Re-calibrating optical instruments: The digital delay line analysis

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Abstract. A digital delay line (DDL) from Oz Optics is used. A delay in optical paths between the fast and slow orthogonal polarizations is introduced using a DDL by adjusting the relative travel distance of the two orthogonal modes. The insertion loss of the DDL is 1.5 dB. Using a Labview programme, we were able to write and read from the DDL. The DDL was adjusted from 0 to 60 ps and the observed first order polarization mode dispersion (FO-PMD) was measured. A histogram that approaches the Maxwellian distribution was obtained using 1018 random values between 0 and 60 ps written to the DDL to adjust it, although not well populated on the tail. Hence the DDL alone can be controlled to generate a distribution approximating the Maxwellian distribution over a large sample size like it is theoretically.

1. Introduction

Polarization mode dispersion (PMD) emulation is the first vital step to undertake in order to analytically understand the complex behaviour of PMD under the laboratory environment over a short time frame. Emulation is also known to be the key to the effective design of adaptive PMD compensators. PMD emulators can be further used in testing for system tolerance, diagnosing system impairments, as calibrators in instruments used for accurate characterisation and measurement of PMD, and as models for deployed fibre links. Therefore, PMD emulation is a novel approach essential in the move towards a cost-effective optical network upgrade through system analysis within the laboratory before field testing. Further reading on emulators can be found in [1]-[7].

A PMD emulator is designed from a combination of different components. These components are configured to ensure a desired PMD statistical outcome is achieved. These components are grouped into two groups namely: optical delay and polarization orientation control components. For this paper, the emphasis will be on optical delay components.

2. Tuneable delay element

Delay lines are modules that are meant to induce a delay time in one of the two orthogonal polarization modes of light. This results in the disparity in arrival times of the two orthogonal modes at the receiver end. These two orthogonal modes belong to the same pulse. The delay represents the FO-PMD in optical networks, which means a delay line is a PMD emulator module. There are different types of delay lines with different control mechanisms which are all designed to induce an adjustable FO-PMD. Some of these variable delay lines are manufactured by Oz Optics Limited, ThorLabs and General Photonics Corporation. This section gives emphasis to the delay line manufactured by Oz

Optics Limited (Figure 1) used in this study. This delay line is referred to as the variable polarization digital delay line (DDL).
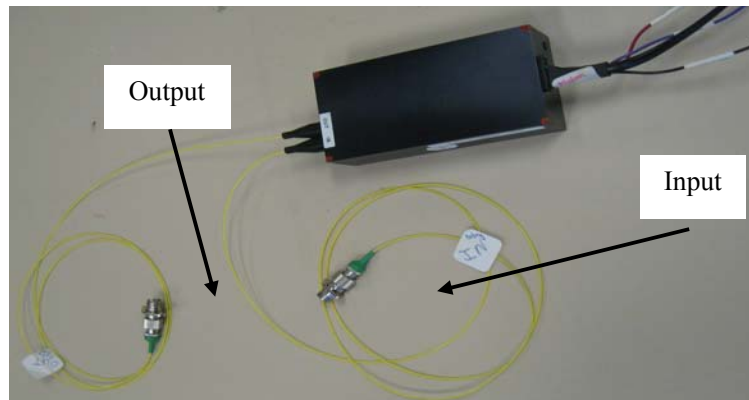

Figure 1. Photograph of the DDL from OZ Optics in the NMMU Fibre Optics laboratory.

The DDL by Oz Optics is an electrically controlled, reflector-style, variable device. It consists of an input fibre collimator, output fibre coupler and polarization beam splitting optics. The optics are mounted and aligned to produce a fixed gap between collimators for one orthogonal polarization and a variable gap for the other orthogonal polarization. The collimator projects light into free space and the coupler collects it into the output fibre. The difference in path travelled by the two orthogonal polarizations is the FO-PMD. The difference in the optical paths is precisely controlled by reflecting the light off a moveable reflector. Most if not all delay lines are equipped with a microprocessor to enable remote communication through an electrical device or personal computer. The DDL used in this study covers over ± 65 ps delay range with a resolution of 0.0017 ps and insertion loss of the DDL is 1.5 dB.

This type of emulator adjusts the PMD without changing the number of fibre sections. This is achieved by changing the birefringence of the material, i.e. a fibre can be subjected to temperature changes which change the birefringence hence changing the PMD [8]. Unlike the delay induction used by Hauer *et al.* [8], in this study, the DDL introduces a delay in optical paths between the fast and slow orthogonal polarizations by adjusting the relative travel distance of the two orthogonal modes.

3. Results and Discussions

A Labview programme was used to write and read from the DDL. The DDL was adjusted from 0 to 60 ps and the observed FO-PMDs were measured. In this study, 1018 values between 0 and 60 ps were randomly generated using Labview to give a variation similar to that in Figure 2 (a). These 1018 random values were written to the DDL to adjust it and the resulting FO-PMD values are those shown in Figure 2 (a). These FO-PMD values were measured using GINTY. The FO-PMD variation in Figure 2 (a) gives a histogram approaching Maxwellian, although not well populated on the tail. This therefore means the DDL alone can be controlled to generate a distribution approximating the Maxwellian distribution over a large sample size.
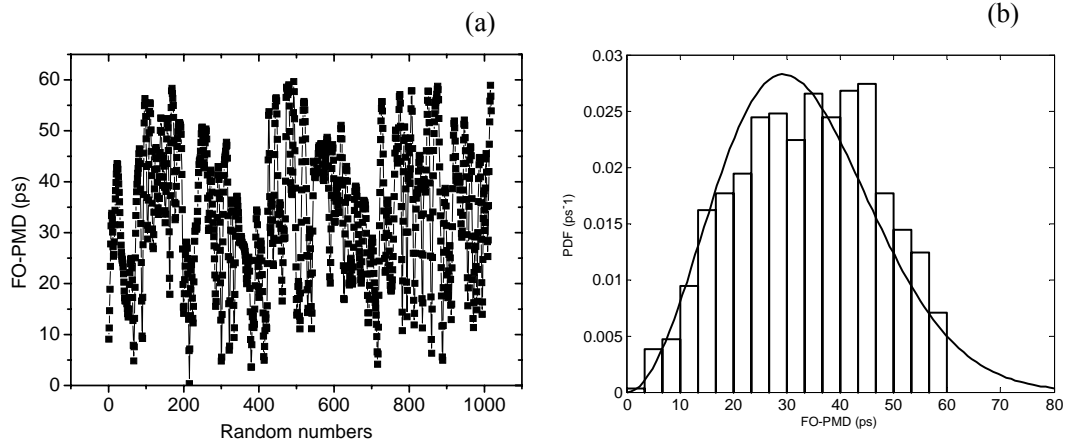
Figure 2. The statistical distribution of the DDL observed FO-PMD after randomly generating 1018 DDL set FO-PMD ($\tau_{\text{set-DDL}}$) values. The solid line in (b) is the Maxwellian distribution fit. GINTY was used to measure the FO-PMD.

4. Conclusion

The DDL was controlled to generating stochastic FO-PMD statistics that approach the Maxwellian distribution. Concatenating several of these types of DDL will make the FO-PMD wavelength-dependent and will result in SO-PMD.

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