Measurement of Polarization Maintaining Optical Fiber by using SLD Channeled Spectrum Interferometry

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Abstract

A new technique for measuring modal birefringence and polarization mode dispersion (PMD) of the optical fiber with the wide band frequency domain interferometry using a super luminescent laser diode (SLD) was described. Two kinds of typical polarization maintaining optical fibers (PMFs) and GRIN lens (SELFOC) were measured as a function of optical wavelength.

Introduction

A single mode optical fiber (SMFs) usually possesses a modal birefringence due to geometrical ansymmetry of core or external stress, which give rise to modal birefringence or polarization mode dispersion (PMD). PMD is one of the key factors which makes sure of the transmission capacity in the Wavelength Division Multiplex (WDM) system as well as the high-speed transmission system. Several techniques have been reported on the characteristics of PMD so far. The relation between PMD and the conventional modal birefringence of the optical fibers, however, has not been understood clearly. In this paper, a new technique for measuring polarization mode dispersion (PMD) with respect to wavelengths of the optical fiber by making use of the wide band frequency domain interferometry based on SLD and a spectrum analyzer is described associated with theoretical analysis of PMD deprived from modal birefringence of the optical fibers.

Theoretical background for measurements

Assuming that a beam of light from SLD is incident on a length of Polarization Maintaining Optical Fiber (PMF) through a polarizer whose axis is set at 45 degree to principal axis of PMF and propagates along the PMF with length L, the orthogonal waves guided along the slow and fast axes in the PMF is superimposed to interfere with each other, depending upon the wavelengths. Therefore the interference pattern will be observed by spectrum scanned with respect to wavelengths by Optical Spectrum Analyzer (OSA).

Here let $\beta x(\omega)$ and $\beta y(\omega)$ be propagation constants along the slow and fast axis of PMF, respectively, define $\Delta\beta(\omega)= \beta x(\omega)-\beta y(\omega)$,

where $Bx(w) = \frac{w}{c} Nx(w), By(w) = \frac{w}{c} Ny(w)$ (1)

and Nx(ω) and Ny(ω) are refractive indices specified by x and y axis.

c is the speed of light in free space, L is optical fiber length

Therefore, the output of channeled spectrum is given by

$$S_{out}(w) = S_{in}(w)\{1 + \cos(\Delta B(w)L)\} \quad (2)$$

As $\omega=2\pi\nu$, then the period is defined as νp,

Modal birefringence $\Delta N(n) = \frac{c}{npL}$ (3)

Thus PMD is expressed in the following equation, taking account of modal birefringence, that is, $\Delta N(\omega)=Nx(\omega)- Ny(\omega)$

$$\frac{d\Delta B(w)}{dw} = \frac{1}{c}\left\{\Delta N(w) + w\frac{d\Delta N(w)}{dw}\right\} \quad (4)$$

If the second term of Eq.(4) is negligible, that is, $\frac{d\Delta N(w)}{dw} \approx 0$, it leads to

$$\frac{d\Delta B(w)}{dw} = \frac{1}{c}\{\Delta N(w)\} \quad (5)$$

In other word, PMD is equivalent to modal birefringence.

Experimental setup is shown in Fig.1. S_{in} and S_{out} mean the spectrums of light source of SLD and the output spectrum observed by OSA the respectively. SMF and MMF are conventional single mode fiber and multi mode fiber equipped with a collimator lens at the output end.

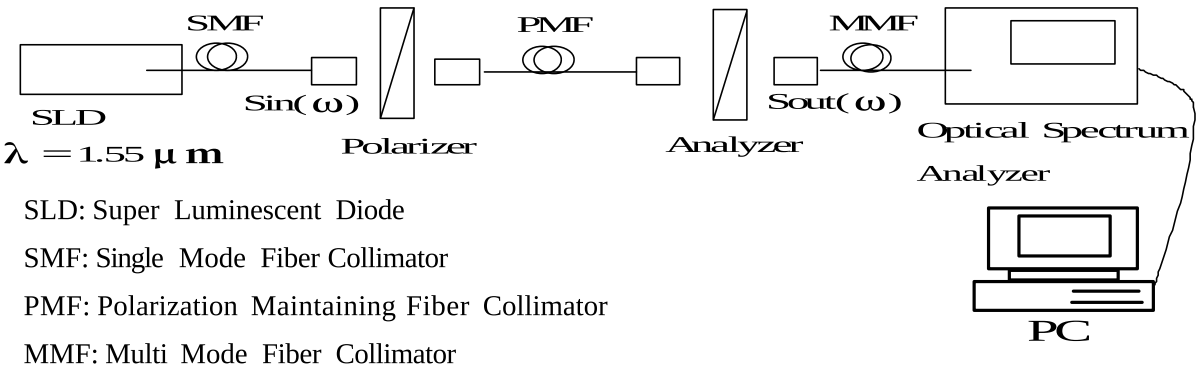


Fig.1 Experimental setup of channeled spectrum interferometry

Experimental Results

A linearly polarized beam from the SLD source with a wide spectrum which ranges from around 1.46[μm] to 1.66[μm] impinges upon P to couple into a sample of PMF with L=1.1[m]. State of polarization(SOP) at the input face was arranged correctly by P and A. As the light wave is propagating along the fiber, the same SOP will be appeared repeatedly at a series of its cross section. Therefore, the output spectrum gives us interference pattern due to superimposing the same SOP along the PMF by scanning wavelength of a spectrum analyzer. Fig. 2(a) and Fig.2 (b) shows spectrum of light source(SLD) and output spectrum respectively.

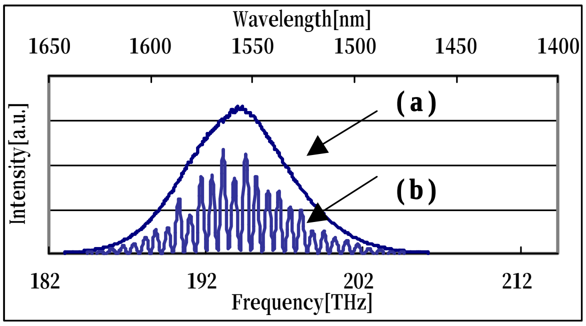


Fig.2 channeled spectrum

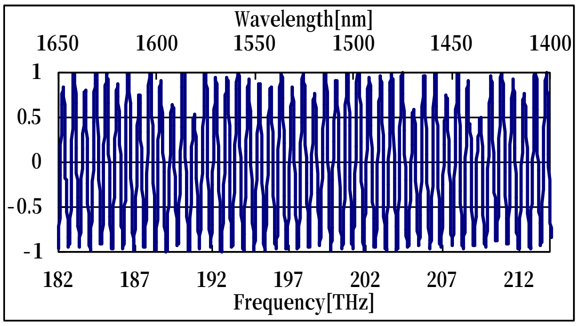
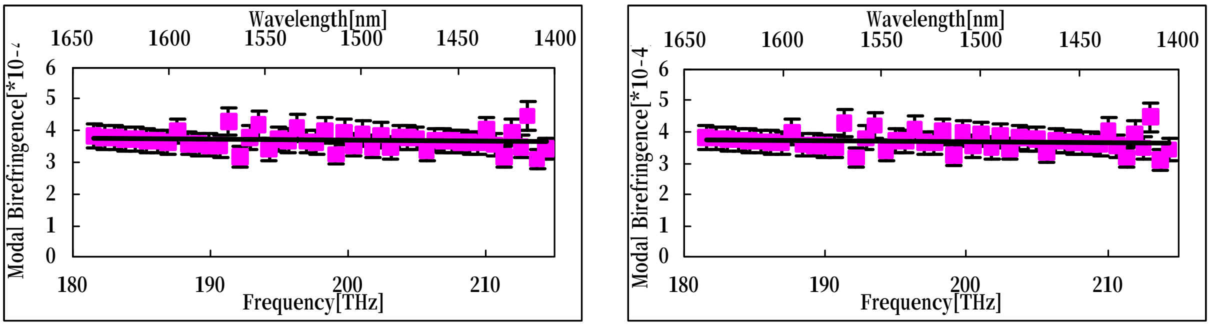


Fig.3 Normalized Spectrum

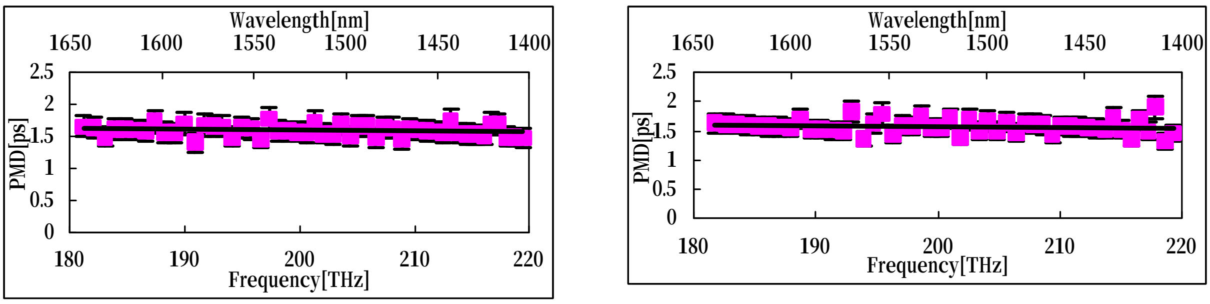
It clearly illustrates the interference pattern within the original spectrum of the SLD. Fig.3 showed the channeled spectrum, which was normalized with respect to original spectrum of SLD. Therefore the periods obtained from the channeled spectrum give modal



(a) Extinction ratio 20dB

(b) Extinction ratio 40dB

Fig.4 Modal Birefringence of PMF's



(a) Extinction ratio 20dB

(b) Extinction ratio 40dB

Fig.5 PMD of PMF's

birefringence of the PMF, that is PMD as described previously.

Fig.4 tells us the wavelength dependence of birefringence of the PMFs with extinction ratios of 20[dB] and 40[dB] respectively. This figure shows that modal birefringence of both PMFs is independent of wavelength near 1.55[μm]. This implies that $d\Delta N(\omega)/d\omega$) 0. Then modal birefringence is not affected by the degree of extinction ratio of the PMF. PMD of two kinds of PMFs obtained by result based on Eq.(5) give us a few dependence of wavelength as well.

Application of PMD measurement

This PMD measurement method gives us a frequency modulated light source having spectrum coming from the output end based on interference pattern with respect to wavelength. Comparison of output spectrum specified by a standard PMF and modulated spectrum through a tested piece could provide modal birefringence of the test piece. Modal birefringence and PMD of SELFOC, whose length is as long as 200mm, as shown in Fig.6. measured by this method was not found.

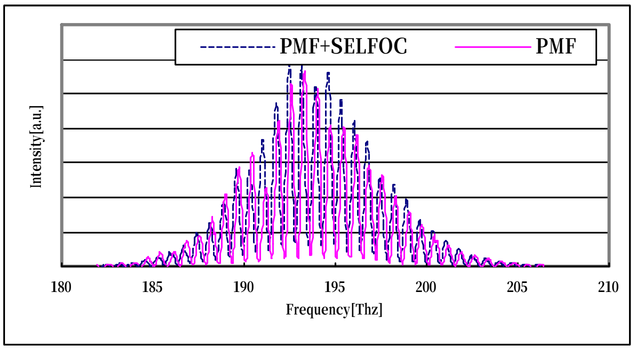


Fig.6. Channeled spectrum of SELFOC

Conclusion

Measurement of Modal birefringence by channeled spectrum interferometry using SLD will give us PMD with respect to wavelength as well. This method has very simple setup without any moving elements to measure PMD and provide a frequency modulated light source to characterize PMD of optical components as well. By measurement of SELFOC lens on this method its PMD was found significantly small.

Acknowledgment

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