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FIBER FAQs

Bend-Optimized **Fiber**

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Bend-Optimized **Fiber**

Bend-Optimized Fiber

As today's FTTx networks push optical fiber to single-family homes and multiple dwelling units, they require smaller distribution cabinets and compact fiber management systems, where fiber is subject to a greater degree of bending.

These conditions have put more stringent demands than ever before on the bend performance of single-mode fibers. However, the need to maintain a very high degree of mechanical reliability hasn't changed. An understanding of the design and performance of bend-optimized fiber will help the user make a more informed decision in specifying a fiber that can support tighter bends but still be very reliable.

What is "bend-optimized" fiber?

Bend-optimized fiber is designed for use in FTTx and premises applications to minimize the effects of increased attenuation resulting from macrobends and microbends in single-mode fiber. Optimized bend performance is valuable in many cable and connectivity applications including low-count cables, small enclosures, or any application where small bend radii may be encountered. Bend-optimized fiber, such as OFS' AllWave® *FLEX* Fiber, can be coiled into a 10 mm radius loop with < 0.5 dB incurred loss at 1625 nm and < 0.2 dB incurred loss at 1550 nm – five times better bending performance than conventional single-mode fibers. These fibers also help improve cable performance in high-stress and low-temperature environments by providing double the microbending performance of conventional single-mode fibers.

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What's the difference between macrobending and microbending?

Optical fibers would not be practical if they had to be kept perfectly straight to guide light. However, deviations from a straight path ("bends") can cause light to scatter and escape from the core of the optical fiber. Bends fall into two categories. Macrobends are bends that are large enough to be seen by the human eye; microbends are microscopic deviations along the fiber axis. A macrobend could be caused by the routing of a jumper in a patch panel; a microbend could result if fiber is squeezed by cable buffer or jacket material as it contracts at very low temperatures. Both types of bends can result in increased attenuation that can degrade system performance.

A bend-optimized product such as AllWave *FLEX* Fiber excels in both types of bend performance, enabling smaller enclosures and novel cable designs. The macrobend performance of AllWave *FLEX* Fiber is five to eight times better than that of standard single-mode fiber, while the microbend performance is more than twice as good. This improved performance is ideal for the "last mile" of FTTx and connectivity applications.

For bend-sensitive applications, are there factors beyond bend-optimization that must be considered?

Bend performance is just one of several parameters that must be considered when designing an optical fiber for bend-sensitive applications; other key parameters include bandwidth, reliability, and compatibility with the installed base. In a well-designed fiber, these properties must be balanced to create a product that will provide the most value to the end user.

Most important is that the fiber is based on a proven design that is fully compliant with International Telecommunications Union (ITU) standard G.652D for single-mode fiber. This ensures that the fiber will work with existing transmission equipment. Also important are low polarization mode dispersion (PMD), excellent attenuation from 1260 nm to 1625 nm even in tight bends, and zero water peak to ensure that the product is ready for any future bandwidth upgrades. And very low splice loss when splicing either to itself or to the existing fiber base is, of course, essential.

The mechanical reliability of the fiber under reduced bends is another important concern. Be wary of any bend-insensitive fiber whose design allows for bends that are so tight that they threaten the mechanical reliability of the fiber. Low loss in a very tight bend (say, 5 to 7 mm in radius) may look like good performance during installation, but a bend this tight could result in a catastrophic fiber break that will disrupt service in the future and be difficult to repair.

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Has the industry developed a new standard for bend-optimized fiber?

Yes, the ITU recently adopted the G.657 standard to describe single-mode fibers with improved bending performance that are suitable for use in access networks. The ITU-T G.657 standard describes two categories of fibers.

- **Class A fibers:** are suitable for use from 1260 to 1625 nm and are actually a subset of G.652D (low water peak) fibers. G.657 Class A fibers have tighter dimensional tolerances than G.652D fibers, for improved connectivity. The attributes of these class A fibers are optimized for reduced macrobend loss while their specifications for attenuation, chromatic dispersion, and PMD remain the same as specified in G.652D. OFS takes its AllWave *FLEX* Fiber a step further by exceeding the G.657 Class A requirements
- **Class B fibers:** are suitable for transmission at 1310, 1550 and 1625 nm for restricted distances that are associated with in-building transport of signals. The class B fibers are capable of low macrobend losses at very tight bend radii, but can have different splicing and connection properties than G.652 fibers due to their varied designs and broad range of MFD values.

Can I splice a bend-optimized fiber like AllWave® *FLEX* fiber to an existing outside plant base composed mostly from matched cladding fiber?

Yes. AllWave *FLEX* Fiber was designed for excellent splice performance both to itself as well as to the embedded base of single-mode fiber. Because this is probably the most important concern that users have, OFS developed a bend-optimized fiber with excellent geometric attributes designed to yield consistently low splice loss.

OFS conducted a comprehensive splice study involving more than 1500 splices between AllWave *FLEX* Fiber to itself and to other standard single-mode fibers. The results, shown in the table below, illustrate the average splice loss for each combination of fibers, measured bi-directionally with an Optical Time Domain Reflectometer (OTDR). One important observation: the nominal mode field diameter (MFD) of AllWave *FLEX* Fiber is slightly smaller than that of standard AllWave Fiber. This explains why average splice loss values between AllWave *FLEX* Fiber and other fiber types are slightly higher than splice loss values between AllWave Fiber and other fiber types. It should also be noted that as with any single-mode fiber, this difference in mode field diameter can lead to one-way OTDR artifacts that are larger than what would be observed if only one fiber type was used. True splice loss is the average of OTDR measurements taken from each direction, not what is observed from a unidirectional measurement.

	AllWave® ZWP Fiber	AllWave® *FLEX* Fiber	Competitive Single-mode Fiber C	Competitive Single-mode Fiber D
AllWave® ZWP Fiber	0.02	0.03	0.03	
AllWave® *FLEX* Fiber		0.02	0.03	0.04

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When should I consider using bend-optimized fiber in my network?

As fiber pushes closer to the home, there are many situations in which a bend-optimized fiber can improve system performance. Some examples:

- **Low count cables:** As the fiber count within cables decreases, they are more likely to experience bends of 30 mm radius or less.
- **High density connectivity:** The improved microbending and macrobending performance and full spectrum capability of products like AllWave *FLEX* Fiber make them an ideal choice for patchcords in demanding applications such as central office and distribution cabinets.
- **Small enclosures:** The design of more compact enclosures for FTTx applications has been made possible by the superior macrobend performance of these fibers, specifically the ability to have bends with radii as small as 10 mm.
- **Low temperature applications:** The improved microbending of bend-optimized fiber boosts the performance of patch cords and cables at temperatures as low as -40°C.
- **Compact cable designs:** The use of bend-optimized fibers results in low attenuation after cabling in the small-diameter designs of today's premises cables and blown fiber units.
- **In-building applications, including drops:** Bend-optimized fiber supports this application without the disadvantages of a G.657B fiber.

What are the key parameters to specify in a bend-optimized fiber?

The best value in a system is a fiber that has optimized bend performance at high levels of mechanical reliability. There are several key design features that need to be considered:

- Good bend performance (without jeopardizing long term reliability)
- Low loss splice compatibility
- High mechanical reliability
- Zero water peak
- Low PMD
- G.652D compliant (fully compliant to the embedded base of single-mode fiber)

I've heard there are different designs of bend-optimized fiber. Which design is best?

In general, there are two ways to improve the bending properties of single-mode fiber. The first is to increase the refractive index of the core, and the second is to change the refractive index of the cladding.

Of the two, the simpler method is to increase the core index. However, this very simple design has several shortcomings. The main problem is that to get the improved bend performance and keep the fiber single-moded, the MFD must be reduced (thus, this is often referred to as the "small core" option). Limits on the range of acceptable MFD for standard single-mode fiber result in two weaknesses for fibers in this category: marginal improvement in bend performance and poor splice performance due to the small core.

The "modified cladding index" option allows improved bend performance while keeping the MFD compatible with the existing base of single-mode product. With OFS' fiber design expertise and highly advanced manufacturing processes, OFS was able to optimize this design approach for its AllWave *FLEX* ZWP Fiber.

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A lower index region around the core of the fiber greatly improves the bend performance, yet AllWave *FLEX* Fiber is still fully compatible with the embedded base. The advantages of the AllWave *FLEX* Fiber design include:

- optimized balance between reliability and bend performance
- twice the microbend performance
- excellent splice performance
- industry-accepted design

Other manufacturers use a more complex modified cladding index option known as the "trench-assisted" design. This design allows for more variable parameters to further improve the bending properties of the fiber, but has several limitations. The complex waveguide is difficult to splice, and the advantages in bend performance are in a region where long-term mechanical reliability is at risk.

This table compares the key parameters of fibers made through each option:

Attribute	Small Core Method	Modified Cladding Index Method	
		AllWave® *FLEX* Fiber process	Trench assisted process
Compliant with G.652D installed base	No	Yes	Yes
Good splice performance	No	Yes	No
Optimized bend performance	No	Yes	No
2X microbend improvement	No	Yes	?
Industry-accepted design	Yes	Yes	No

For additional information please contact your sales representatives. You can also visit our website at **www.ofsoptics.com/ofs-fiber** or call **1.888.fiberhelp**. For regional assistance, contact:

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