ofs
A Furukawa Company

Application Notes

OFS Bend-Optimized Single-Mode Fibers:
FTTH Application and Splicing Guidelines

The growth of FTTH installations worldwide is bringing optical fiber into places it hasn't gone before, including single-family homes, apartment buildings, condominiums, and cell sites. In addition, smaller outside plant cable designs, cabinets, and space requirements have driven demand for new fibers that are less sensitive to bends than standard single-mode fibers.

Why do we need bend-insensitive single-mode fibers? Quite simply, because standard fibers can lose much of their signal when bent down to a 10 mm radius, and nearly all of the signal when bent to a 5 mm radius.

The initial application for bend-insensitive fibers was in connectivity applications such as central offices, cabinets, and some outside plant drop cabling in which the fiber could be subjected to tighter-than-normal bends.

Now some fibers are being installed in new pathways - for example, around doorframes and wall studs - where they are being bent and stapled like copper by installers, some with no previous fiber experience. New applications use advanced adhesives to attach fiber and route it around corners.

When a 5 mm cable is placed around a corner at a 90° angle, the fiber bend radius can be 5 mm, and possibly smaller. Running a cable with standard single-mode fiber (compliant with the G.652.D standard) around *just one* of the many corners in a room or hallway can create so much loss as to render a network inoperable.

To make things even more challenging, the next generation of PON equipment uses longer wavelengths that are up to four times more sensitive to bends than what is being used today (Fig. 1). This means that even if a link is operational today with a particular fiber type, bend loss on that link will increase in the future as next-generation technologies using longer wavelengths come on line.

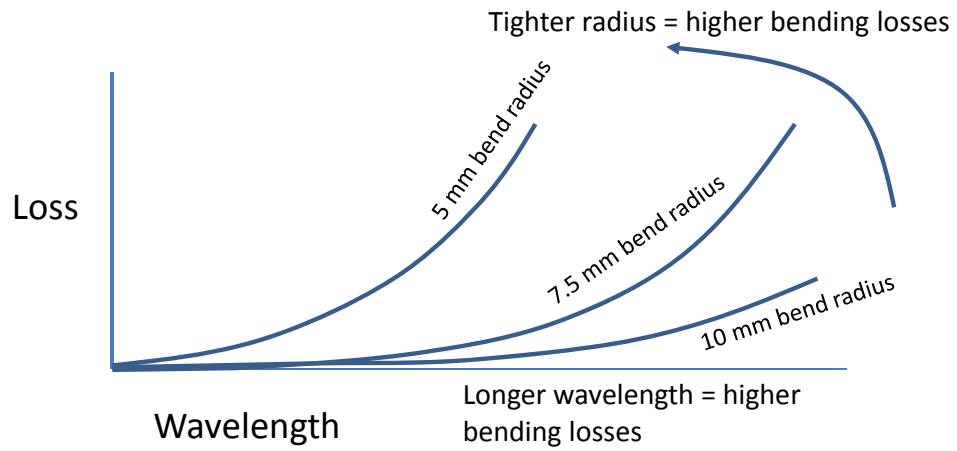


Fig. 1: Longer wavelengths, such as those used in next-generation PON systems, can result in bend losses that are up to four times higher than those in today's systems.

These conditions have led to the development of bend-insensitive single-mode fibers, which have been recently standardized in ITU recommendation G.657.

Types of Bend-Insensitive Single-Mode Fibers

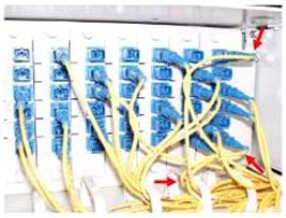
Bend-insensitive fibers are not just slightly different versions of single-mode fiber. The core index of refraction profile often looks very different and more complex than that of a standard single-mode fiber.

The mode field diameter of bend-insensitive fibers is also smaller than that of standard fibers. While this mismatch actually results in only a small amount of splice loss, an Optical Time Domain Reflectometer (OTDR) may show an exaggerated loss (or "gainer") when splicing a G.657 bend-insensitive fiber to a G.652 fiber, often causing confusion for inexperienced splicing personnel.

OFS manufactures three types of single-mode fibers optimized for bending applications. Our AllWave® *FLEX* fiber (compliant to the G.657.A1 standard) is often used for bend-challenged outside plant cables, including some microcable designs with very tight bends in the cable structure. This results in unacceptable attenuation with standard single-mode fiber, and requires a bend-insensitive fiber to achieve losses that are acceptable in the outside plant. Even standard OSP cables for which fiber bending in closures is a concern can benefit from AllWave *FLEX* fiber.

This fiber type is also recommended for applications such as drop cables to the single-family home because it enables smaller cable diameters and tighter bends while limiting bend-induced attenuation.

OFS' AllWave *FLEX*+ fiber (G.657.A2) has even better bend performance than G.657.A1 fiber. It is primarily used in central offices, data centers, cabinets, and buildings where tighter bends may help to decrease the size of enclosures, and where some protection against accidental tight bends down to 7.5 mm radius is beneficial.



Both of these fibers are used in parts of the network where the bends are *managed*, meaning that the network operator has the ability to control the fiber bend radius, and the bends are typically not smaller than 7.5 mm.

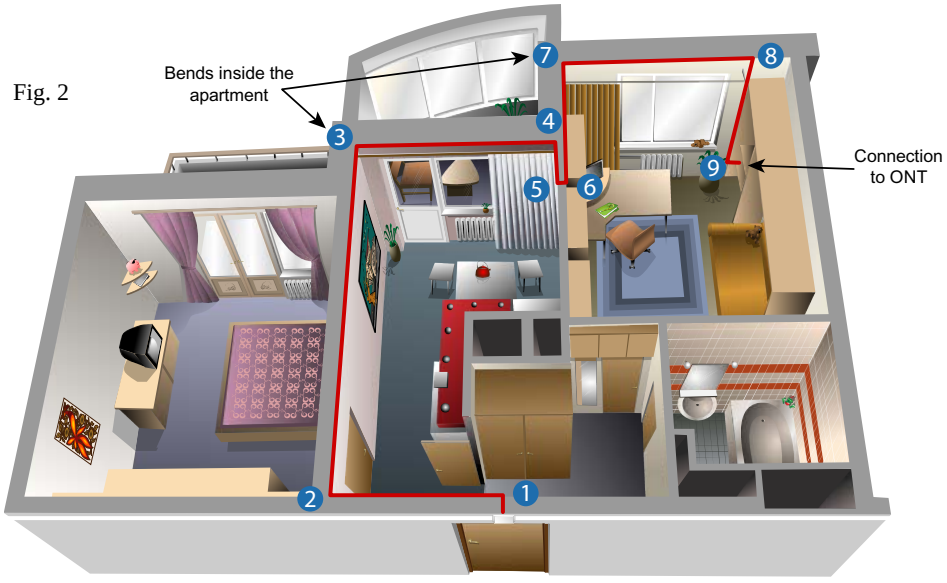
However, once the fiber enters the residence, the customer typically dictates the terms, and bends can become *unmanaged.* For these applications, OFS offers EZ-Bend® fiber, used in EZ-Bend cable and the EZ-Bend InvisiLight™ Optical Solution for inside living unit deployments. Compliant to G.657.B3, it provides ultra-bend insensitivity where it is needed (typically in homes or apartments in mass FTTH deployments).

This means cables may be run around the many corners along a hallway, around windows and door frames, and along other pathways with significant numbers of very tight bends. The cables may be secured by stapling or by the use of specially designed adhesives, which leads to very tight unmanaged fiber bends down to a 5 mm radius.

MDU and In-Residence Drop Applications

The attenuation performance of a drop cable inside an MDU building or residence can mean the difference between providing service to an end customer – or not. The red line in Fig. 2 represents a hypothetical network within a home. Inside the apartment, in this relatively short and simple installation, there are nine 90º angles.

Fig. 2



Total attenuation in an MDU building or residence is composed of several main factors:

- Inherent loss of the fiber for the length of cable deployed
- Bending loss
- Splice loss and connector loss.

Fig. 3 shows the loss of various single-mode fiber types inside a 4.8 mm cable installed within a residence. Note that the loss of standard single-mode fiber in this installation is literally "off the chart."

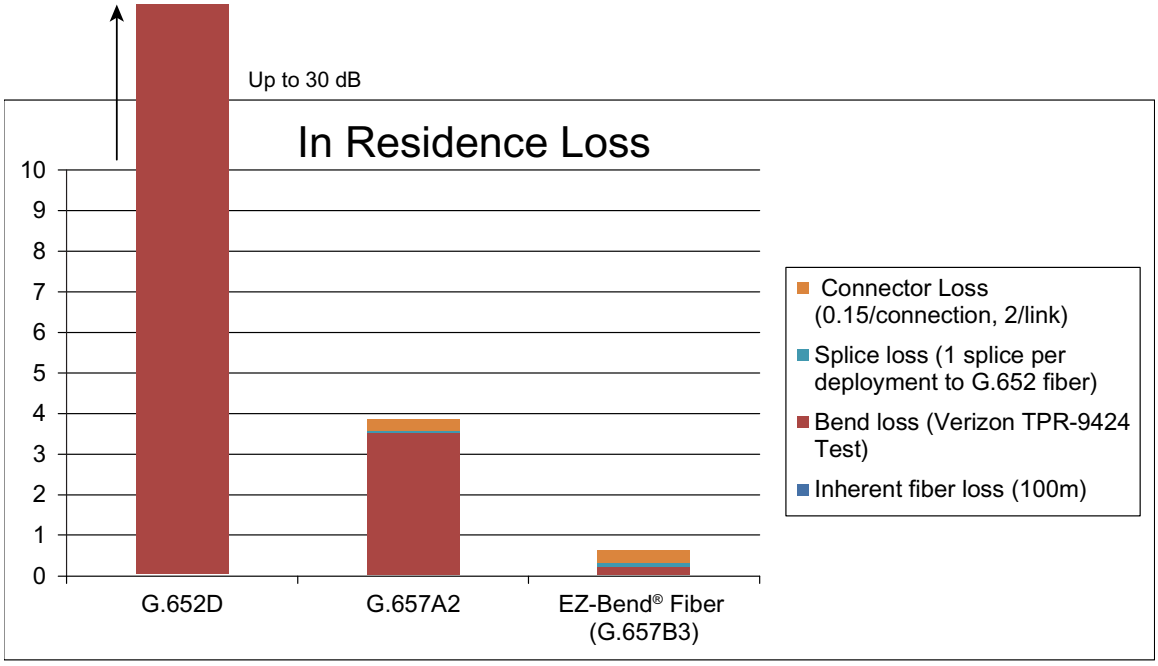


Fig. 3: Loss possible for an in-residence 4.8 mm fiber cable installation. High bending loss is the largest factor.

Splice and connector loss, although important, are not as critical as bending loss in this application. Use of EZ-Bend ultra-bend-insensitive fiber results in negligible bend loss and a total loss well within service provider requirements.

Fusion Splicing and Measurements Guidelines

If a fusion splice machine offers a program on the menu for splicing EZ-Bend, AllWave *FLEX+* or AllWave *FLEX* fibers to standard single-mode fiber, that program should be used.

If this program is not available on the splicer, consult with the fusion splicer manufacturer for specific programs that may be available for splicing EZ-Bend fiber or other fiber types. EZ-Bend fiber can be successfully spliced to itself or other fibers with a multimode splice program if an EZ-Bend-specific splice program is not available.

When using an OTDR, a bi-directional measurement is required to measure the splice loss accurately, as highlighted in TIA/EIA FOTP-61, “Measurement of Fiber or Cable Attenuation Using an OTDR.” The actual loss of the splice is the average of the two measurements.

As mentioned earlier, bend-insensitive fibers are not just slightly different versions of single-mode fiber. The core index of refraction profile often looks very different from, and more complex than, that of a standard single-mode fiber. The mode field diameter of bend-insensitive fibers is also smaller than standard fibers. While this mismatch actually results in only a small amount of splice loss, an exaggerated loss (or “gainer”) can result. Fig. 4 superimposes a hypothetical OTDR trace with the relative fiber mode field diameters to show why “gainers” and exaggerated losses occur.

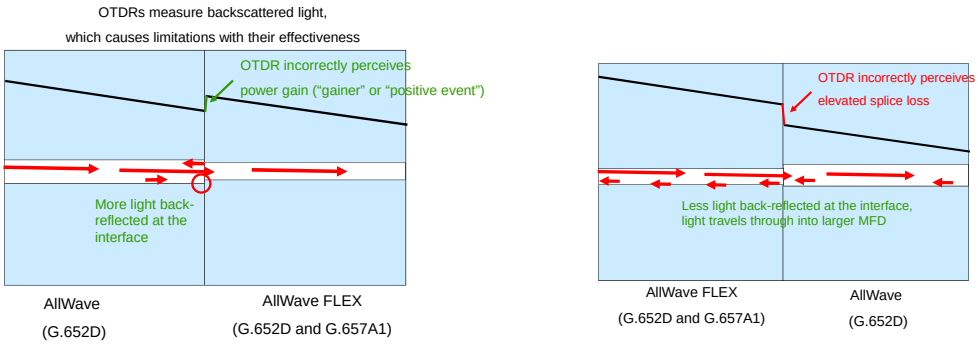


Fig. 4

Gainers and exaggerated losses are normal in OTDR measurements. The key point is when using an OTDR to measure splice loss, measuring in both directions and averaging the gainer with the exaggerated loss will result in an accurate splice loss measurement.

Fiber Identifier Compatibility

After a fiber is installed, it is occasionally useful to detect the presence of a signal on the fiber without disconnecting the link. So-called fiber identifiers work by bending the cable in a way that causes a controlled amount of light to escape and be captured by a detector without disrupting service on the link. AllWave *FLEX* fiber and AllWave *FLEX+* fiber are fully compatible with fiber identifiers available from OFS and other manufacturers.

Summary

The growth of fiber installations is bringing more optical fiber into places it hasn’t gone before, including homes, apartment buildings, condominiums and cell sites. In addition, smaller outside plant cables, cabinets, and space requirements have driven demand for new fibers that are less bend sensitive than standard single-mode fibers meeting the G.652D standard. Different OFS bend-optimized fibers are designed for different applications, with AllWave *FLEX* fiber used for bend-challenged outside plant applications, AllWave *FLEX+* fiber used for central office and remote cabinet applications, and EZ-Bend fiber and cable used for customer drop applications.

When used according to OFS guidelines, these fibers can make the difference between providing long-term reliable service and not being able to connect a customer, so it's important for network designers, builders, and operators to have a good understanding of the capabilities of these fibers.