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The Impact of Gating Timing Jitter on a 160 Gb/s Demultiplexer

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Abstract: The impact of gating timing jitter on a 160Gb/s demultiplexer is investigated by using two pulse sources with different timing jitter properties. It is found that jitter in the range 20kHz-10MHz is essential to minimize.

OCIS codes: (060.2330) Fiber optics communications; (060.4510) Optical communications

1. Introduction

Currently, the most efficient way to realize ultra-high speed single channel optical transmission systems is to use Optical Time Division Multiplexing (OTDM). In order to demultiplex the high-speed signal, an ultra fast all-optical switch is needed. A Non-linear Optical Loop Mirror (NOLM) has on numerous occasions shown great potential for providing ultra-fast switching, due to the ultra fast optical non-linear response associated with fibers [1-2]. It has been shown theoretically that relative timing jitter between the data and control signal degrades the BER performance [3-4]. Furthermore, as the data signal bit rate is increased, timing jitter requirements on the data and control signal become more stringent [3]. However, the impact of timing jitter has only been investigated experimentally at the line rate of 2.5 Gb/s and 20 Gb/s, where the requirements to jitter are modest. In this paper, we experimentally investigate the effects of timing jitter on a NOLM based demultiplexer at 160 Gb/s. Furthermore, we investigate the interplay between the control signal pulse width and timing jitter to achieve error-free performance of the system.

2. Experimental set-up

The experimental set-up used to generate a 160 Gb/s OTDM signal and to demultiplex the data signal to 10 Gb/s is shown in Figure 1.

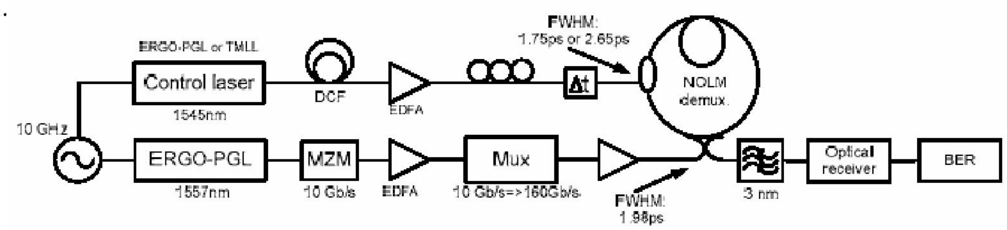

Fig. 1. Experimental set-up used to investigate the effects of data to control signal timing jitter on NOLM switching BER performance.

The optical data signal is generated by a solid state modelocked Erbium Glass Oscillator Pulse Generating Laser (ERGO-PGL) at 10 GHz and 1557 nm. The data signal pulses are externally modulated with a pseudorandom bit sequence (PRBS) with length 2^7-1 using a Mach-Zender Modulator (MZM) and injected into a high-power EDFA. The pulses generated from the ERGO-PGL at the transmitter are approximately 2 ps wide. The 10 Gb/s data signal is then multiplexed to 160 Gb/s by a passive fiber delay polarization and PRBS maintaining multiplexer. The 160 Gb/s data signal is additionally amplified by an EDFA to 25 dBm before being injected into the NOLM. For the control pulses, required to demultiplex the 160 Gb/s signal, we have tested two different types of pulse sources: a solid state ERGO-PGL (similar to the one at the transmitter) and an external cavity semiconductor Tunable Mode Locked Laser (TMLL). The ERGO-PGL and TMLL used to generate control signal pulses have different phase noise (timing jitter) properties. The FWHM of the control signal pulses is varied (2.68 ps and 1.75 ps) in order to investigate the performance of the NOLM-gate dependence of control signal pulse width and timing jitter at high bit rates. The data and control signal pulses are synchronized to the same synthesizer. The wavelength of the control signal pulses is kept constant at 1545 nm. The HNLF used in the NOLM is a 500 m commercially available fiber with a relatively flat dispersion slope (zero disp. ~ 1551nm, slope ~ 0.017ps/nm^2, γ ~ 10 W^{-1}km). Finally, after the demultiplexing, the 10 Gb/s signal is sent through a 3 nm optical band-pass filter to filter away control pulses and it is then injected into a pre-amplified 10 Gb/s receiver for BER evaluation.

3. Signal characterization

In Figure 2(a), the Single Sideband to Carrier Ratio (SSCR) of the data and control signal pulse sources are shown. It is observed that the data signal SSCR curve ($\tau_{jitt.}$=131fs) and control signal SSCR ($\tau_{jitt.}$=91fs, ERGO-PGL) closely follow each other as expected (they are fully synchronized). The reason for the slight increase in the data signal jitter is due to multiple EDFA amplification.

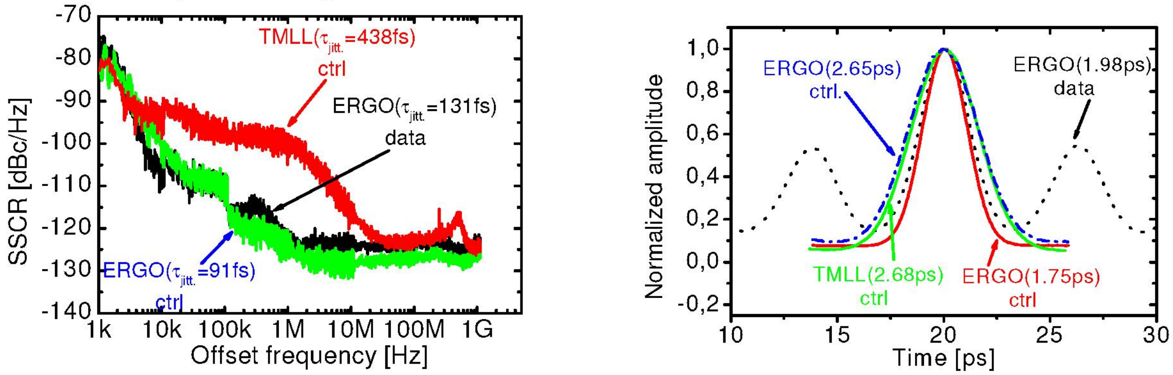

Fig. 2 (a) SSCR of the data and control signal pulse sources measured at the input of NOLM. Jitter integration range: 20 KHz-80MHz. (b) Autocorrelation traces of the data and control signal pulses at 160 Gb/s and 10 GHz, respectively, measured at the input of the NOLM.

Figure 2(a) shows that the TMLL exhibits more phase noise in the range 20 kHz - 10 MHz compared to the ERGO-PGL pulse sources. This is because the modulation bandwidth of the TMLL is relatively large (~ 1 MHz), allowing the phase noise from the reference (synthesizer) signal to be directly transferred, and also because the TMLL itself is noisy due to ASE. The ERGO-PGL lasers use an internal Phase-Locked Loop (PLL), with a bandwidth of only 10 kHz, in order to obtain synchronization with the reference signal. In this way, the phase noise contribution from the reference signal is filtered away. Furthermore, the ERGO-PGL itself has low noise at frequencies exceeding the PLL bandwidth. By using the ERGO-PGL and TMLL as control signal pulse sources, the impact of excess jitter in the range from 20 kHz – 10 MHz is investigated. In Figure 2(b), autocorrelation traces of the data signal together with the control signal pulses are portrayed. A clean and smooth autocorrelation traces of the 160 Gb/s data signal pulses with FWHM of 1.98 ps (deconvolved pulse) are observed. Figure 2(b) also contains the autocorrelation traces for the ERGO-PGL control signal laser source with a FWHM of 2.65 ps (deconvolved pulse) and 1.75 ps (deconvolved pulse) together with the TMLL with FWHM of 2.68 ps (deconvolved pulse). By using short pieces of the Dispersion Compensating Fiber (DCF) we were able to tune the pulse widths of the ERGO-PGL and TMLL.

4. ERGO-PGL vs. TMLL

In order to exclude the influence of the control signal pulse widths, the pulse widths of the ERGO-PGL and the TMLL are matched to approximately 2.65 ps, see Figure 2(b).

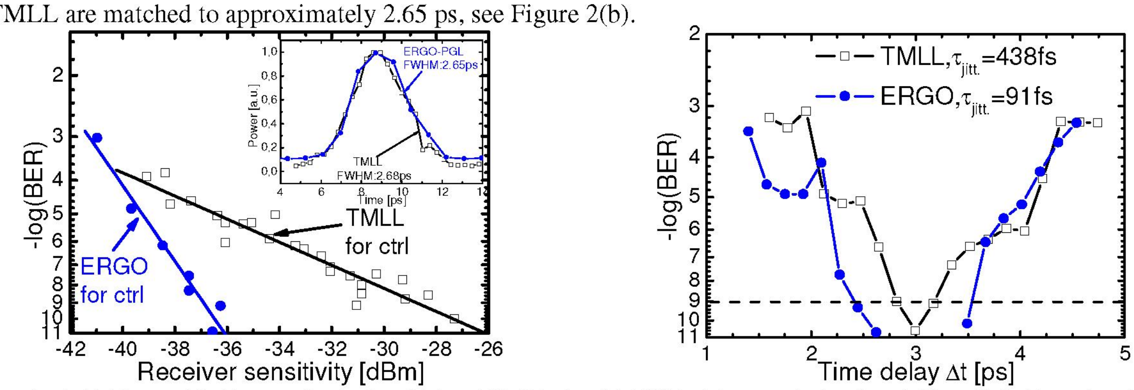

Fig. 3. (a) Measured BER curves for the demultiplexed 10 Gb/s signal. FWHM of the controls signals: ~ 2.65ps. (b) BER as a function of relative time delay between data and control signal pulses.

The inset in Figure 3(a) shows the measured switching windows, (integrated power of the demultiplexed signal as the relative time delay, Δt, (see Figure 1) between the data and control signal is varied), when the ERGO-PGL and the TMLL are used. It is observed that the widths of the switching windows are approximately the same. Figure 3(a) shows BER curves for the 160 Gb/s to 10 Gb/s demultiplexed signal in the two cases. In Figure 4(a), the receiver sensitivity of all the 16 channels is shown when the ERGO-PGL control pulse source is used. All channels are error-free with an average sensitivity of -37.5 dBm. The corresponding receiver sensitivity is -28.3 dBm when the TMLL is used for control signal generation; see Figure 3(a). The TMLL with 438 fs timing jitter results in approximately 9 dB penalty compared to the ERGO-PGL laser with 91 fs timing jitter. In Figure 3(b), BER as a function of relative time delay, Δt, is plotted for the ERGO-PGL and the TMLL used as control pulse sources. (The power used for the measurement is: P_{rec}+3dBm). It is observed that when the timing jitter is 91 fs we have a time-offset margin of 1.4 ps for the error free performance (BER=10^{-9}) compared to 0.34 ps when the timing jitter is 438 fs. Thus, as the timing jitter in the range 20 kHz - 10 MHz is increased, the requirement for the synchronization between data and control signal pulses, in order to obtain error free operation (BER=10^{-9}), increases.

5. Investigation for different FWHM.

In this section, the ERGO-PGL is used for control signal generation and the system performance in the presence of timing jitter, is investigated as the control signal pulse width is decreased. The FWHM of the control signal pulses takes values of 2.65 ps and 1.75 ps.

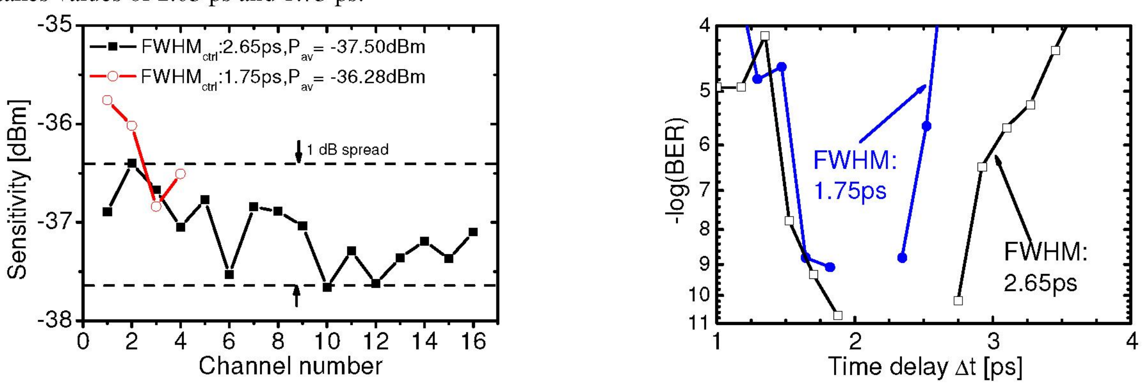

Fig. 4. The ERGO-PGL is used for control signal generation and the FWHM is 2.65ps and 1.75ps, respectively. (a) Measured sensitivity. (b) BER as a function of relative time delay between data and control signal pulses.

The receiver sensitivity of the 160 Gb/s to 10 Gb/s demultiplexed data signal is shown in Figure 4(a) for the FWHM of 2.65 ps and 1.75 ps, respectively. The corresponding receiver sensitivity is -37.5 dBm and -36.3 dBm, respectively. Furthermore, BER curves have been measured as a function of relative time delay, Δt, between data and control signal pulses, see Figure 4(b). It is observed that as the FWHM of the control pulses is decreased from 2.65 ps to 1.75 ps, the time delay tolerance, in order to obtain a BER of 10^{-9}, decreases from 1.10 ps to 0.50 ps. This is because the FWHM of the data signal pulses is 1.98 ps and for the narrow control data signal pulse width of 1.75 ps, the effects of timing jitter become more severe due to the almost equal pulse widths. As the control signal pulse width is increased to 2.65 ps, the control signal pulses are broader than the data signal pulses, thus overlapping all the time irrespective of the jitter. The switching (demultiplexing) of the data signal pulses is then less affected by the control signal timing jitter. However, the control signal pulse width should not become too large in order to avoid the crosstalk from the neighbouring channels.

5. Conclusion

The impact of timing jitter on 160 Gb/s demultiplexer has been investigated. It has been shown that the excess timing jitter in the frequency range from 20 kHz to 10 MHz is of great importance; in increase from 91 fs to 438 fs leads to a penalty of 9 dB and decreases the allowable time misalignment between data and control signal pulses, by approximately 1 ps. Furthermore, the impact of timing jitter can be reduced if the control signal pulses are broader than the data signal pulses.

6. References

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