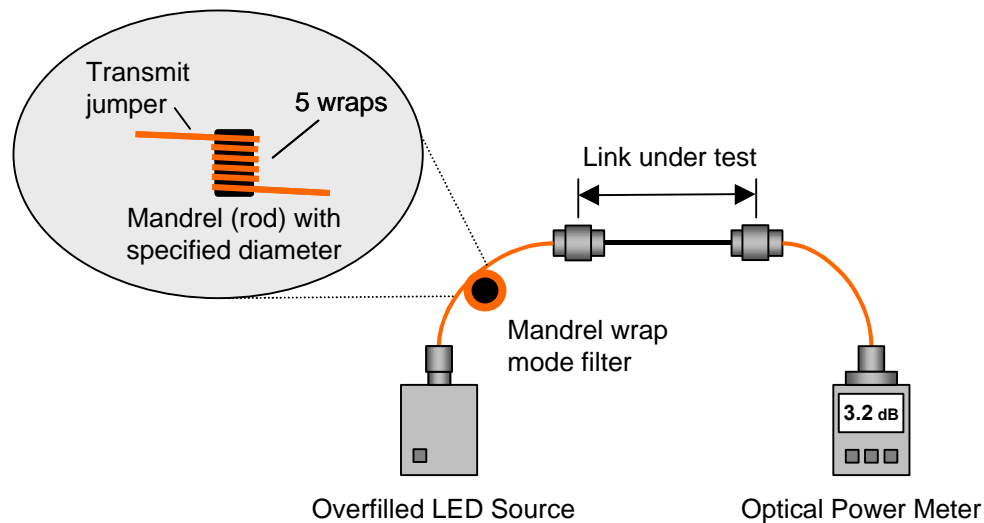


# The Mandrel Wrap

## Meeting TIA Light Source Requirements for Measuring Insertion Loss on Multimode Optical Fiber Links

The standard on commercial building telecommunication cabling, TIA/EIA-568-B, specifies that insertion loss measurements of multimode optical fiber links be made using an overfilled light source, such as an LED, with a mandrel wrap mode filter on the transmit jumper<sup>1</sup>, as illustrated in **Figure 1**. This application note explains why the TIA requires the use of a filtered LED light source and how to make a mandrel wrap mode filter.



**Figure 1** The TIA now requires that insertion loss measurements of multimode optical fiber links be performed using a filtered LED or equivalent light source.

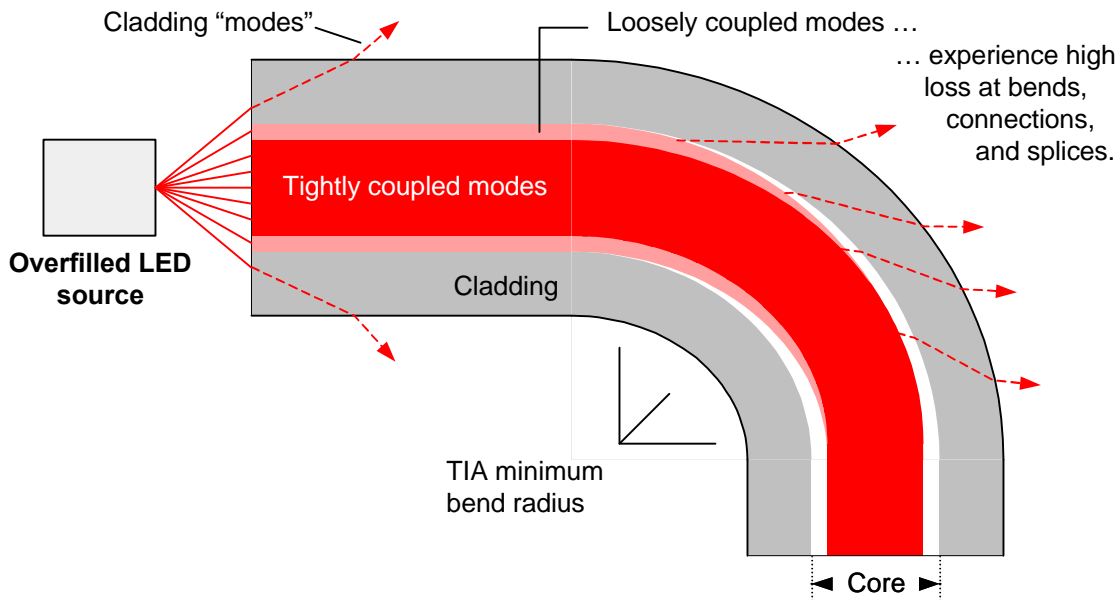
### What is an overfilled source?

An optical fiber is composed of a light-carrying **core** surrounded by light-retaining layer called the **cladding**. The core diameters of multimode fibers are large enough to allow light to travel along different paths called modes. Low-order modes have low angles relative to the core and are confined to the inner regions of the core. High-order modes have high angles relative to the core and travel throughout the core, including the outer region of the core.

<sup>1</sup> TIA-568-B.3 also allows the use of an LED or other type source with internal “beam optics”. However this type of “controlled launch” LED source costs about \$500 more than an overfilled LED source and can be used to test only one multimode fiber type. Thus two controlled launch sources would be required to match the functionality of a single overfilled LED source with 50 and 62.5 μm mandrels.

Low-order modes that meet TIA multimode fiber specifications, including *maximum* fiber attenuation, connector loss, and splice loss, as well as *minimum* fiber bend radius, are called **tightly coupled modes**. High-order modes that don't meet TIA specifications (and any light launched into the cladding) are called **loosely coupled modes**.

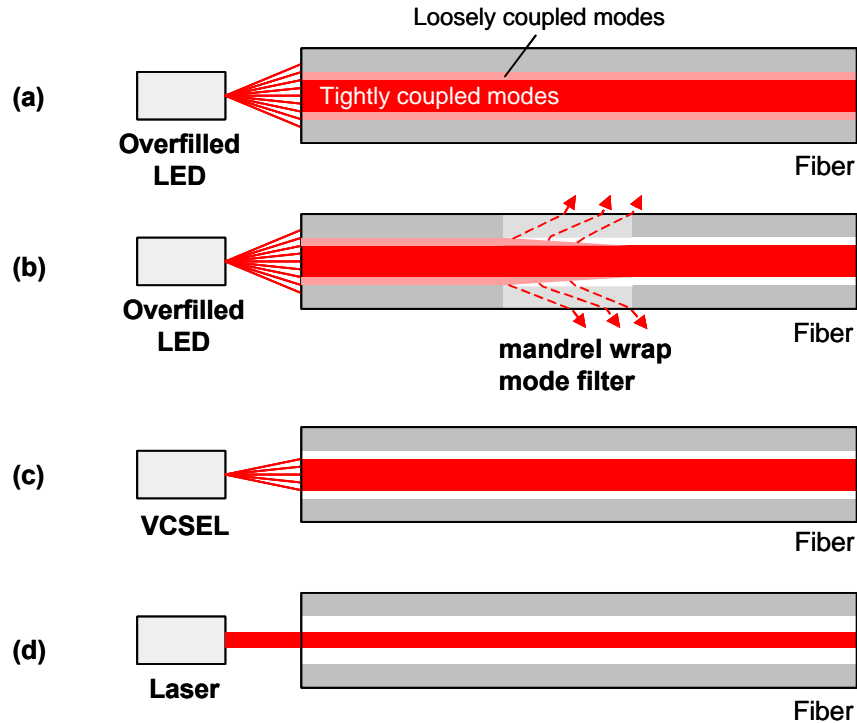
An **overfilled source** (Figure 2) launches both tightly and loosely coupled modes into a multimode fiber. Virtually all field-portable LED light sources, as well as multimode fiber test adapters used with premises cable test sets, are overfilled sources.



**Figure 2** An overfilled source will launch both tightly and loosely coupled modes into a multimode fiber. Tightly coupled modes will be transported by a multimode fiber link with acceptable fiber attenuation and component loss. However, loosely coupled modes will experience excessive loss at connections, splices, and fiber bends, even bends that exceed minimum TIA bend radius specifications.

### Which Light Source Is Best for Measuring Multimode Insertion Loss?

For years test equipment manufacturers have debated the advantages of different light source types for measuring insertion loss on multimode fiber links. Advocates of overfilled LED sources believed these sources provide the truest measure of insertion loss because transceivers used in 10 Mb/s Ethernet, 100 Mb/s Ethernet, and other LED-based LAN systems are overfilled. Advocates of **filtered LED** sources, which are overfilled LED sources that have been filtered to remove loosely coupled modes, argued that they provide lower and more consistent loss readings than unfiltered LED sources. And recently some test equipment vendors have proposed using VCSEL (vertical cavity surface emitting laser) or laser sources for multimode insertion loss testing because the “SX” (850 nm) and “LX” (1300 nm) versions of Gigabit Ethernet are VCSEL and laser-based respectively.

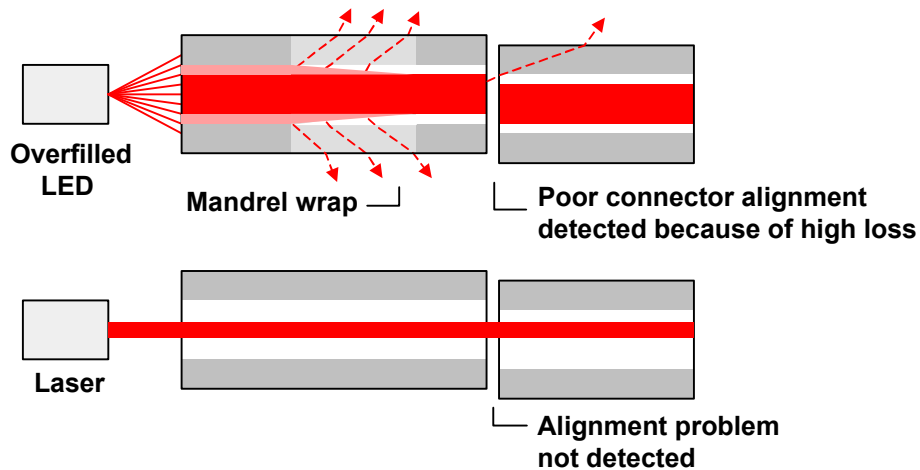


**Figure 3** Four light source types have been considered for measuring insertion loss on multimode links: (a) overfilled LED, (b) overfilled LED with a mandrel wrap or other type mode filter, also known as a controlled launch source, (c) VCSEL, and (d) laser.

However, at least within the standards world, the debate is over. The two parts of TIA/EIA-568-B that deal with fiber, TIA/EIA-568-B.3 published in April 2000 and TIA/EIA-568-B.1, which is expected to be published in 2001, require that insertion loss tests of multimode fiber links shall be performed using an overfilled source, such as an LED, with a mandrel wrap mode filter on the transmit jumper<sup>2</sup>. The TIA requires the use of a filtered LED or equivalent source for multimode loss testing for the following reasons:

- ✧ All multimode fiber attenuation and component insertion loss specifications are based on the use of a filtered LED (or equivalent) source.
- ✧ The TIA wants contractors to be able to use their existing 850/1300 nm hand-held LED sources, or multimode fiber test adapters, to test 50 and 62.5  $\mu$ m multimode fiber links for any application including Gigabit Ethernet and 10 Gigabit Ethernet.
- ✧ VCSELs of different designs can generate different mixes of loosely and tightly coupled modes. Therefore VCSELs, in general, produce less repeatable loss measurement results than filtered LED sources.
- ✧ Lasers significantly under fill multimode fiber cores. Therefore loss measurements made with lasers may not detect poorly mated connectors (**Figure 4**) and other link problems.

<sup>2</sup> Or “beam optics” built into the source. But such sources are expensive as discussed in note 1.



**Figure 4** A filtered LED will do a better job than a laser source of detecting poorly mated connectors and other link problems.

### How Does a Mandrel wrap Mode Filter Work?

A mandrel wrap introduces five small radius loops in the transmit jumper. The mandrel diameters specified by the TIA cause high bend loss in loosely coupled modes but low loss in tightly coupled modes. Thus a mandrel wrap acts as a “low pass” mode filter that effectively removes all loosely coupled modes generated by an overfilled source while passing tightly coupled modes with little attenuation. Any attenuation of tightly coupled modes caused by the mandrel wrap is accounted for in the referencing step of the standard TIA one-jumper insertion loss measurement method.

### How Much Difference Will a Mandrel Wrap Make?

Insertion loss tests of multimode fiber links and patch cords performed at Noyes Fiber Systems using overfilled LED sources showed that a mandrel wrap reduced measured insertion loss by 0.25 to 0.5 dB on 62.5  $\mu$ m links and up to 0.9 dB on 50  $\mu$ m links. These changes are relatively small compared with the maximum channel attenuation allowed by older LAN systems such as 10BASE-FL (12.5 dB) or 100Base-FX (11 dB). However they are significant relative to the maximum channel attenuation allowed by Gigabit Ethernet, which can be as low as 3.2 dB. Moreover, without a mandrel wrap it is very difficult to certify short backbone links to TIA-568-B attenuation limits, which can be as low as 1.5 dB.

### How Can I Make a Mandrel wrap Mode Filter?

TIA/EIA-568-B.1 contains the following simple instructions and table:

*(When making insertion loss measurements the transmit jumper) ... should be wrapped in five non-overlapping turns around a smooth round mandrel (rod) during the reference calibration of the source to the detector and for all loss measurements. The mandrel diameter depends on fiber core size and shall be as specified ... (in Table 1 below):*

**Table 1** TIA mandrel diameters

Multimode Fiber Type	Mandrel Diameter for Bare Fiber	Mandrel Diameter for 3 mm Jumpers
50 $\mu$ m	25 mm (1.0 in)	22 mm (0.9 in)
62.5 $\mu$ m	20 mm (0.8 in)	17 mm (0.7 in)

Note that mandrel diameter depends on the diameter of the transmit jumper jacket. Specifically, mandrel diameter equals the diameter specified for bare fiber minus the jacket diameter. For example, a 50  $\mu$ m jumper with a 1.6 mm jacket would require a mandrel diameter of: 25 mm - 1.6 mm = 23.4 mm.

To make a mandrel wrap mode filter you can wrap the transmit jumper five times around a rod, for example a wooden dowel, of the proper diameter and use tape to keep the mandrel in place. To make things even easier, Noyes has developed TIA-compatible mandrels that can be attached in seconds to 62.5 or 50  $\mu$ m multimode fiber jumpers with 3 mm jackets. These mandrels have grooves to ensure the transmit jumper makes exactly five wraps around the mandrel. Part numbers for the Noyes mandrels are listed in **Table 2**.

**Table 2** Noyes Mandrels for Jumpers with 3 mm Jackets

Part Number	Description
5400-00-0900	Kit with two mandrels, 62.5 and 50 $\mu$ m fiber, 3 mm jacket
5400-00-0201	Mandrel, 62.5 $\mu$ m fiber, 3 mm jacket
5400-00-0202	Mandrel, 50 $\mu$ m fiber, 3 mm jacket

### Example Procedure

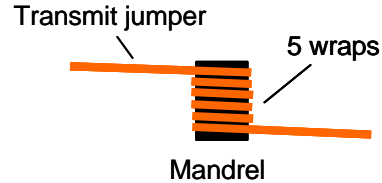
The procedure on the following page illustrates how to measure the attenuation of multimode fiber links using an LED light source, optical power meter, and mandrels available from Noyes Fiber Systems. This example assumes the link under test is terminated by ST connectors at both ends. However it can easily be adapted for links terminated by other connector types by using the appropriate test jumpers and adapter caps.

What you will need:

- ✂ (1) Noyes OLS 1-DUAL 850/1300 nm LED source
- ✂ (1) Noyes OPM 5-2C optical power meter
- ✂ (1) Noyes ST adapter cap (for the optical power meter)
- ✂ (1) Noyes 62.5 or 50  $\mu$ m mandrel (see Table 2)
- ✂ (2) test jumpers with 3 mm jackets and the same fiber type (50 or 62.5  $\mu$ m) as the multimode link under test
- ✂ (1) ST-ST (mating) adapter

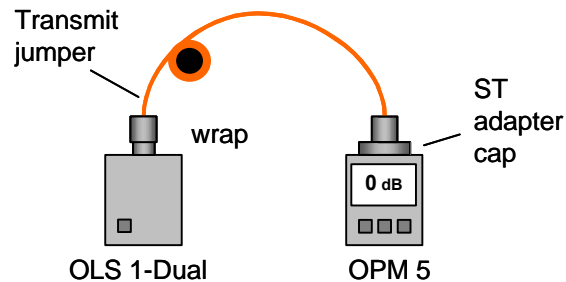
## Procedure – Testing multimode ST links using a mandrel wrap

**1 Attach Mandrel** — Wrap the transmit jumper five times around the mandrel and attach it to the output port of the OLS 1 (LED source). Attach the ST adapter cap to the input port of the OPM 5 (optical power meter). Turn both units on and set wavelength to 850 nm.



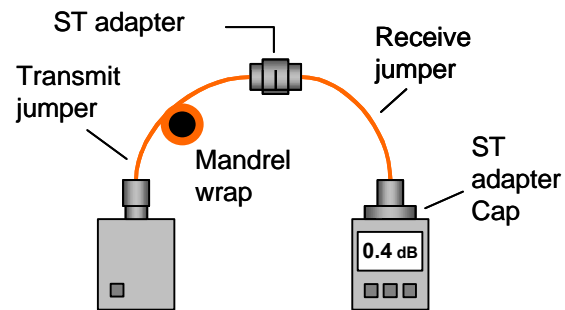
**2 Set Reference (One Jumper Method)** — Connect the output of the OLS 1 directly to the input (ST adapter cap) of the OPM 5. Then press and hold the Set Ref (set reference) key until the word “HELD” appears.

When you release the Set Ref key the OPM 5 should display “0 dB” (+/- 0.05 dB) indicating that the power measured at output of the transmit jumper has been recorded as the reference level for your insertion loss measurements.



**3 Check Jumpers** Disconnect the transmit jumper from the OPM 5 (be sure NOT to remove the end of the jumper connected to the OLS 1). Attach the receive jumper to the OPM 5.

Mate the free ends of the transmit and receive jumpers using the ST-ST adapter. Verify that the insertion of this mated connector pair is well under 0.75 dB, the maximum allowed by the TIA. Noyes recommends that the loss of your mated test jumpers be  $\leq 0.4$  dB. If not, clean both jumpers and repeat steps 2 and 3.



**4 Test Links** Connect the OLS 1 and OPM 5 to opposite ends of the first link to be tested. Store the insertion loss measured by the OPM 5 by pressing the STORE key.

You can repeat Step 4 to measure the insertion loss of each multimode link at 850 nm. Then, if required, set both units to 1300 nm and repeat Steps 2 thru 4 to measure the insertion loss of your multimode links at 1300 nm. The OPM 5 can store insertion loss results at 850 and 1300 nm for up to 500 fibers.

