Wavelength Transparent DPSK Demodulation Using Delay-Asymmetric Nonlinear Loop Mirror

Mable P. Fok[#] and Chester Shu
Department of Electronic Engineering and Center for Advanced Research in Photonics,
The Chinese University of Hong Kong, Shatin, N. T., Hong Kong
E-mail: mpfok@ee.cuhk.edu.hk
[#]Present address: Department of Electrical Engineering, Princeton University, Princeton, NJ 08544, USA

Abstract

Wavelength transparent DPSK demodulation is demonstrated using the delay-asymmetric nonlinear loop mirror (DANLM). The operation is explained by wavelength-dependent optical path difference between the two interfering branches.

Introduction

Differential phase shift keying (DPSK) signal provides remarkable transmission performance by minimizing the transmission impairment from fiber nonlinearities. For direct detection of the DPSK signal, an optical DPSK demodulator is required at the receiver to convert the phase modulation into intensity modulation. Different approaches have been demonstrated for demodulating the DPSK signal. Examples include the use of a phase-shifted fiber Bragg grating [1], an all-fiber delay-line interferometer [2-3], and a birefringent fiber loop [4]. However, all the above approaches are wavelength sensitive and require precise temperature control and stabilization for their operation.

In this paper, we demonstrate a wavelength transparent DPSK demodulation scheme using a delay asymmetric nonlinear loop mirror (DANLM) that was recently proposed [5]. Operation of the DANLM is based on four-wave mixing and wavelength dependent group delay of the DPSK signal. A unique advantage of the DANLM is its capability for demodulating DPSK signals at variable bit rates and bit periods [5]. In this paper, we further demonstrate wavelength transparent operation of the DANLM. The wavelength tolerance of the demodulation process is measured for both the DANLM and the conventional 1-bit fiber delay interferometer. When the input DPSK signal wavelength is detuned, a widely opened eye diagram can be obtained only with the DANLM.

Experimental Setup

Figure 1 shows the experimental setup of the wavelength transparent demodulation scheme. The DANLM is based on a conventional loop mirror with an additional nonlinear element to initiate FWM and a dispersive element to introduce wavelength dependent delay. The operation principle is described in [5]. Unlike other types of nonlinear loop mirrors that are based on nonlinear phase modulation, FWM preserves both the phase and the amplitude information of the signal.

In the experiment, a 64-m dispersion flattened photonic crystal fiber (PCF) is used as the FWM nonlinear medium. The DANLM uses a 600-m standard single mode fiber to provide ~10 ps/nm GVD at the wavelength range of interest. A 10-Gb/s NRZ DPSK signal is generated at 1553.8 nm by modulating the laser output with a 2^{31}-1 PRBS using a phase modulator. The DPSK signal is combined with a CW control light from a tunable laser and the output is boosted by a fiber amplifier. The amplified light is launched to the input of the DANLM where FWM and optical delay take place. By tuning the wavelength of the control, the amount of delay can be continuously varied [6]. The device is relatively stable as the two branches share the same physical path and experience the same environmental disturbances.

A tunable optical bandpass filter is used to filter out the demodulated DPSK signal. It is worth noting that both the constructive and destructive demodulated outputs can be obtained from the DANLM through the use of an optical circulator. Therefore, balanced detection can be supported with the setup.

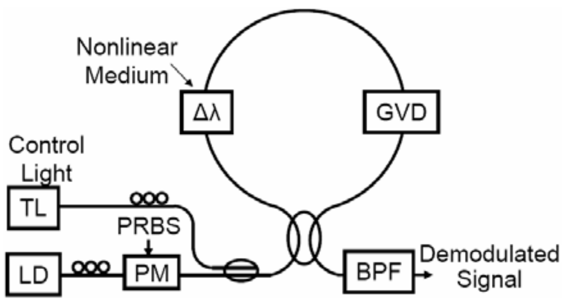

Figure 1. Experimental setup of the wavelength transparent DPSK demodulation scheme using DANLM. TL: tunable laser, LD: laser diode, PM: phase modulator, PRBS: pseudorandom binary sequence, GVD: group velocity dispersion, Δλ: wavelength shift, BPF: optical bandpass filter.

978-1-4244-2229-6/08/$25.00 ©2008 IEEE

Experimental Results

To ensure that the demodulation is purely resulted from FWM and GVD, the control signal is first removed from the setup. At the output of the DANLM, a CW light is obtained that corresponds to the original DPSK signal. Fig. 2 (a) and (b) shows the time profiles of the output signal at the constructive and the destructive output ports, respectively.

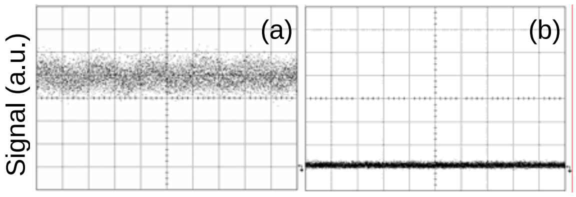

Figure 2 : Time profiles of the DPSK signal after the DANLM without pump light (a) constructive port (b) destructive port.

By launching a CW pump light at 1548.8 nm to the DANLM, demodulation of the DPSK signal is achieved. The eye diagram of the demodulated DPSK signal is shown in Fig. 3(a)i. A widely opened eye is obtained. To study the wavelength transparent property of the DANLM, the wavelength of the CW pump light is fixed while that of the DPSK signal is detuned. Fig. 3(a)ii to (a)iv show the eye diagrams of the demodulated DPSK signal with wavelength detuned by 0.01 nm, 0.02 nm, and 0.03 nm, respectively. No degradation is observed and widely opened eye diagrams are obtained throughout the detuning of the signal wavelength.

A conventional 1-bit fiber delay interferometer (DI) is used for comparison as a DPSK demodulator. The DI is optimized for demodulating 10-Gb/s DPSK signal. The same DPSK signal is launched to the DI, and a widely opened eye diagram is obtained as shown in Fig. 3(b)i. When the DPSK signal wavelength is detuned by 0.01 nm, signal degradation is obtained as shown in Fig. 3(b)ii. Eye closure is observed when the detuning is increased to 0.02 nm and 0.03 nm, as shown in Fig. 3(b)iii and (b)iv, respectively.

To explain the difference in wavelength sensitivity of the DPSK demodulation between the DANLM and the conventional DI, it is noted that the DANLM provides a wavelength-dependent optical path difference between the two interfering branches, while that of the conventional DI is fixed. As a result of FWM in the DANLM, when the input signal wavelength is detuned by a certain amount, the wavelength of the output component will be shifted by exactly the same amount in the opposite direction. Hence, the relative delay of the two branches will be automatically adjusted in the GVD medium to ensure a wavelength transparent operation.

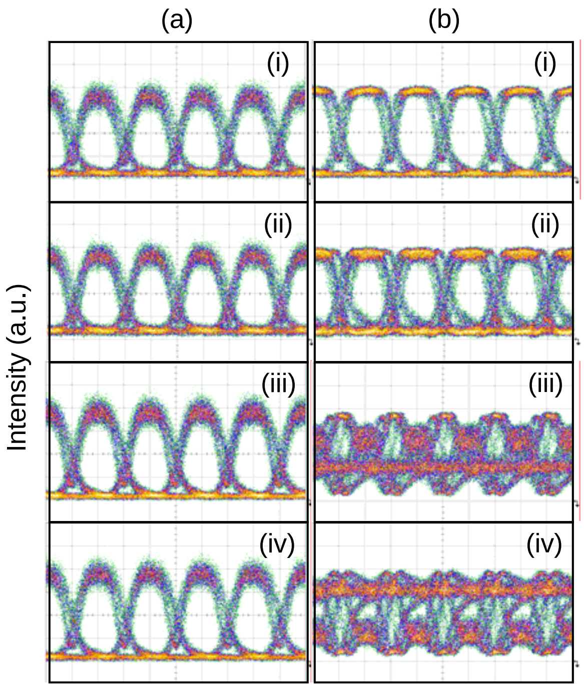

Figure 3: Eye diagrams of the demodulated DPSK signal using (a) DANLM and (b) conventional 1-bit fiber delay interferometer. Wavelength detuning (i) 0.00 nm (ii) 0.01 nm (iii) 0.02 nm (iv) 0.03 nm.

Conclusion

A wavelength transparent DPSK demodulation scheme has been experimentally demonstrated using the DANLM. The eye diagrams of the 10-Gb/s demodulated signals are widely opened over the detuning range of the signal wavelength. Operation of the DANLM is based on FWM and GVD that result in asymmetric optical delay to the counter propagating light branches. The wavelength-dependent optical path difference provides the explanation for wavelength transparent operation of the device.

References

1. T. Kim et al, IEEE Photon. Technol. Lett., vol. 18, (2006) pp.1834 – 1836.
2. E. Swanson et al, IEEE Photon. Technol. Lett., vol. 6, (1994) pp. 263 – 265.
3. Y. K. Lize et al, IEEE Photon. Technol. Lett. vol. 19, (2007) pp. 1886 – 1888.
4. C. W. Chow et al, IEEE Photon. Technol. Lett., vol. 17, (2005) pp. 1313 – 1315.
5. M. P. Fok et al, OFC/NFOEC (2008) PDP24.
6. M. P. Fok et al, IEEE J. Lightw. Technol., vol. 26 (2008) pp. 499 – 504.