IMPROVING SPLICE LOSS MEASUREMENT REPEATABILITY

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Splice loss testing requires the measurement of the optical power output from a freshly cleaved fiber prior to fusion splicing. This testing is performed during the manufacture of numerous telecommunications components, such as couplers, multiplexers, OADMs and EDFA pump modules. In order to maintain product quality and consistency, it is critical that this measurement be both accurate, and, most importantly, repeatable. Repeatability from measurement to measurement by a single operator, amongst different operators on a single workstation, and amongst various workstations, ensures production consistency and enables proper process control. This article reviews the most important sources of measurement inconsistency, and presents recent advances in detection system design that have been developed to improve measurement repeatability when working from cleaved fiber ends.

Limitations of Bare Detectors

The simplest way to measure fiber output power is to bring the fiber end in close proximity to a bare semiconductor photodetector; this is usually tilted slightly to eliminate reflections from re-entering the fiber. Unfortunately, several factors combine to limit the repeatability of this approach. The first of these is the inherent non-uniformity in the spatial response of the InGaAs detectors commonly used for this application. Typically these detectors have a "sweet spot", occupying approximately the central 60•70% of the active area, over which they are most consistent. However, even in this region, the detector response can vary as much as X% over the surface. For this reason, fiber optic power meters normally position the fiber or connector end a short distance from the detector, allowing the emission pattern to fill across the detector's central area. Readings taken outside this central area generally exhibit a substantially larger variation.

This inconsistent response becomes particularly problematic when measuring the light exiting a cleaved, unpolished fiber end. This is because light exits a fiber from an extremely small area near the center of its endface, and, even though the cleave may look clean and straight, small localized variations often cause the emission pattern to be somewhat off-axis and non-symmetrical. This asymmetry makes the measurement process very sensitive to the exact orientation of the fiber; indeed, simply rotating the fiber can produce a variation in the recorded power as the brightest portions of the fiber output change position and angle of incidence on the detector surface. This effect is exacerbated if the fiber output intensity distribution is not rotationally symmetric (see Figure 1).

The variations in angle of incidence that occur due to fiber orientation, cleave angle, output intensity distribution and detector tilt also introduce a polarization dependent response (PDR) into the measurement process. This is because the reflectivity of a dielectric surface, such as a detector, is highly polarization dependent at non-normal angles. The meter's polarization dependent response limits its overall repeatability, and, in particular, limits how well polarization dependent loss (PDL) can be measured and controlled during component manufacture.

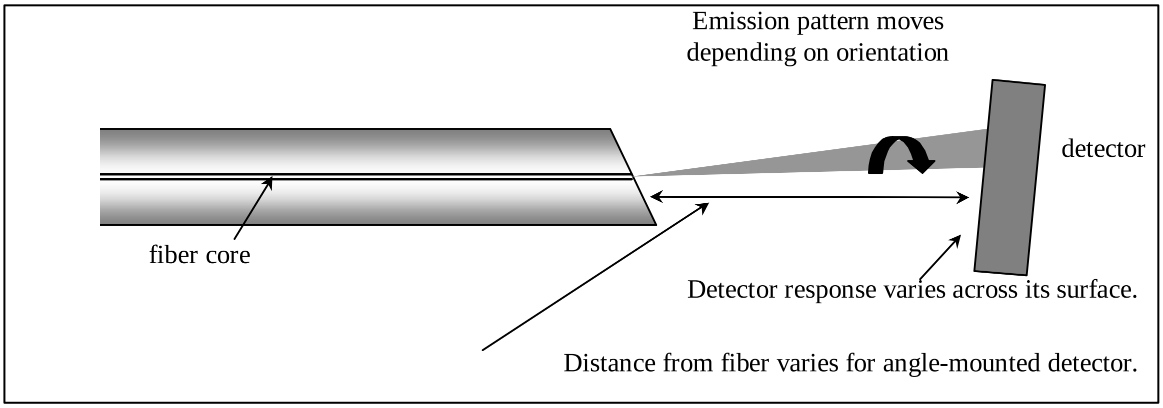


Figure 1.

Taken together, all these factors usually limit the consistency of splice loss measurements made using a bare detector to typically on the order of 0.1 dB.

Improvements in Integrating Sphere Technology

The most common approach for overcoming the limitations of a bare detector is the use of an integrating sphere. A conventional integrating sphere is a hollow ball containing ports for light input and a detector (see Figure 2). The entire inside surface of the sphere is coated with (or is made from) a material that has a high diffuse reflectance. The purpose of an integrating sphere is to completely randomize the input intensity distribution, and thus eliminate from the measurement process all effects due to input beam structure and polarization characteristics.

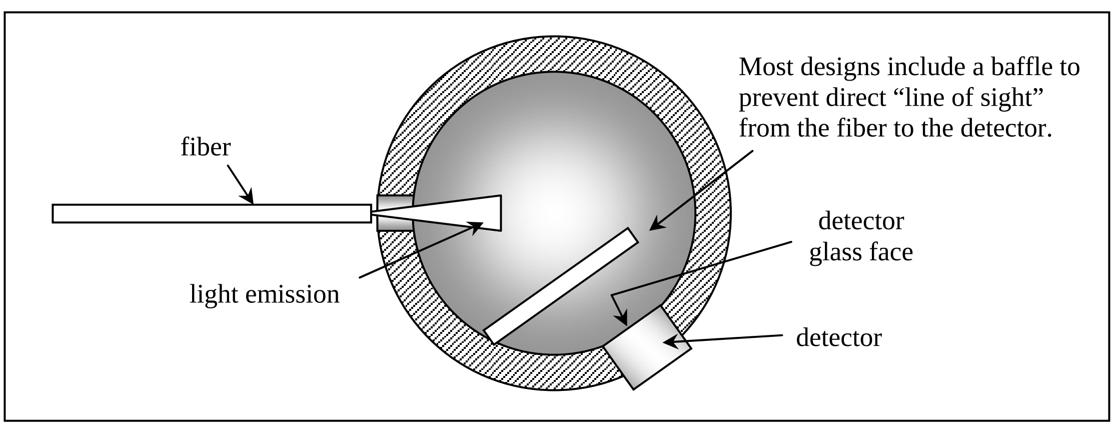


Figure 2.

While integrating spheres represent a tremendous advance over bare detectors, the traditional implementation of this approach usually still limits bare fiber measurement repeatability to about 0.01 dB. In response to the industry's need for greater repeatability in bare fiber measurements (such as splice loss testing), ILX Lightwave has introduced several innovations into integrating sphere technology.

In a typical integrating sphere, the detector surface itself forms part of the inner sphere. This coated glass surface generates specular reflections that vary with polarization. The ILX Lightwave solution to this problem is the patented dual chamber integrating sphere, as shown in Figure 3. In this configuration, the detector is removed from the main integrating sphere. Instead, the detector port in the main sphere leads to a second, smaller sphere in which the detector is mounted out of direct "line of sight" of the primary chamber. Removing the detector surface from the main chamber and replacing it with a second integrating sphere, dramatically reduces the overall polarization sensitivity of the measurement system.

Another significant performance improvement has been achieved by modifying the geometry of the input port. Traditionally, the input port is aligned along the centerline of the sphere. ILX Lightwave has found that moving this port well off the centerline results in more randomized beam distribution, thus reducing measurement dependence upon input beam structure. In this configuration, the side of the sphere opposite the input port is not normal to the fiber axis. This almost completely prevents direct backreflections from re-entering the fiber. Additionally, a single port is used for both bare and connectorized fibers, rather than separate ports for each. Consistently placing both bare and connectorized fibers in the same relationship to the sphere further enhances measurement repeatability.

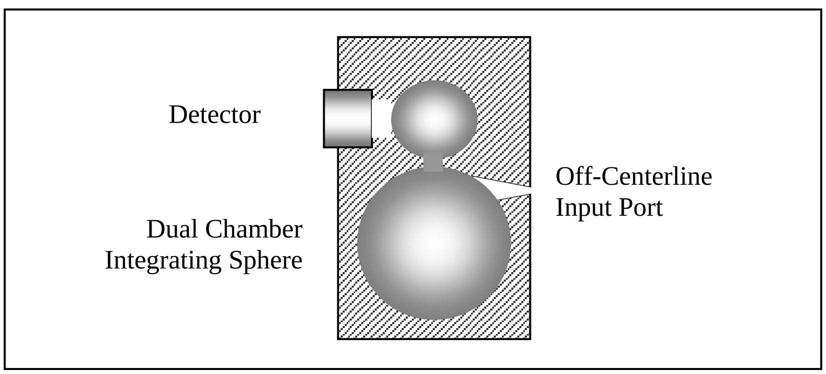
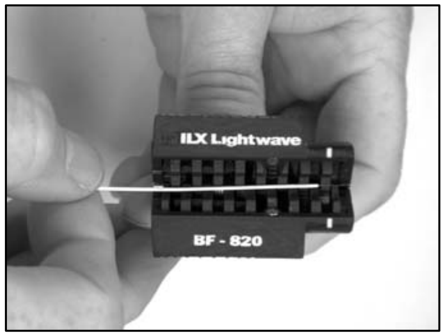


Figure 3.

Through extensive testing ILX Lightwave has also determined the optimum size, depth and shape of the input port. The goal of this work was to maximize the allowable variation in fiber insertion depth, so that production measurements become less tedious and less dependent on operator technique. The balance struck from this investigation allows over 5 mm variation in fiber insertion depth with less than 0.002 dB variation in measurement response.

The fiber holder is the final essential component of the measurement system. To achieve high repeatability, the holder must consistently position the fiber and completely block ambient light from entering the integrating sphere. The holder must not bend or apply pressure to the fiber, otherwise stress induced birefrigence can create PDR. Furthermore, to be useful in a production setting, very little care should be required in order to properly place the fiber in the holder. To meet these requirements, ILX Lightwave has developed a patented fiber holder based on a series of interleaved V-grooves. This design automatically centers the fiber almost regardless of how it is placed in the holder, applies virtually no undue pressure to the fiber and is very effective at blocking ambient light. This “hairclip” holder is easily opened with one hand while the fiber is inserted with the other.



Conclusion

The net result of the improvements in integrating sphere technology developed at ILX Lightwave is a measurement system that demonstrates very high repeatability (typically 0.002 dB) and low PDR (typically 0.001 dB) when used with cleaved fiber endfaces having the normal range of surface variations found in a production environment. Furthermore, the system is not very sensitive to the exact placement or insertion distance of the fiber; in fact, the insertion distance can vary by about 5 mm without any effect on the measured value. These characteristics enable manufacturing personnel to quickly perform accurate, repeatable measurements under real world, production line conditions.

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