Low-Loss Requirements Drive Changes in Measurement Designs

Introduction

For the past several years, an industry concern has been the accuracy of low-loss measurements, in particular for optical connectors and components, primarily driven by higher and higher data rates across the network and the corresponding tighter loss budgets. Traditional (or legacy) insertion loss (IL) measurement approaches provide solutions of approximately ±0.1 dB, which is easily four to five times the desired value today.

After re-examining old approaches to measurements, new technologies and approaches are now used to address this need. While cost pressures continue to be a strong differentiator for manufacturers, they must still consider improvements in performance.

This paper discusses several key properties that the light source/power meter combination requires as well as several recent changes that JDSU implemented in its equipment to increase the accuracy of these measurements.

Basic Measurement

The basic equation for IL when using dB units is shown below.

$$IL\,[\text{dB}] = P_{DUT}\,[\text{dBm}] - P_{Reference}\,[\text{dBm}]$$

$P_{Reference}$ is the power measurement taken *without* the device under test (DUT) connected, while P_{DUT} is the measurement taken *with* the DUT connected.

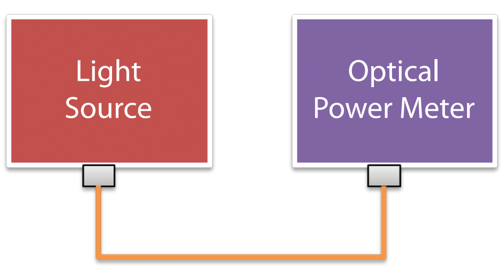

Figure 1a. Step 1: Measure reference power from the light source

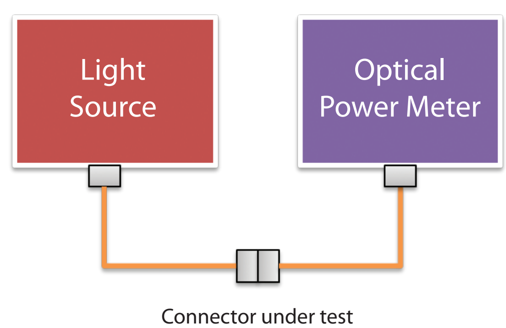

Figure 1b. Step 2: Measure power with the DUT in the path

Figures 1a and 1b show that the measurement uses two basic types of instrumentation: an optical light source and a power meter. In many cases, they may be part of one instrument.

The Optical Power Meter

Relative to 10 years ago, new chip technology and more powerful, smaller processors have enabled a fundamental change to the price vs. performance trade-offs for optical power meters, as Figure 2 illustrates.

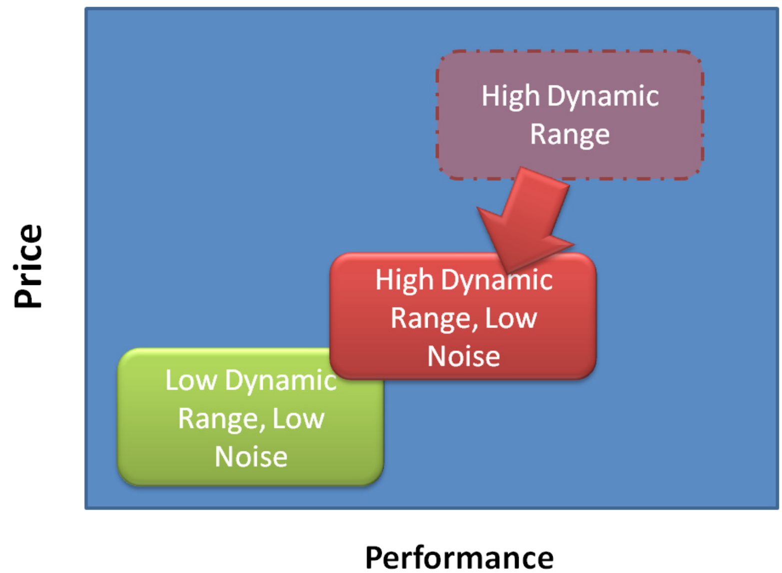

Figure 2. New technologies provide new, improved optical power meters while managing increased costs

Connector testing applications require a relatively small dynamic range, typically between 0.1 and 2 dB. Historically, this fact was used to design solutions with lower-end power meters; however, achieving the required IL accuracy required a higher powered optical light source.

New power meter designs can now extend the range of accurate measurements, allowing the use of much lower power sources, and they offer the chance to make better, more accurate measurements as illustrated in Figure 3. For Power Meter 1 (old technology), the total uncertainty limits us to operate in the gray region, whereas Power Meter 2 (new technology) allows us to operate in the green region, as the total uncertainly is much lower at lower powers.

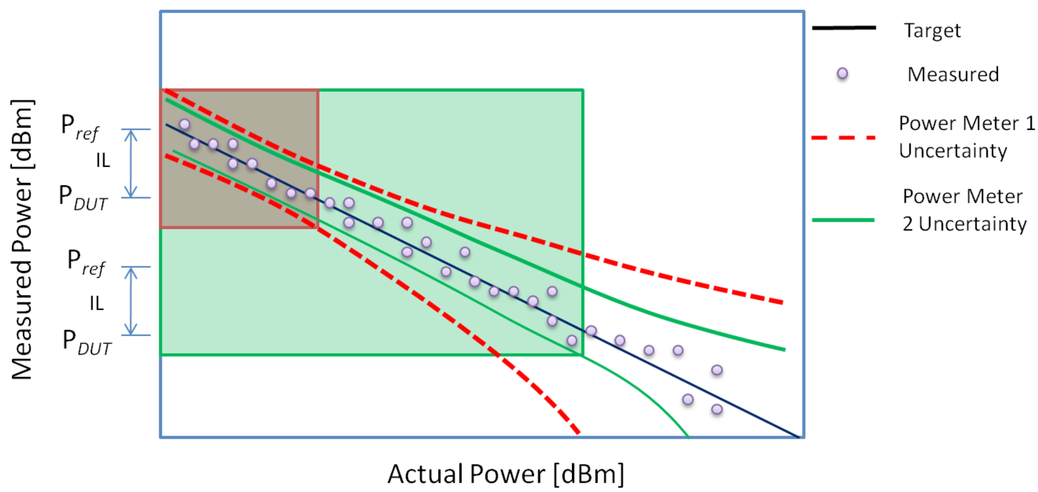

Figure 3. Comparing two optical power meters with Power Meter 2 having improved measurement uncertainty

This new operating range allows us to consider a whole new class of optical sources and tackle some of the key issues that prevent us from making the highly accuracy IL measurements that manufacturers desire.

The Light Source

Subtle properties of the light source provide greater impact on the overall IL measurement than generally recognized. Depending upon the setup, most traditional IL meters (such as the older JDSU RX or RM) employ a Fabry-Perot-style laser with powers between 0 and –10 dBm. This high power was required to overcome the poor performance of the optical power meter, as discussed previously.

However, several undesirable properties occurred as a result of this high power. Output power and power stability are commonly understood parameters with fairly straightforward impact. Less appreciated are the parameters that impact optical interference, or the way light can constructively and destructively interfere with itself. Properties such as coherence length, degree of polarization, mode beating, and line width can all have measureable impacts on performance. Table 1 provides a high-level summary of some of these issues. One notable conclusion is that many of these "difficult" parameters can be mitigated by choosing lower power optical sources.

Optical Source Comparison	**CW VCSEL Laser**	**CW FP Lasers**	**Super Luminescent LED (SLED)**	**Ultra Short Pulses FP Lasers**	**CW LED**
Output Power	High	Medium	High	Medium/Low	Low
Mode Competition	High	High	Low	Low	None
Degrees of Polarization	High	High	High	Extremely Low (<2%)	Extremely Low (Zero)
Coherence Length	Very High	High	Short	Very Short	Extremely Short
Narrow Line Width	Extremely Narrow	Narrow	Broad	Very Broad	Broadest
Cost	$	$$	$$$	$$	$

Table 1. Source property comparison

At a qualitative level, red indicates parameters that tend to decrease stability, while green indicates those that offer better stability.

If selection is based only on optical power, clearly the first three source types would be required. However, when considering the secondary parameters that impact measurement stability, the last two are very desirable. Leveraging our new optical power meters, JDSU IL measurement solutions now utilize low power sources and are able to deliver superior stability.

The Power Meter (Detector and Detector Interfaces)

JDSU has also extensively reviewed our approaches to the optical detectors selected and their connection interfaces. Several factors drove us to do this, but primarily the need to increase stability and accuracy and to flexibly support both single- and multi-fiber (MT-style ferrule) connectors.

First we considered the type of detector with the power meter, because several sizes and options on the market today have various drawbacks and benefits. Table 2 provides a break out of these options and the various parameters that affect the overall accuracy and stability.

Detector Comparison	2 mm InGaAs	3 mm InGaAs	10 mm InGaAs	10 mm Ge	Integrating Sphere
Coupling Loss/Efficiency	Medium (Limited for Multimode)	High	High	Medium	Low
MT Connector Ready	No	No	Yes	Yes	Yes
Spatial Variations	Low	Low	Medium	Medium	Low
Wavelength Range	Good	Good	Good	Medium	Good
Expense	Low	Low	Very High	High	Medium
Field Attach	No	No	No	No	Yes

Table 2. Detector size option comparison

As Table 2 shows, the detectors compared are strongly differentiated based on their ability to support MT-based connectors. For single-fiber-based components, 2 or 3 mm InGaAs remains the best choice. However, they clearly are not the best choice for MPO/MTP-based devices. Large area detectors (10 mm) support both single- and multi-fiber applications but suffer due to their cost and the addition of measurement uncertainties due to spatial variation in efficiency, as shown in Figure 4.

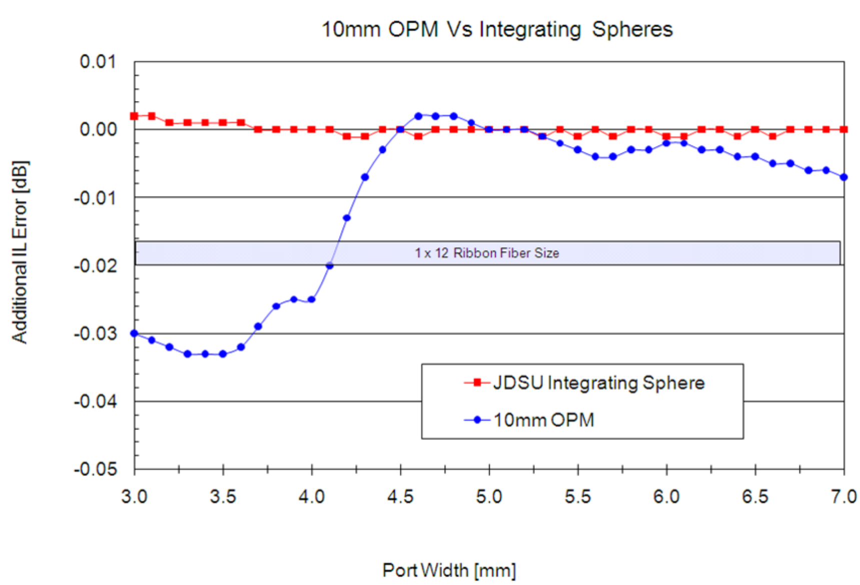

Figure 4. Spatial error comparison using the JDSU integrating sphere and 10 mm photodiode

JDSU decided to leverage integrating sphere technology as an alternative to lower costs, improve spatial performance, and minimize overall uncertainty. Low coupling efficiency enables us to leverage our optical power meter performance to open up improvements in other areas. As a second unique capability, JDSU developed an innovative "Field Attach" Integrating Sphere design that allows manufacturers to use the native 2 or 3 mm interface for single-fiber measurements.

Temperature and Drift Effects

One final area to consider is temperature and drift effects. The basic IL equation in Figure 1 has these key parameters hidden in it that are not often discussed and are difficult to manage and remove from the overall uncertainty of IL measurements, and this is why. The first step in measuring IL is the *Reference* measurement. Users will measure one or many DUTs in succession; however, if the launch power from the source or the gain of the power meter changes between each measurement, it immediately impacts the measurement by adding drift to the IL uncertainty. In most practical manufacturing test setups, the time difference can result in hours if not days.

Temperature control of optical sources is required; but, for the highest stability over time, the temperature control must be coupled with monitoring of key power parameters internal to the test solution. When done properly, one can achieve the performance shown in Figure 5.

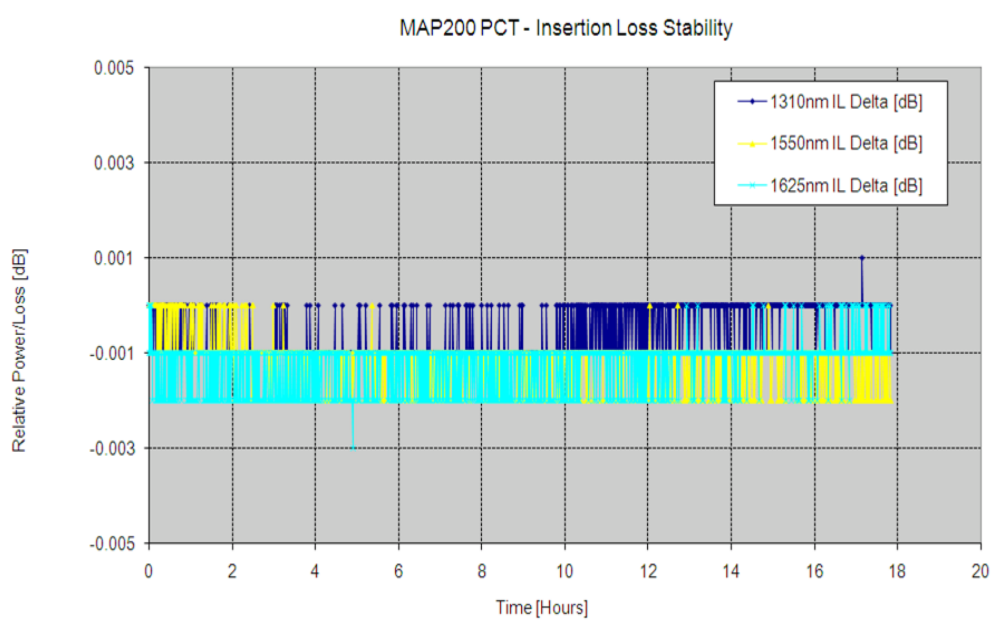

Figure 5. IL stability performance after 18 hours without taking a reference measurement

What does it all mean?

Relative to the legacy JDSU test solutions (and of many competitors), the new MAP-200-based solutions leverage this new thinking and use new lower power optical sources as enabled by higher performance optical power meters and enhanced source control/monitoring. Table 3 provides a summary comparison between our new MAP-based solutions and our legacy RX platform.

Category	mORL-A1 and mIL-A1	RX3000 (and similar)
Power Meter	New high dynamic range	Low dynamic range
Source Monitoring	Enhanced, real time	Limited
Source Selection	Low power, high stability	High power, destructive and constructive interference
Detector Interface	2/3 mm with field attached integrating sphere	Fixed 2, 3, or 10 mm

Table 3. New MAP-based IL/ORL solution compared to the legacy RX3000

In general, the most noticeable impact for customers will be an overall increase in accuracy and repeatability during testing. With the removal of much of the temperature and drift component removal, users can also reference less and increase throughput.

Table 4 shows the increase in performance based on uncertainty calculated using the methods described in the Generalized Uncertainty Method (GUM) as published by the Joint Committee for Guides in Metrology.

Single-Mode Uncertainty Example	Single Fiber		Integrating Sphere	
	Measurement	Uncertainty	Measurement	Uncertainty
Reference Power	−20.000 dBm	0.01 dB	−49.000 dBm	0.01 dB
Measurement Power	−20.100 dBm	0.01 dB	−49.100 dBm	0.01 dB
Additional Uncertainties				
Source Monitoring		0.01 dB		0.01 dB
Polarization Effects		0.000 dB		0.000 dB
Source Stability		0.002 dB		0.002 dB
Spatial Variations		0.000 dB		0.005 dB
Insertion Loss	0.100 dB	±0.025 dB	0.100 dB	±0.032 dB

Table 4. Example of an uncertainty calculation

While the table does not exhaust all possible measurement scenarios, it illustrates the impact of the improved optical power meter performance. As a comparison, the IL accuracy state indicated for the JDSU RX meter is ±0.15 dB, clearly not what the industry desires.

For questions or additional information, please contact your JDSU sales representative.

Test & Measurement Regional Sales

NORTH AMERICA	LATIN AMERICA	ASIA PACIFIC	EMEA	WEBSITE: www.jdsu.com/test
TEL: 1 866 228 3762	TEL: +1 954 688 5660	TEL: +852 2892 0990	TEL: +49 7121 86 2222	
FAX: +1 301 353 9216	FAX: +1 954 345 4668	FAX: +852 2892 0770	FAX: +49 7121 86 1222	

30168445 000 0611 LOWLOSSREQCHANGEMEASUREDESIGNS.WP.OPT.TM.AE
June 2011