An Overview of Polarization Extinction Ratio Measurement Methods

Overview

Polarization extinction ratio (PER) is a measure of the degree to which light is confined in a principal linear polarization mode. It is defined as the ratio of the power in the principal polarization mode to the power in the orthogonal polarization mode after propagation through a device or system, expressed in dB.

$$PER = 10\log_{10}\frac{P_{principal}}{P_{orthogonal}}(dB)$$

The PER measured at any point in the system is the result of the cumulative effects of the polarization properties of the light source (light not fully polarized or not linearly polarized), misalignments at fiber connections or splices, and propagation through the fiber or device itself up to the measurement point.

PER is an important performance parameter for systems or devices which require that light propagating through them remain linearly polarized and aligned to a particular axis. In such cases, the PER should be as high as possible. Typical values vary by device, from 18-20 dB in many passive components, to 50-60 dB or higher in some polarizers or polarizing waveguides.

PER can also be used as a proxy for measuring the degree of polarization (DOP) of a depolarizer or low-polarization light source. In such cases, the PER will be close to 0, because the light is evenly distributed over all polarizations.

There are several methods of measuring PER. The most suitable method depends on the application.

Rotating Polarizer Method

The rotating polarizer method is the simplest PER measurement method. The output of the device under test (DUT) is connected to a PER meter which contains a rotating polarizer followed by a photodetector. The polarizer performs a full rotation to measure the maximum power P_{max}, which corresponds to the principal linear polarization state, and the minimum power P_{min}, which corresponds to the orthogonal polarization state, and the instrument then calculates the polarization extinction ratio using:

$$PER = 10\log_{10}\frac{P_{\max}}{P_{\min}}(dB).$$

The PER meter also determines the DUT's output connector key alignment angle from the relative angle between the connector key and the polarizer angle corresponding to maximum power.

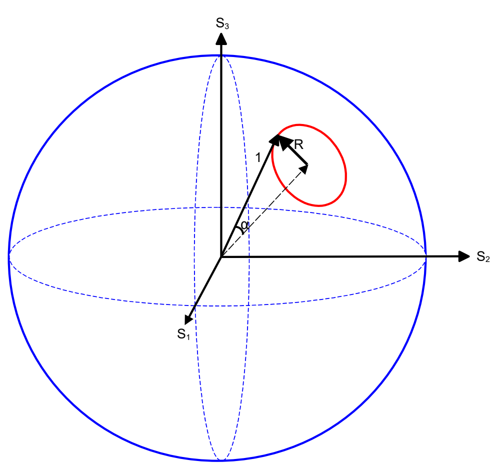
This method can measure both high and low PER; however, because it bases its measurement on the power ratio between orthogonal linear polarization components of light, it cannot distinguish between unpolarized light and circularly polarized light.

The accuracy of measurement depends on the ER of the rotating polarizer, the quality of the detection circuit and minimization of internal reflections that can add noise to the measurement. For example, the ERM-202, which uses a high ER rotating polarizer and a photodetector circuit with low polarization dependent responsivity and high dynamic range, can accurately measure PER up to 50 dB.

For measurement of high PER DUTs, a broadband light source should be used in order to measure the worst-case (minimum) PER for that DUT. The light source coherence length should be shorter than λ_{center} *l_{PM} /beat length, where λ_{center} is the center wavelength of the light source and l_{PM} is the length of PM fiber under test. When a narrow band laser source with a coherence length much longer than λ_{center} *l_{PM} /beat length is used, the polarization components of the light aligned to the slow and fast axes will be coherent. If they are either in phase or antiphase, the output light will be linearly polarized even if the input light is misaligned. Generally, the instantaneous PER values are not stable because of the variable phase difference between the slow and fast axes caused by stress changes in the PM fiber or temperature fluctuations, so the instantaneous PER cannot be used for device performance specification. In this case, the PER meter should be operated in minimum search mode and the performance specification should be the minimum ER measured by the PER meter as the fiber is stretched or heated/cooled.

Polarimeter Method

In PM fiber, light polarized along the slow axis and light polarized along the fast axis travel at different speeds. If light launched into a PM fiber is not fully aligned to one of these axes, or is not fully polarized, it will contain both slow and fast axis polarization components. The relative phase delay between these orthogonal polarization components, and therefore, the polarization state of the light, changes as the light propagates through the fiber. Similarly, varying the relative phase delay between the two orthogonal polarization components at the fiber output, either by heating or stretching the PM fiber or by sweeping the wavelength of the input light, will cause the state of polarization of the output light to rotate along a circle on the Poincaré sphere. The rotation axis of the circle is defined by the slow axis of the fiber and the radius of the circle by the misalignment of the light to the slow axis.



A polarimeter can measure this circular evolution of the SOP and calculate the PER from the size of the fitted circle. If the polarimeter has a free space input, it can also determine the DUT output connector key alignment angle from the location of the circle on the sphere. Fiber-coupled polarimeters cannot provide key alignment angle information because SM fiber between the DUT output and the polarimeter optical head input can change the position (but not the size) of the circle.

Because the accuracy of the measurement depends on how well the polarimeter can measure the SOP evolution and how well the circle can be fitted, this method is generally not suitable for measuring high PER (as the circle collapses to a point, it becomes harder to fit) or PER of low DOP DUTs (a polarimeter’s SOP measurement is unreliable if the DOP is very low). In addition, measurement of long or high birefringence DUTs can be difficult. Swept wavelength measurement of such DUTs requires either a continuous sweep or very small wavelength steps; otherwise, the distance between consecutive SOP data points can be too large to obtain a good fit to the circle.

Examples of instruments that use this method include the POD-201 and PSY-201, which use fiber-coupled polarimeters, and the PSGA-101A, which uses a free space polarization analyzer.

Distributed Polarization Crosstalk Measurement Method

An interferometer-based distributed polarization crosstalk measurement instrument such as the PXA-1000 is able to measure the intensity and location of all crosstalk events in highly birefringent DUTs such as PM fiber coils or systems, or Y-branch waveguides. PER can be calculated by integrating the effects of all crosstalk events in the DUT. This type of measurement provides the most detailed information about a complex PM fiber system. Because it measures the crosstalk caused by individual features of the DUT such as connectors, splices or sections of stressed or defective PM fiber, it is possible to evaluate the contribution of these individual features to the total PER. It is also possible to exclude sections of the DUT from the PER calculation. Because the PXA-1000 has very high crosstalk measurement sensitivity, it can characterize extremely high PER DUTs.

Summary

Because PER measurement methods have different capabilities and limitations, Luna Innovations offers multiple types of measurement instruments to suit the requirements of different applications and DUTs. The table below summarizes important differences between methods. For more information, visit lunainc.com.

	Rotating Polarizer (ERM-202)	Fiber-Coupled Polarimeter (PSY-201/POD-201)	Free-Space Polarimeter (PSGA-101A)	Distributed Crosstalk Analysis (PXA-1000)
Cumulative PER measurement of DUT	✓	✓	✓	✓
Can measure very high PER	✓			✓
Can measure very low PER	✓	✓	✓	
Can distinguish between unpolarized and circularly polarized light		✓	✓	
Requires stretching/heating fiber or wavelength scanning		✓	✓	
Measure output connector key alignment	✓		✓	
Detect stress on output connector			✓	
Can measure PER of PM fiber DUT with SM fiber in the measurement path		✓	✓	
Can exclude sections of fiber from PER calculation				✓

PSGA-101A

PSY-201

PXA-1000

POD-201

ERM-202