

# VIAVI

## Comparing Optical Return Loss (ORL) Measurement Methods

This paper reviews two techniques for measuring ORL: time-domain measurements and optical-continuous-wave reflectometry (OCWR). Both techniques are described in IEC IEC 61300-3-6. This paper will describe the differences in sensitivity between the two methods and how to generate equivalent measurements. While the OCWR method is more traditional, the newer time-domain method has become by far the most popular due primarily to its ease-of-use, increased dynamic range, and speed.

As with any discussion on ORL, proper cleaning and inspection is critical and it must be stressed that the repeatability of a connection under test is a major contribution to the changes often observed. As ORL can only be measured on a mated optical connector, the ORL will change over time on a connector which is mated over and over again due to small changes to the surface.



Figure 1. VIAVI Time Domain IL/ORL Meter

### Sources of ORL

ORL is the ratio between the light launched into a device and the light reflected by a defined length or region. For all ORL measurements, regardless of method, length is a critically important factor and it is defined differently for the two different methods.

### Reflections

Reflections are caused by a change in the index of refraction as light moves from one material to the next. The Fresnel formalism is used to describe these reflections and so these are often referred to as Fresnel reflections. In the case of an optical connector, reflection is caused by the mechanical interface, minute air gaps, geometry misalignments, and microscopic oxide films on the surface of the fiber created during polishing. Figure 2 shows a cross section of an optical connector. The region where the two fibers meet causes a much localized, discrete optical reflection.

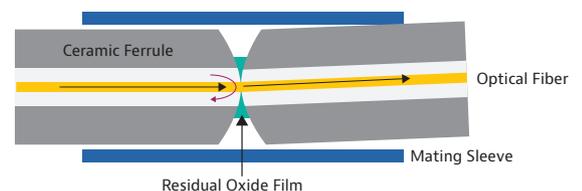


Figure 2. Cross section of an optical connector. The interface between the two different optical fibers is a source of a Fresnel reflection.

## Scattering

Scattering occurs when light interacts with small discrete particles. These particles can be impurities, defects, or even regions of mechanical stress. There are many types of scattering, but the most common type in optical fiber is Rayleigh scattering which follows the familiar  $\lambda^{-4}$  dependence. The important difference between Rayleigh scattering and Fresnel reflections is that Rayleigh scattering occurs along the total length of the fiber.

For example, a simple 2 m length of SMF-28 will typically have between 69 and 70 dB of ORL. This is important and will play a major role in understanding the difference between the two ORL measurement techniques.

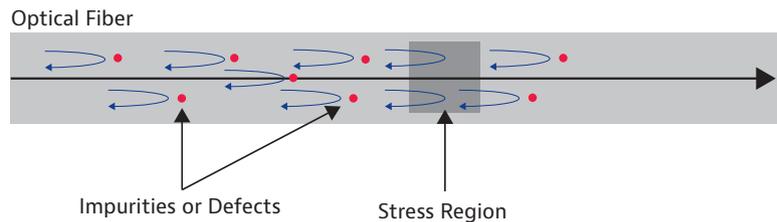


Figure 3. Light traveling in the core of an optical fiber will scatter off of defects and regions of localized stress to cause return loss.

The details described above are greatly simplified. A more thorough discussion can be found in *Introduction to Optics*, Pedrotti & Pedrotti, Prentice-Hall, 1987.

## ORL Measurement Methods

Below are brief descriptions of the two most common ORL measurement techniques. Details of these methods are generally provided in IEC 61300-3-6.

### OCWR

OCWR relies on making a basic power-meter measurement of launch power with no device connected and compares this to the optical power reflected back. Figure 4 shows the basic connection sequence.

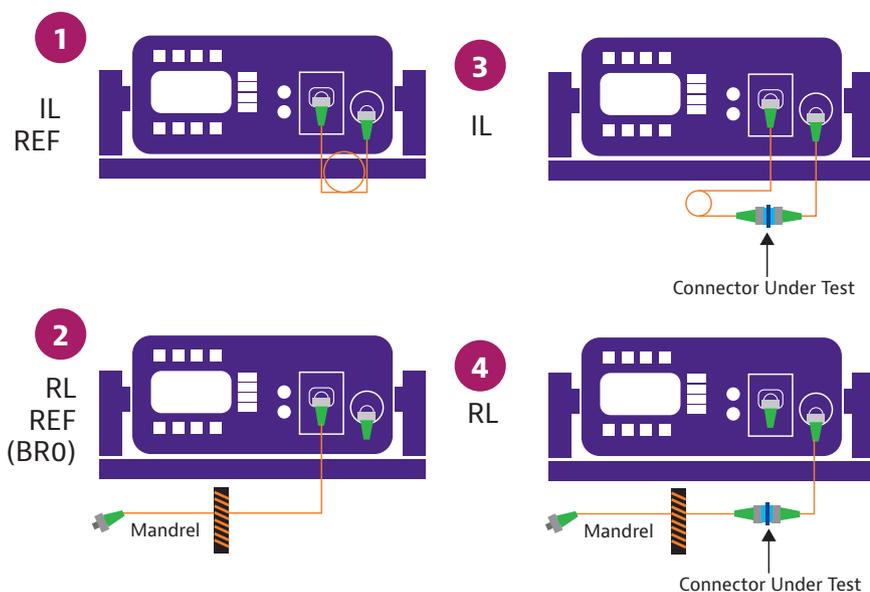


Figure 4. The OCWR technique requires manual terminations before and after the device under test (DUT) to define the measurement region.

What is critical to notice is the use of mandrel terminations. These terminations define the length or region over which the RL measurement is made. This is further shown in Figure 5.

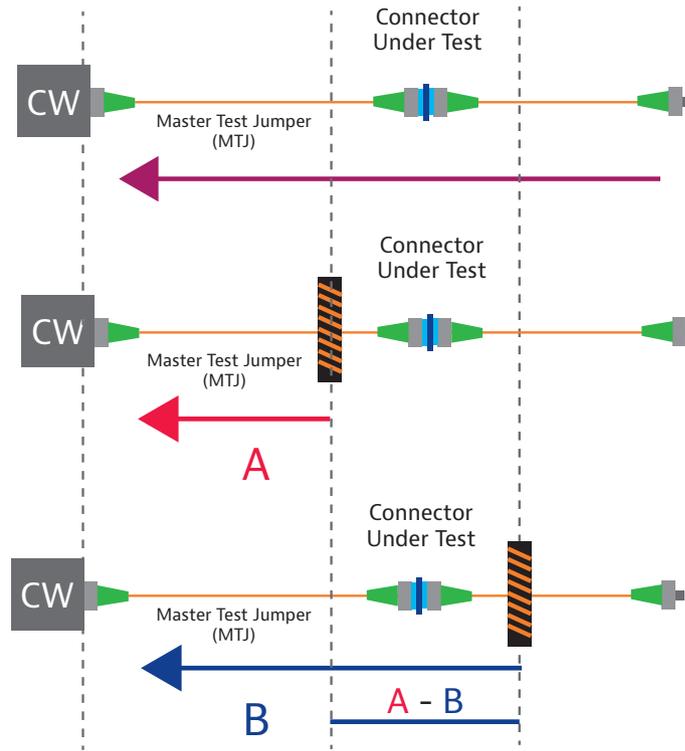


Figure 5. The use of mandrel terminations is critical for making accurate, reproducible OCWR measurements. The region measured is defined by a first mandrel, often referred to as BR0, and a second mandrel to remove the contributions from the optical fiber beyond the device or connector under test.

It is imperative to note that the OCWR method cannot distinguish between Rayleigh backscatter and Fresnel reflection. In most cases, it is not practical to define the A-B region much shorter than 1.5 m. Therefore, all OCWR measurements will, at a minimum, include 1.5 m of Rayleigh backscatter contributions. This fundamentally sets the lowest ORL measurement level to around 70 dB.

### Time-Domain Method

The time-domain method leverages technology from the familiar OTDR used for fiber measurements. Importantly, there is a difference in the way they are calibrated. OTDR reflection measurements are referenced to the region just before the region under test, while ORL measurements are referenced to the power at the end of the reference launch cable. Figure 6 shows the basic measurement setup.

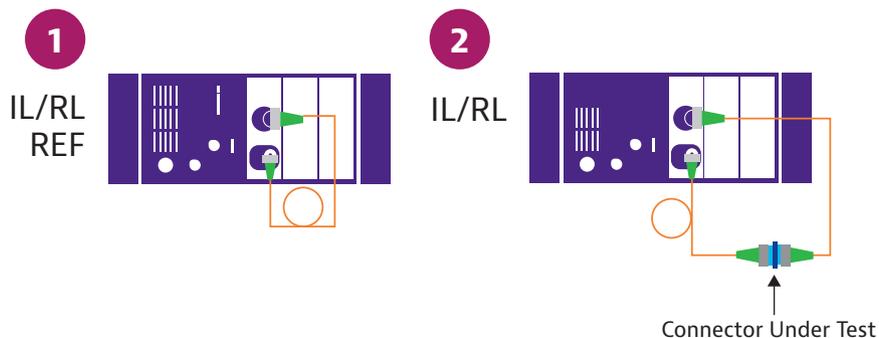


Figure 6. A basic measurement setup. No manual mandrels are required as the window region is defined in software.

Using this method, the basic setup is greatly simplified as no manual mandrel wraps are required. The measurement can be made in two simple steps. As shown in Figure 7 below, it is still important to define the measurement window region over which the ORL measurement will be made. For this method, these windows are set in software and are defined by looking at the signal reflected back over a specific period of time.

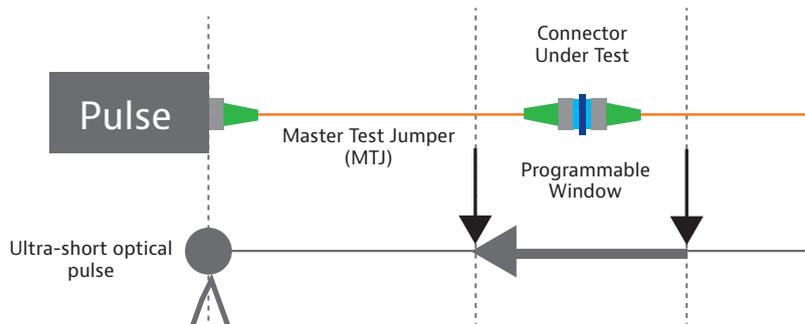


Figure 7. Windows in the time-domain method are set in software.

A significant advantage of the time-domain method is the ability to distinguish between Rayleigh and Fresnel reflections. The nature of the signal (intensity and localization) lets a user choose to measure the RL of an optical connector without a contribution from the optical fiber. This increases the dynamic range from 70 to 80 dB.

### VIAMI Discrete Mode

Discrete mode uses the window setting to search for a single peaked reflection and report only the ORL from that event. Given the finite resolution, the search windows should not typically be set to less than 0.5 m. If there are multiple Fresnel reflections in the window, only the maximum will be reported. In discrete mode, changing the window positions around a DUT will not cause the value to change.

### VIAMI Integral Mode

Integral mode takes the sum of all of the power reflected from window regions. This mode most closely resembles the OCWR measurement, in particular when the connector ORL is less than 60 dB and the influence of the Rayleigh backscatter becomes significant. Given the finite resolution of the unit, the window setting should not be set to less than 1.5m in width while in this mode.

It is important to note that the Rayleigh backscatter in fiber is not absolutely constant and varies over its length. Moving a window of the same width across a length of fiber or around a connector will cause small changes in the ORL due to the changes in the backscatter. This can change the value by  $\pm 0.5$  dB.

## VIAVI Setup Recommendations

The following are recommended setups for common measurements.

### Optical Connectors

For optical connectors, VIAVI recommends the use of Discrete Mode and activation of the VIAVI pre-set conditions where window settings are automatically set. This removes the contributions of the Rayleigh backscatter and provides the true ORL of the optical connector.



Figure 8: ORL set-up screen for an optical connector measurement

### Fiber, Components, and Distributed Reflections

For fiber, larger optical components, and devices with distributed reflections, VIAVI recommends the use of Integral Mode and activation of the VIAVI pre-set conditions where window settings are automatically set. The window settings are designed to remove the ORL contributions of the optical connectors used to connect the DUT or cable. If the DUT is connected with long optical patch cords, it may be advantageous to turn off the pre-set condition and move the window settings closer to the DUT.



Figure 9: ORL setup screen for Integral Mode measurement.

## Equivalent Measurements between OCWR and Time Domain

When comparing OCWR measurements to time-domain measurements, the following conditions should be met:

- The start window must not be less than 0.25 m in front of the connector.
- The width of the window should not be less than 1.5 m.
- The total length of the window must be the same as the length of fiber used in the OCWR method.

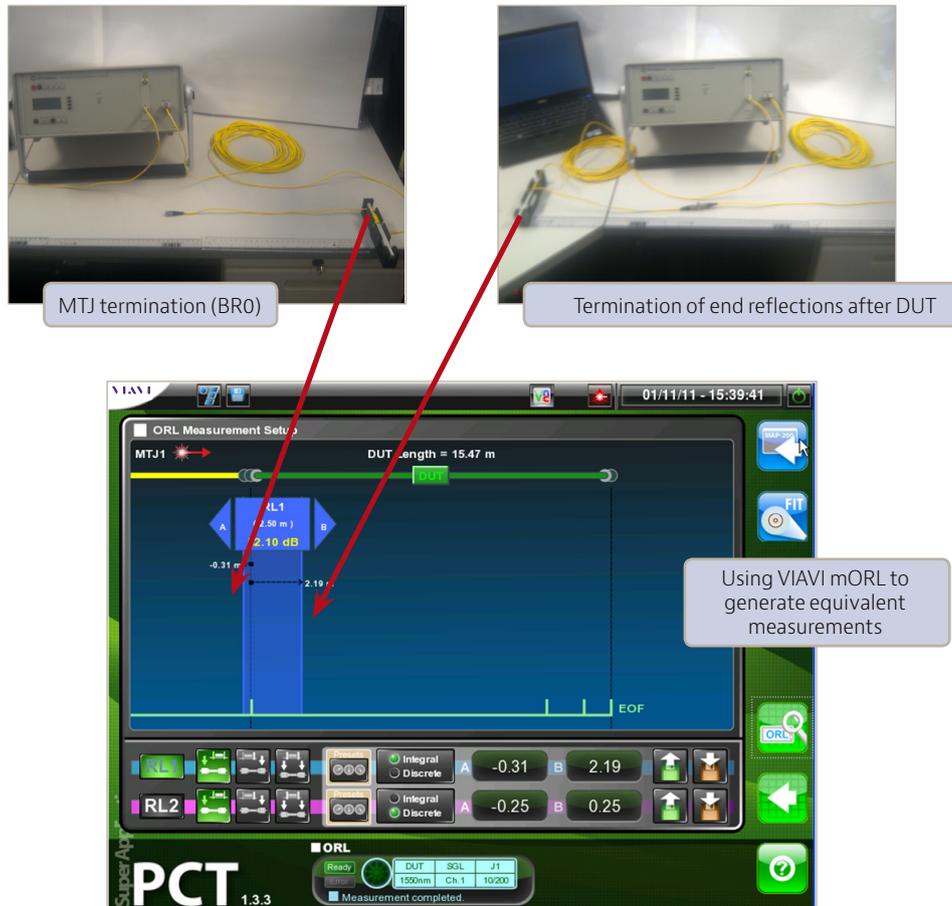


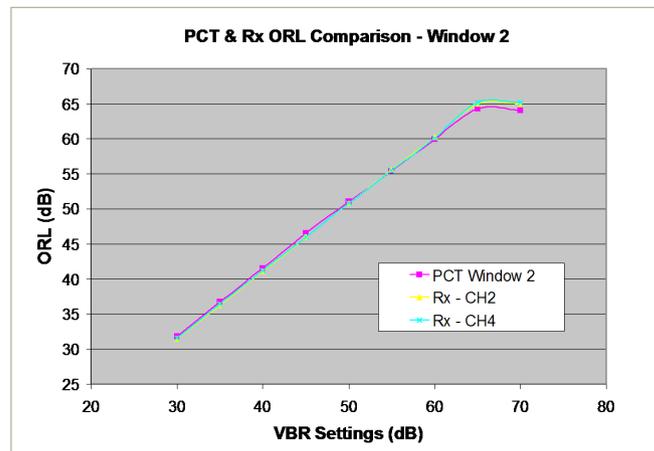
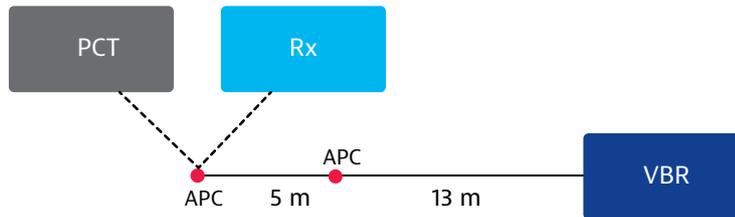
Figure 10. Comparison of the physical setups for OCWR and time-domain measurements.

## Measurement Examples

This final section will provide some measurement examples to illustrate the points described.

### Linearity

The below is an experiment performed at VIAVI to compare the results of the two techniques. A VBR is a single-ended device with a programmable level of reflection. Window settings are set to be equivalent to the lengths defined by the mandrels required by the OCWR technique.



## Summary

Time-domain measurement has become the primary method for measuring ORL due to the simplicity of implementation and its flexibility. It has the advantage of being able to differentiate between the two sources of ORL: Fresnel reflections and Rayleigh backscatter.

With proper care and understanding, window settings can be made to generate equivalent measurements. However, for optical connectors, the Discrete Mode is generally preferred and greatly simplifies the setup by removing contributions from the optical fiber.