Accuracy issues in comparisons of time- and frequency-domain polarization mode dispersion measurements

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If experimental comparisons are to be made between time- and frequency-domain measurements of polarization mode dispersion PMD, they must be done with a good understanding of the systematic and random uncertainties present. In this paper, I quantify sources of systematic uncertainties in time domain PMD measurements and demonstrate correction techniques on experimental data.

Until recently, theoretical and experimental work [1-10] claimed to support an equality between PMD measured in the time domain as the square root of the second moment σ of the autocorrelation function and PMD measured in the frequency domain as the RMS differential group delay (DGD), so that RMS DGD/σ = 1. However, the recent theory of Heffner [11] shows the issue to be more complicated, with RMS DGD/σ depending on the spectral shape of the time domain measurement source and only for large values of PMD-bandwidth product does the ratio demonstrate a constant value 0.866 which disagrees with previous theory by about 13%. Most of the referenced attempts to measure the RMS DGD/σ ratio lacked the precision to see a 13% effect. Furthermore, standard second moment evaluations of time-domain PMD have several sources of systematic uncertainties large enough to nullify comparison efforts. These systematic errors were avoided by one recent experimental work [12] which used a curve-fitting method to measure σ giving a value of RMS DGD/σ close to 0.9. However, curve-fitting is not always considered to be rigorous enough. So, I present corrections here which allow significant reductions of the systematic biases of the standard second moment calculation.

Measurements of PMD in highly polarization-mode-coupled optical fibers using an interferometric or equivalently wavelength scanning with Fourier transform (WSFT) technique produce an autocorrelation function illustrated by the one-sided example of Figure 1. This time domain response is a quasi-random amplitude (due to random phasing) under a Gaussian envelope. The PMD of the fiber can be measured by finding the square root of the second moment of this curve [13,14]

$$\sigma = \sqrt{\frac{\int I(t)\,t^2 dt}{\int I(t) dt}}. \qquad (1)$$

However, in calculating this quantity, systematic errors due to numerical integration, data clipping and central peak removal are encountered and must be corrected.

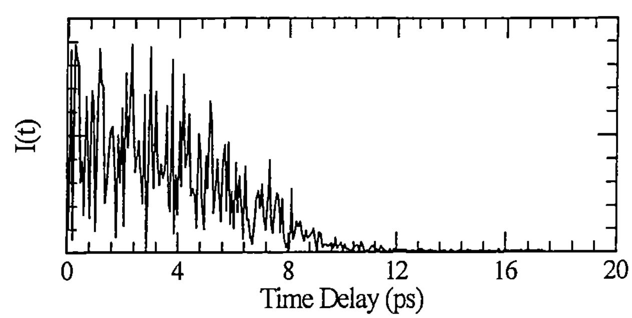

Figure 1 Typical Fourier-transformed wavelength scanning data.