | Design Wavelength ^a | MFD ^b | NA | Core Index ^c | Cladding Index ^c | Cut-Off | Attenuation ^d | Beat Length ^e | Cladding Diameter | Coating Diameter | Strip Tool |
|---------|--------------------------------|--------------------------|-------------|-------------------------------|-------------------------------|----------------|--------------------------|--------------------------|---------------------------|----------------------------|------------|
| HB980T | 980 nm | 5.3 - 6.4 μm | 0.13 - 0.15 | 980 nm: 1.45647 ^f | 980 nm: 1.45068 ^f | 870 - 970 nm | \leq 3 dB/km | \leq 2 mm | 125 \pm 1 μm | 245 \pm 15 μm | T06S13 |
| HB1250T | 1310 nm | 8.1 - 9.9 μm | 0.11 - 0.13 | 1310 nm: 1.45094 ^g | 1310 nm: 1.44680 ^g | 1100 - 1290 nm | $<$ 2 dB/km | $<$ 2 mm | 125 \pm 1 μm | 400 μm \pm 5% | N/A |
| HB1500T | 1550 nm | 9.6 - 11.7 μm | 0.11 - 0.13 | 1550 nm: 1.44813 ^g | 1550 nm: 1.44399 ^g | 1290 - 1520 nm | $<$ 2 dB/km | \leq 2 mm | 125 \pm 1 μm | 400 μm \pm 5% | N/A |

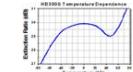
- The design wavelength is the wavelength at which the fiber is typically used. In practice, the fiber will transmit the TEM₀₀ mode at wavelengths up to approximately 200 nm longer than the cutoff wavelength.
- Mode Field Diameter (MFD) is specified as a nominal value. It is the beam diameter at the 1/e² power level in the near field. See the *MFD Definition* for more information.
- The index provided is nominal, at nominal operating wavelength.
- Attenuation is a worst-case value, quoted for the shortest design wavelength.
- The Beat Length is measured at 633 nm for all HB fiber types. To a first approximation, beat length scales directly with operating wavelength.
- The index of refraction provided is for an NA of 0.13.
- The index of refraction provided is for an NA of 0.11.

| Part Number | Description | Price | Availability |
|-------------|--------------------------------------------------------------------------------|--------------------------------------------------|--------------|
| HB980T | Design Wavelength: 980 nm, Telecom Optimized PM Fiber, 5.3 - 6.4 μ m MFD | \$20.78 Per Meter Volume Pricing Available | Today |
| HB1250T | Design Wavelength: 1310 nm, Telecom Optimized PM Fiber, 8.1 - 9.9 μ m MFD | \$20.78 Per Meter Volume Pricing Available | Today |
| HB1500T | Design Wavelength: 1550 nm, Telecom Optimized PM Fiber, 9.6 - 11.7 μ m MFD | \$20.78 Per Meter Volume Pricing Available | Today |

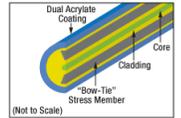
[Hide Bow-Tie, PM Fiber, Bend- and Temperature-Insensitive , 800 - 1000 nm](#)

Bow-Tie, PM Fiber, Bend- and Temperature-Insensitive , 800 - 1000 nm

- ▶ Optimized for Bend- and Temperature-Resistance Performance
- ▶ Ideal for Fiber Optic Gyroscope (FOG) Applications
- ▶ Bow-Tie Stress Members



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Bow-Tie PM Fiber Cross
Section

This polarization-maintaining fiber is optimized for fiber optic gyroscope (FOG) applications. It is designed for optimal performance over a wide temperature range and with a small coil radius. Extinction ratios of 29.5 dB at -40 °C and 28.5 dB at -60 °C are typical for this fiber.

| Item # | Design Wavelength ^a | MFD ^b | NA | Core Index ^c | Cladding Index ^c | Cut-Off | Attenuation ^d | Beat Length ^e | Cladding Diameter | Coating Diameter | Strip Tool |
|--------|--------------------------------|-------------------|-------------|------------------------------|------------------------------|--------------|--------------------------|--------------------------|--------------------|----------------------|------------|
| HB800G | 830 nm | 3.7 - 4.9 μ m | 0.14 - 0.18 | 830 nm: 1.45954 ^f | 830 nm: 1.45282 ^f | 660 - 800 nm | ≤ 5 dB/km | ≤ 1.5 mm | 80 \pm 1 μ m | 165 \pm 10 μ m | T04S10 |

- The design wavelength is the wavelength at which the fiber is typically used. In practice, the fiber will transmit the TEM₀₀ mode at wavelengths up to approximately 200 nm longer than the cutoff wavelength.
- Mode Field Diameter (MFD) is specified as a nominal value. It is the beam diameter at the 1/e² power level in the near field. See the *MFD Definition* for more information.
- The index provided is nominal, at nominal operating wavelength.
- Attenuation is a worst-case value, quoted for the shortest design wavelength.
- The Beat Length is measured at 633 nm for all HB fiber types. To a first approximation, beat length scales directly with operating wavelength.
- The index of refraction provided is for an NA of 0.14.

| Part Number | Description | Price | Availability |
|-------------|--------------------------------------------------------------------------|--------------------------------------------------|--------------|
| HB800G | Design Wavelength: 830 nm, FOG Optimized PM Fiber, 3.7 - 4.9 μ m MFD | \$20.78 Per Meter Volume Pricing Available | Today |