Techniques for Measuring the PDL of Optical Systems or Components

Overview

As an optical signal passes through a birefringent optical element, different polarization states may experience different optical power losses (as shown in Fig 1); this *polarization-dependent loss* (PDL), which can also be wavelength dependent, is defined as

$$PDL(dB) = 10\ \log\left(\frac{\mathrm{P}_{\min}}{\mathrm{P}_{\max}}\right),$$

where P_{min} and P_{max} are the minimum and maximum output powers, respectively, from a device due to varying input polarizations.

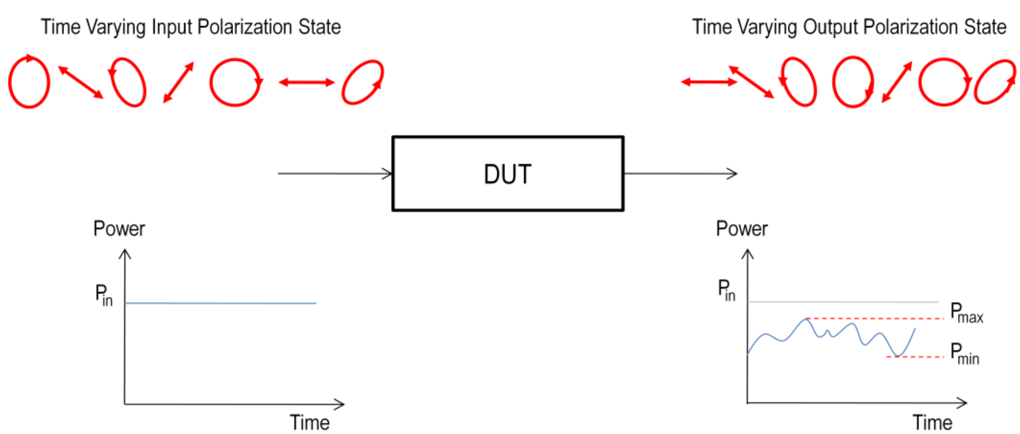

Figure 1 Output power fluctuates as a function of different input polarization states.

Why do we need to measure PDL?

As a result of rapidly accelerating demand for higher bandwidths, data center connections are migrating from 25G/100G to 400G/800G transmission speeds. Coherent receivers are expected to be able to mitigate the effects of PDL because it limits the bandwidth capacity of high-speed communication systems. Unlike other impairments that can be compensated for, such as polarization mode dispersion (PMD), PDL causes pulse distortion that cannot be compensated for. To ensure network quality of service, the PDL of each component should be minimized, and the maximum cumulative PDL of the network must be maintained below a designated limit. For example, standardization work was done by the OIF 400ZR IA and IEEE P802.3ct Task Forces (400GBASE-ZR) to specify the maximum polarization dependent loss in the link to be 2 dB, excluding transmitter polarization imbalance.Therefore, accurate PDL measurements are required for almost all optical components, sub-modules and modules as part of the specified standard parameters.

What are the available PDL measurement techniques?

There are three standard techniques commonly used to measure the PDL of optical systems or components: 1) Polarization scrambling/scanning, 2) Maximum/minimum search, and 3) Matrix measurements using Mueller or Jones matrices. Each method has its own advantages and disadvantages in terms of measurement speed, accuracy, optical bandwidth and calibration requirements.

In the polarization scrambling/scanning method, a high speed polarization scrambler is used to generate a sufficiently large, uniformly distributed subset of all possible polarization states at the input to the device under test (DUT) while the DUT's output power is monitored. PDL is then calculated from the maximum and minimum output power values obtained from the subset. The MPC-201, which uses fiber squeezing technology, can be used to generate up to 20,000 states of polarization (SOP) per second with uniform sphere coverage. Its intrinsic insertion loss of < 0.1 dB and PDL and activation loss of < 0.01 dB make it an attractive solution for PDL measurement. It should be noted that factors such as Poincaré sphere coverage during the test, the PDL of the DUT, measurement time and detector bandwidth affect the accuracy of measurement of the maximum and minimum transmission of the component.

To reduce measurement time and improve measurement accuracy, the maximum/minimum search method can be used for deterministic, automatic and unambiguous determination of PDL. The PDL-201 uses an active feedback polarization control algorithm and a fiber squeezer polarization controller to systematically and rapidly search for the maximum and minimum transmittances without the need to measure all possible SOPs. The direct measurement of maximum and minimum power transmittances assures high measurement speed, high accuracy, large measurement dynamic range, wavelength insensitivity and calibration-free operation.

By contrast, matrix-based measurement methods using Jones-or Mueller-matrices do not require the direct detection of the maximum and minimum transmission. Rather, they measure optical transmission at a set of fixed SOPs that do not generally coincide with the maximum and minimum transmissions. The PDL is then calculated from the matrix elements obtained from the optical intensity measurements at the reference states. For large-scale production environments that may require wavelength-dependent PDL measurements over relatively large wavelength ranges, an automatic, high-speed PDL measurement system isessential. For single port components, the PSGA-101 and OVA-5000 can be used to measure the PDL/IL vs. wavelength in a few seconds with unmatched accuracy. For multi-port WDM components, the OCA-1000 can measure PDL/IL vs. wavelength for up to 8 ports simultaneously.

Which method should I select?

The method that should be selected depends on the requirements of the application. The following table provides a comparison of the three methods and the recommended applications.

Applications		Polarization Scrambling /Scanning Method (MPC-201)	Maximum/Minimum Searching Method (PDL-201)	Matrix Method (OCA-1000, PSGA-101, OVA-5000)
Single wavelength, Single-channel	Testing time	Slow	Fast	Fast
	Recommended method?	No	Yes	Yes
Single wavelength, Multi-channel	Testing time	Medium	Slow	Fast
	Measure different channels at the same time?	Yes	No	Yes (OCA-1000)
	Recommended method?	Yes	No	Yes (OCA-1000)
Wavelength scanning, Single- or multi-channel	Testing time and sweeping mode	Stepped sweep mode Too slow	Stepped sweep mode Too slow	Stepped sweep mode: (PSGA-101) Continuous sweep mode: (OVA 5000, OCA-1000) Fast
	Recommended method?	No	No	Yes

Summary

In a fiber link which contains many optical components with different PDL values, the total PDL in the system needs to be controlled. It is now necessary to accurately and rapidly test the PDL of all optical components. Luna innovation offers the most complete PDL testing solutions to fit a wide range of customer needs and requirements. For more information, [visit lunainc.com](https://lunainc.com).