BELDEN

Application Note

Optical Fibers

Belden W&C B.V.

January 2021

BELDEN

Table of Contents

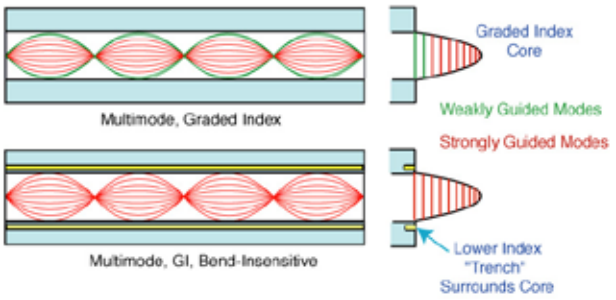
Bend Insensitive Optical Fibers

Optical fiber is sensitive to stress, particularly bending. When stressed by bending, light in the outer part of the core is no longer guided in the core of the fiber so some is lost, coupled from the core into the cladding, creating a higher loss in the stressed section of the fiber.

Fiber coatings and cables are designed to prevent as much bending loss as possible, but it's part of the nature of the fiber design. Bending losses are a function of the fiber type (SM or MM), fiber design (core diameter and NA), transmission wavelength (longer wavelengths are more sensitive to stress) and cable design.

In 2007, a new type of „bend-insensitive" singlemode fiber was introduced, followed by multimode fiber in 2009.

An optical "trench" - the term used for a ring of lower index of refraction material - was built into the fiber to basically reflect the lost light back into the core of the fiber. And in 2009, manufacturers introduced multimode fibers that showed using a similar technique could also improve bending loss in these fibers.

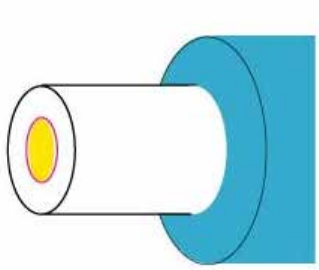


In regular graded index multimode fiber, there are many modes (or rays of light - about 400 of them) being transmitted down the fiber. The inner modes are „strongly guided" which means they have little sensitivity to bending stresses. But the outer modes are „weakly guided" which means they can be stripped out of the core when the fiber is bent.

Bend-insensitive fiber adds a layer of glass around the core of the fiber which has a lower index of refraction that literally „reflects" the weakly guided modes back into the core when stress normally causes them to be coupled into the cladding

The trench surrounds the core in both BI SMF and BI MMF to reflect lost light back into the core.

See the red ring around the core on this fiber drawing.



Compatibility With Conventional Fibers

One question that often arises is are these fibers compatible with regular fibers. Can they be spliced or connected to other conventional (non-BI) fibers without problems? How does the inclusion of higher order modes affect bandwidth?

That answer seems to be yes for all SM fibers. Since only one mode is guided in the core, the trench has a minimal impact on system performance and measurement.

For BI MMF, losses are within limits. Splicing an BI MMF to a conventional MMF gives splice losses less than 0.13 dB @ 850nm and less than 0.1 dB @ 1300nm. Splicing the BI MMF to itself gives splice losses less than 0.05 dB.

Single Mode Optical Fibers

Bend insensitive Single Mode optical fibers were primarily produced to support the fibre to the home (FTTH) applications. FTTH is growing and the demand for optical fibers suitable for transmission at 1550nm to utilize the DWDM application spectrum is increasing in the backbone networking.

1550nm is sensitive to bending and nowadays the trend is to use smaller cabinets and fiber storage mediums in order to reduce the installation space.

If backbone cables are sensitive to bending, the fiber optic cables will show increase in attenuation over a period of time under small bends.

To overcome these problems, optical fiber manufacturers have come up with bend insensitive optical fiber that can be used in the feeder cables as well as backbone cabling network. The trend in the FTTH scenario is moving towards further small bends and the demand from FTTH installation fields reaches up to 5 millimeter.

ITU-T standard

- ITU-T recommendation G.657 published on December 2006 had only two versions of Single mode fibers categorized as G.657.A and G.657.B. The difference between these fibers was in the permissible bending radius.
- Single mode optical fibers complying with ITU-T G.657A were developed with the purpose of using at FTTH sites. G.657A category fibers are therefore compliant with G.652 category fibers also. This back compatibility makes the G.657A category fibers suitable for access networks used for FTTH. The other category, G.657.B did not need to be compliant with G.652 fibers until recently. However due to further technical improvements the current G.657.B category fibers are also backwards compatible with G.652 category fibers.

Guidance

- ITU-T G.657.**A** fibers were developed to be bend tolerant up to **15mm** radius
  ITU-T G.657.**B** fibers were developed to be bend tolerant up to **7.5mm** radius
- The recent trends and the announcements from Industry leaders shows that single mode Optical fibers that is bend insensitive up to 10mm bending radius is categorized as **G.657.A.1** fibers. Fibers that are bend insensitive for bending radius upto 7.5mm are called **G.657.A.2** fibers. Both are compliant with G.652 recommendations as well.
- The industry leaders have recently introduced new versions of high performance bending insensitive fibers that are categorized as **G.657.B.3.** These fibers can tolerate a bending radius of **5mm** ! Also these fibers are fully G.652 compliant.

Multi Mode Optical Fibers

First the optical network market has seen several introductions of various grades of single-mode fiber with enhanced macro-bending performance down to a **5 mm** bend radius. These fibers have been primarily used in residential buildings applications with challenging installation environments.

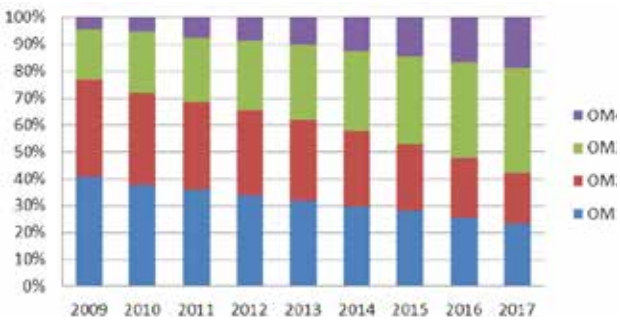
The last couple of years several 50 micron multimode fibers with enhanced macro-bending performance were introduced to reduce the challenges encountered in installations in local area network (LAN) **data centers**.

Trends in Fiber technology

It is recognised that **OM3**, introduced in 2002, represented a significant development in terms of bandwidth of multimode optical fiber. However, the performance levels attained today are signi-ficantly in excess of that milestone.

The multimode variant, currently termed **OM4**, provides more than twice the laser/VCSEL bandwidth of OM3 and is targeted to provide greater useable distance and lower system implementation costs for the next generation 40 Gb/s and 100 Gb/s Ethernet solutions that are currently in development.

There is a relentless demand for higher bandwidth and higher speed applications. In data centers currently 60% of the amount of cable is fiber and this number is increasing. Fibers with 10Gb/s Ethernet performance (OM3 and OM4) are preferred.OM3/OM4 has been the majority of 50 micron multimode fiber worldwide demand since 2012.



Bend-insensitive Multi Mode technology

Through precise engineering these bend-insensitive multimode fibers with the added benefit of improved bend are able to maintain an equivalent level of bandwidth, attenuation and temperature performance.

Bend-insensitive 50 micron multimode fiber is full backwards compatible with existing 50 micron multimode fiber and fully compliant to the OM2, OM3 and OM4 standards.

Features and benefits

Bend-insensitive multimode fiber has been designed to enhance fiber management in data centers, high performance computing and enterprise LANs.

This fibertype offers extremely low bending loss at both the 850 and 1300 nm operating windows, while maintaining excellent long term fiber strength and reliability. The fiber can be installed in loops as small as **7.5 mm** radius with less than 0.2 dB bending loss at 850 nm and 0.5 dB at 1300 nm.

Maximum induced bend loss performance at 850nm	Standard for Multimode fibers IEC 60793-2-10	Bend Insensitive MMF (no standard currently)
Bend radius	37.5 mm	7.5 mm
Number of turns	100	2
Conventional MMF	0.5 dB	–
Bend insensitive MMF	–	0.2 dB

Cabling infrastructure is increasingly subjected to tight bending, and will therefore cause increased signal loss and reduced system reliability.

With bend-insensitive multimode fiber it is possible to get the bandwidth performance of OM3/OM4 fiber without worrying about tight bends due to challenged installations, fiber caught in cabinet doors or cable ties that are pulled too tight. It is now possible to bend cables to significantly tighter bend radii without fear of impacting the performance of the optical fiber system.

THE TRUTH ABOUT OS1 AND OS2

There is a great deal of confusion about the purpose and meaning of the **cabled** Single Mode optical fibre Categories OS1 and OS2.

This confusion exists at all levels of the industry and affects, in equal measure, the suppliers of optical fibre and optical fibre cable, distributors, installers, customer and their consultants.

This Application Note explains the differences between the specifications of OS1 and OS2

Guidance

- OS1 and OS2 are **cabled** Single Mode optical fibre specifications
- Category OS1 is appropriate to **Indoor and Universal tight buffered** cable constructions
- Category OS2 is appropriate to **Outdoor and Universal loose tube** solutions (where the cabling process applies no stress to the optical fibres)
- Cables with either OS1 or OS2 performance are constructed from B1.3 optical fibres (also known as ITU specification **G.652D**) or B6_a fibres (a less bend sensitive single mode optical fibre which is similar to, and compatible with, B1.3. Also known as ITU specification **G.657**)
- OS1 or OS2 performance is not related to Single Mode optical fibres according to ITU specification **G.655** (Non Zero Dispersion Shifted fibre)

European standards and ISO/IEC

- The European Standard **EN 50173-1:2007** states that both **OS1 and OS2** cabled optical fibres can **only** be constructed from **B1.3 (or ITU G.652D)** and **B6.a (or ITU G.657)** optical fibre according to **EN 60793-2-50**.

  Unfortunately, ISO/IEC have not made this logical leap - even in the latest proposed amendment of ISO/IEC 11801 (which now features both OS1 and OS2). This is summarised in Table 1:

Cabled optical fibre Category	Optical fibre of EN/IEC 60793-2-50	Maximum attenuation (dB/km)		
		1300 nm	1383 nm	1 550 nm
OS1 (EN 50173-1:Ed.2:2010)	B1.3, B6_a	1,0	1,0	1,0
OS2 (EN 50173-1:Ed.2:2010)	B1.3, B6_a	0,4	0,4	0,4
OS1 (ISO/IEC 11801 Ed.2.2:2010)	B1.1, B1.3, B6_a	1,0	-	1,0
OS2 (ISO/IEC 11801 Ed.2.2:2010)	B1.1, B1.3, B6_a	0,4	0,4	0,4
OS2 (ISO/IEC 24702: 2006)	B1.3	0,4	0,4	0,4