Accuracy in PMD measurements

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Polarization mode dispersion (PMD) measurements are complicated by their large variance for typical measurement conditions [1]. Consequently, much care has been taken in improving and quantifying the precision of PMD measurements. However, this is sometimes at the expense of the absolute accuracy. This paper describes some of the current work being done on establishing accuracy for PMD measurements.

The primary cause for the lack of accuracy characterizations of PMD measurements is the lack of an artifact standard with stable, well characterized, highly mode-coupled PMD. NIST built a mode-coupled artifact and tested it in a round robin measurement of 16 participants [2]. The artifact is a stack of 12 quartz waveplates with their optic axes aligned at random but known orientations providing stable mode coupling. However, unlike mode-coupled artifacts made of concatenated lengths of polarization maintaining fiber [3], exact knowledge of the geometry of the NIST waveplate stack allows a theoretically predictable PMD. Figures 1 and 2 show the round robin performance of the mode-coupled artifact and an unmodified spool of fiber. The precision improves from the fiber to the artifact. Also, an estimate of the accuracy of the measurements on the artifact is available. In Figure 2, the vertical axis is the participant's reported PMD measurement normalized to the theoretical prediction for the measurement method and wavelength range used. The error bars represent the uncertainty of this theoretical prediction and could be reduced for stronger mode-coupling, larger PMD, or more statistically independent measurements by the participant. Currently, NIST is developing a similar artifact with 35 waveplates which we hope will allow greater accuracy.

PMD measurement accuracy has also been aided by recent theoretical work. Theory by Heffner [4] illustrates an approximately 10% systematic disagreement between PMD values measured according to the accepted methods in the

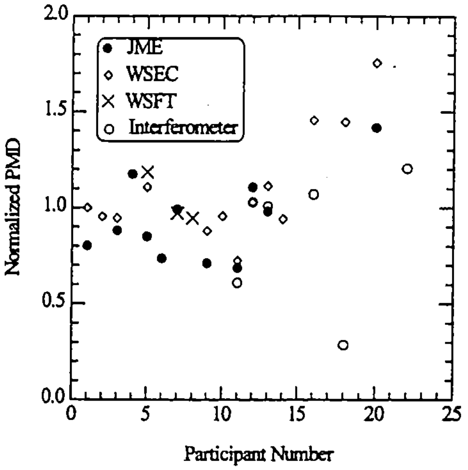

Figure 1 Normalized round robin results for PMD measurement on a spool of 25 km of single mode fiber.

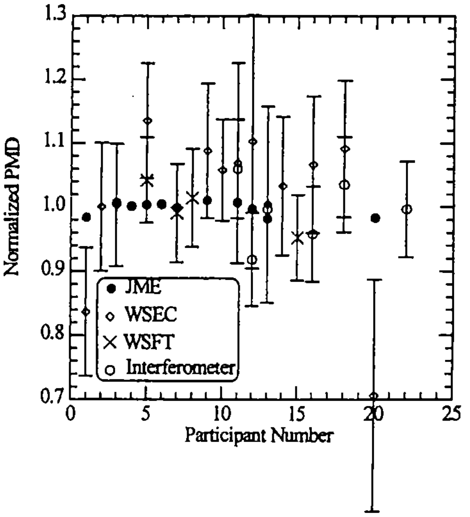

Figure 2 Normalized results for PMD measurements on a mode-coupled artifact (1.0 on the y-axis indicates agreement with theory).

time and the frequency domains. This discrepancy was previously unnoticed theoretically because the descriptions of time domain [5,6] and frequency domain [1] measurements came from different definitions of PMD. Until recently [7], this discrepancy also went unnoticed experimentally [8-15].

This illustrates two more hindrances to establishing the accuracy of PMD measurements. First, the large random uncertainties (typically 10-30% for single measurements) often mask smaller systematic measurement errors. However, systematic errors are also routinely introduced during the data analysis in several PMD measurement techniques. These errors are often ignored in light of reducing measurement noise, and sometimes, data reduction techniques are judged by their repeatability (robustness) rather than their accuracy.

Examples of systematic errors incurred through noise reduction are seen in two common measurement methods. In the technique of wavelength scanning with extremum counting, the number of extrema in a spectral response plot for a test fiber between crossed polarizers is proportional to the PMD of the fiber [1]. Noise in the system creates false extrema, and a currently accepted method is to ignore any extrema below some selected noise threshold [16]. However, no discrimination is made between noise peaks and true peaks, allowing systematic errors of several percent for thresholds as low as 1%. Another example involves measurements in the time domain where PMD is measured as the second moment σ of the field autocorrelation of light through a test device. Often, the wings of the Gaussian-shaped function are clipped to remove measurement noise[16,17]. However, this data clipping typically reduces the measured σ by about 10% (masking the ~10% discrepancy discussed previously). Figure 3 shows the systematic errors due to clipping.

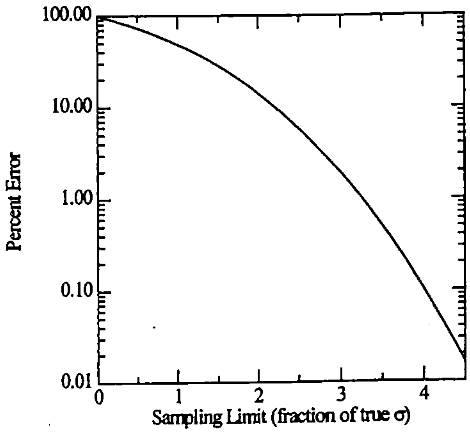

Figure 3 Simulated error in measured σ for a Gaussian function sampled to a fraction of its true σ.

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