CD insensitive PMD monitoring by Using FBG Notch Filter in 57-Gbit/s D8PSK and 38-Gbit/s DQPSK systems

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Abstract: A CD insensitive PMD monitoring scheme based on measuring RF power is demonstrated experimentally. By using a narrow band FBG notch filter, one of sideband is filtered out and the corresponding RF power can be used as CD insensitive PMD monitoring signal. It is experimentally shown that the proposed method is efficient on measuring the DGD values in 57-Gbit/s D8PSK and 38-Gbit/s DQPSK systems.

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1. Introduction
In order to meet the demand of broadband applications, the capacity of the optical transmission systems has grown rapidly in recent years. Polarization mode dispersion (PMD) is one of major impairments which limit the performance of high-speed, long haul optical fiber transmission systems. PMD accumulates in fiber and many in-line components. Deleterious PMD effects are stochastic, time varying, and temperature dependent. Moreover, the instantaneous first-order PMD (i.e., differential group delay (DGD)) follows a Maxwellian probability distribution, always with some finite probability of network outage. As a result, real-time PMD monitoring technique attracts a lot of interests. Various methods have been reported to monitor and compensate PMD in optical network systems. One method was proposed measuring the difference between two optical frequency components for the two orthogonal principal states of polarization (PSPs) [1]. However, polarization tracking is required in the system. Another method was reported to measure the DGD by monitoring the degree-of-polarization (DOP) of received signal [2, 3]. This method dependent on the pulse width of the signal and the DGD monitoring range is small for short pulses. Eye diagram and delay-tap sampling reveal the effect of PMD [4, 5], while it is still challenging to measure the value of PMD in the presence of other impairments. RF tone power can be used to monitor PMD [6, 7]. However, it is also affected by chromatic dispersion (CD). Therefore, CD insensitive PMD monitoring techniques are necessary.

In this paper, we extend the method in [7] and place an FBG notch filter at 10 GHz away from the carrier in 57-Gbit/s and 38-Gbit/s transmission systems. CD insensitive PMD monitoring was realized based on RF power measurement. This method has following advantages: (1) DGD measurement range is large; (2) transparent to modulation format; and (3) photodetector (PD) with small bandwidth is used. It is experimentally shown that the proposed method is effective for CD insensitive PMD monitoring for differential 8-level phase-shift keying (D8PSK) and differential quadrature phase-shift keying (DQPSK) signals.

2. Principle and system setup

Fig. 1 shows the principle of proposed method. The carrier and sidebands have the same polarization state at the transmitter. After transmission through a piece of fiber with DGD, the carrier and sideband become out of phase and the amplitude of beating component decreases. If the DGD equals to half period time of a certain frequency, the optical components at two orthogonal polarization states have a phase shift of \( \pi \) and there is no beating component at corresponding RF frequency. Therefore, the RF power changes as a function of DGD. In our setup, an FBG is placed at 0.08 nm away from the carrier, and 10 GHz RF power is used as the PMD monitoring signal. Compared with the scheme in [7], the measurement range is increased from 26.3 ps to 50 ps in 57-Gbit/s D8PSK system and requirement of PD bandwidth is decreased to 10 GHz. As the optical component at 10 GHz away in one sideband is filtered out, CD does not affect the amplitude of RF tone and the method is insensitive to CD.
Fig. 2 shows the experimental setup of the proposed scheme. 57-Gbit/s D8PSK signal was generated by using one in-phase/quadrature (I/Q) modulator and one phase modulator (PM). The symbol rate of the system is 19-Gbit/s. Several spans of dispersion compensation fiber (DCF) were used to supply different CD values. First-order PMD was emulated by utilizing two polarization beam splitters (PBSs) and a tuneable optical delay line. An FBG notch filter was placed at 10 GHz away from the carrier to eliminate the effect of CD on RF power. A PD with 10 GHz bandwidth was used to detect the optical signal. An electrical bandpass filter with bandwidth of 100MHz and a power meter were utilized to measure the RF power at 10GHz.

3. Experimental results and discussion

Fig. 3 shows the optical spectrum (with resolution of 0.01nm) of a 57-Gbit/s D8PSK signal filtered by an FBG notch filter. The optical component at 10 GHz away from the carrier was filtered out by an FBG (with bandwidth of 0.06 nm and reflection of 15 dB). Therefore, the 10 GHz RF power can be used as monitoring signal to obtain CD insensitive DGD. Fig. 4 shows 10 GHz RF tone power as a function of DGD value in 57-Gbit/s D8PSK system. Different CD values were introduced by several pieces of DCF. The intensity of 10 GHz RF tone is quite small at a DGD of 50ps. This is due to the optical components at the two orthogonal polarization states have a phase shift of $\pi$ and the beating component destruct completely at 10GHz. The RF power varies as a function of DGD and the measurement range is 0–50ps. As one of sideband is filtered out by the FBG notch filter, 10 GHz RF power is insensitive to CD.

The proposed scheme is transparent to modulation format. It is experimentally demonstrated that the method is also effective for DQPSK system. Fig. 5 shows the optical spectrum of a 38-Gbit/s DQPSK signal filtered by an FBG notch filter placed at 10 GHz away from the carrier. Fig. 6 shows RF tone power at 10 GHz as a function of DGD value in the 38-Gbit/s DQPSK system. It is observed that the proposed method is also effective for CD insensitive PMD monitoring in DQPSK system. The FBG notch filter can be placed closer to the carrier, and the DGD measurement range will be increased further. However, the bandwidth of the FBG should be much narrow to avoid the filtering of carrier.

References