High-Speed Chromatic Dispersion Monitoring of a Two-Channel WDM System using a single TPA Microcavity

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Abstract: Chromatic dispersion monitoring of two 160Gb/s wavelength channels using a TPA Microcavity is presented. As the microcavity exhibits a wavelength resonance characteristic, a single device could monitor a number of different WDM-channels sequentially.
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OCIS codes: (320.7110) Ultrafast nonlinear optics, (060.2330) Fiber optics communications

1. Introduction

Due to continued growth of the Internet and the introduction of new broadband services, it is expected that individual channel line rates will exceed 100Gb/s in the next 5 years. One of the major limitations to operating at such high data rates will be the amount of Chromatic Dispersion (CD) introduced. Dispersion management can be used, but it will not compensate for additional CD fluctuations that arise due to variation of temperature [1], or mechanical stress. Such variations will become a serious problem when individual line rates exceed 40Gb/s. It is important to develop new CD monitoring techniques that have the ability to operate at such high data rates. In this paper a technique based on the optical nonlinearity of Two-Photon Absorption (TPA) in a specially designed microcavity is utilized for wavelength selective, CD monitoring of two WDM channels, each operating at 160Gb/s. TPA is a nonlinear optical-to-electrical conversion process that occurs in semiconductors when two photons are simultaneously absorbed to generate a single electron-hole pair. The TPA photocurrent is proportional to the square of incidence optical power falling on the detector. It is this nonlinear response that allows TPA to be used for CD monitoring. The average TPA photocurrent generated by an incident optical signal with a power envelope $P(t)$ is given by [2]:

$$I_{TPA}^{Av} \propto \frac{P_{ave}^2}{D} \quad \text{where} \quad D = \frac{\langle P(t) \rangle^2}{\langle P^2(t) \rangle} \quad (1)$$

where D is the generalized duty cycle and <…> means time averaging. As the duty cycle increases with CD, the average TPA photocurrent will change accordingly, allowing for the CD monitoring of ultra-fast optical signals without the need for fast electronics [3]. One way to overcome the inherent inefficiency associated with TPA is to employ Resonance Cavity Enhancement (RCE) technology within the detector. One interesting feature of using a RCE-based device is the fact that the incident signal is only enhanced over a narrow wavelength range determined by the device design [4]. This allows the monitoring of a single wavelength channel without the necessity of using an additional external optical filter. Also as the cavity resonance wavelength peak can be easily tuned by tilting the device, allowing different wavelength channels to be monitored using a single device.

3. Experimental results

Before carrying out the experimental work, the TPA microcavity used was initially characterized. Fig.1(a) displays the cavity resonance characteristic for the device, with a measured 3dB cavity bandwidth of 265GHz (2.1nm). Fig.1(b) shows that the resonance wavelength tunability of the microcavity exceeds 80nm, allowing the entire C-band to be monitored using a single device. The experimental setup for TPA-based CD monitoring is shown in Fig.1(c). Two 10GHz RZ optical pulse trains were generated using wavelength tunable (1480-1580nm) actively mode-locked pulse sources. The wavelength channels were separated spectrally by 10nm, operating at wavelengths of 1556nm and 1546nm respectively. Both channels were combined and modulated with 2^7-1 RZ PRBS data signal. Each channel then entered a 10-160Gb/s bit rate multiplexer, consisting of four independently switch-able stages. The higher bit rate WDM signal then passed through various lengths (0-80m) of dispersion compensating fiber (D=-99.3ps/km.nm) before being incident on the TPA microcavity. The power level falling on the TPA microcavity was fixed at 6dBm. The generated photocurrent for the varied DCF lengths and multiplexed data rates were measured on the PicoAmmeter. Initially the cavity was set to normal incidence angle to monitor the CD of the first

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channel (1556nm). The cavity was then tilted by 22º (cavity resonance wavelength shifted by 10nm) to monitor the second channel at 1546nm.
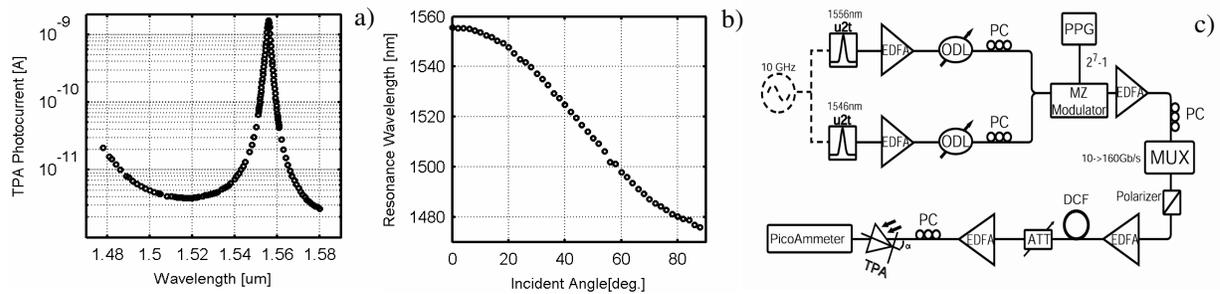
Fig. 1 (a) Cavity resonance characteristic, (b) Cavity resonance wavelength for varied incident angle, (c) Experimental Setup

The experimental results are shown in Fig.2 (a) for the first channel and in Fig.2 (b) for the second channel. The TPA photocurrent decreases with an increase in the accumulated dispersion (ps/nm) in accordance with Eq.1. Both signals flatten out at the same level for given incident angle. The levels however, differ for tilted device since the cavity enhancement factor depends on the incident angle. Therefore the optical field within cavity and the generated TPA photocurrent decreases with increased angle. As can be seen for both wavelength channels the monitoring range is limited by pulse overlapping to 4ps/nm for 160Gb/s and 6ps/nm for 80Gb/s. Above these threshold values the overlapped pulses can combine coherently resulting in reconstruction of the original periodic signal (Talbot effect [5]). In our experiment however, this self-imaging effect is suppressed by the PRBS modulation and by the fact that coherency of signal degrades after propagation through a system. The residual reconstruction can be visible for 160Gb/s signal above the 4ps/nm threshold. The overall effect of this pulse (coherent or incoherent) overlapping will be to limit the range over which the CD of the signal can be monitored. As a result, this techniques is more suited for monitoring of small levels of CD fluctuations in high-speed (>100Gb/s) optical communications systems.
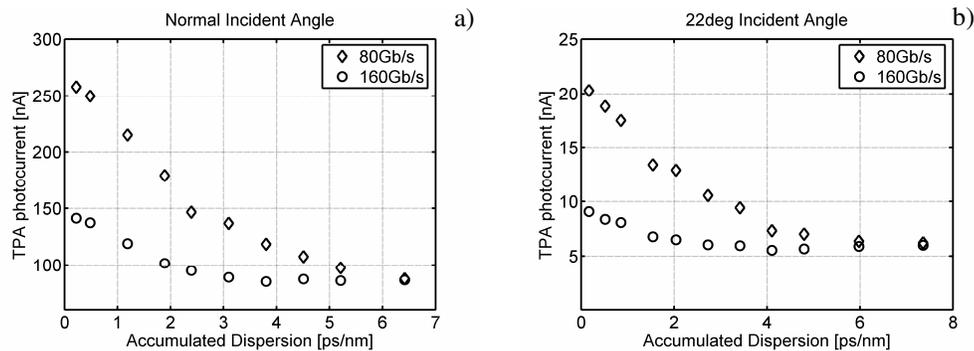
Fig. 2. CD monitoring of 80 Gb/s and 160 Gb/s data signal at (a) 1556 nm (normal incident angle) and (b) 1546 nm (22° incident angle)

4. Conclusion

The experimental results demonstrate CD monitoring of two, high-speed WDM signals using a single TPA microcavity. Due to the ultra-fast nature of the TPA effect, and the resonance response of the microcavity, a single device can be employed to monitor a large number of WDM channels, each operating at a data rate exceeding 100Gb/s. Such a device is ideally suited for the monitoring of small fluctuations of CD arising from variation of temperature or mechanical stress.

5. References

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