Generating a Square Switching Window for Timing Jitter Tolerant 160 Gb/s Demultiplexing by the Optical Fourier Transform Technique

Oxenløwe, Leif Katsuo; Galili, Michael; Clausen, A. T:; Jeppesen, Palle

Published in:
European Conference on Optical Communications, 2006. ECOC 2006.

Link to article, DOI:
10.1109/ECOC.2006.4801171

Publication date:
2006

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Oxenløwe, L. K., Galili, M., Clausen, A. T., & Jeppesen, P. (2006). Generating a Square Switching Window for Timing Jitter Tolerant 160 Gb/s Demultiplexing by the Optical Fourier Transform Technique. In *European Conference on Optical Communications, 2006. ECOC 2006.* (pp. 1-2). IEEE. https://doi.org/10.1109/ECOC.2006.4801171

Generating a Square Switching Window for Timing Jitter Tolerant 160 Gb/s Demultiplexing by the Optical Fourier Transform Technique

L.K. Oxenløwe, M. Galili , A.T. Clausen and P. Jeppesen
COM•DTU Department of Communications, Optics and Materials, Technical University of Denmark, building 345V, DK-2800, lo@com.dtu.dk

Abstract *A square spectrum is optically Fourier transformed into a square pulse in the time domain. This is used to demultiplex a 160 Gb/s data signal with a significant increase in jitter tolerance to 2.6 ps.*

Introduction

For high bit rate data signals, timing jitter becomes an important detrimental factor [1], and hence means to introduce jitter tolerance in switches are very attractive. Previously, a highly bi-refringent fibre has been used to generate a pulse with an elongated top, which was implemented in a 160 Gb/s regenerator [2]. Another approach has been to design a sinc-shaped filter corresponding to a square-shaped pulse, which was demonstrated in an 80 Gb/s demultiplexing experiment [3].

In this paper, we show a novel approach to generate square switching windows and demonstrate its use in a 160 Gb/s OTDM demultiplexing experiment. The technique relies on the optical Fourier transform technique, as e.g. described in [4], where a certain spectral shape is transformed to he same shape temporally by an appropriate combination of frequency chirping dispersion. We show that the demultiplexer offers a 2.6 ps timing jitter tolerance this way, as opposed to 1 ps when using Gaussian switching windows.

Principle and experimental set-up

The main goal in this paper is to generate a square switching window, to reduce the timing jitter influence on the switching performance. To this end, we construct a flat-top square-shaped pulse, which we use as control pulse in an ultra-fast fibre-based switch – here, a non-linear optical loop mirror (NOLM) – which has a switching window determined by the control pulse shape.

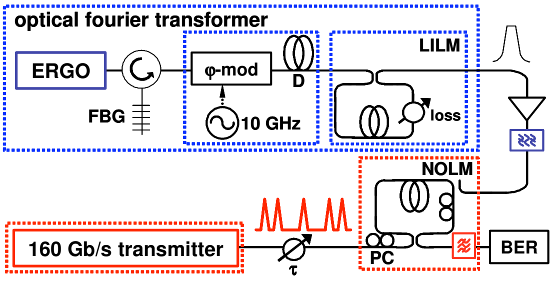

Figure 1. Schematic set-up for jitter tolerant demux

As shown in the schematic figure 1, the control pulse source is generated by the optical Fourier transform technique [4]. A 2 ps pulse with a 3.5 nm 3-dB broad spectrum (derived from Erbium glass oscillating pulse source, ERGO) is filtered in a specially designed fibre Bragg grating (FBG) with a square filter function with a 3-dB bandwidth of 2 nm. This square spectrum is injected into a chirp-dispersion unit, where it is phase modulated (φ-mod) at 10 GHz. By matching the induced chirp to the total dispersion (D) of a dispersive medium (here 4.5 km standard single mode fibre SSMF), the transformation from the spectral domain to the temporal domain is complete, and square pulses are obtained. These pulses have some pedestals, which are suppressed by passing them through a loss-imbalanced loop mirror (LILM), which works by virtue of a differential self-phase shift in the two loss-imbalanced arms. The square pulses are subsequently amplified and used to gate a NOLM demultiplexer, which demultiplexes a 160 Gbit/s 2^7-1 PRBS, single-polarisation optical time division multiplexed (OTDM) data signal down to 10 Gb/s for subsequent bit error rate measurements. The temporal displacement between data and control pulses is controlled by an optical time delay (τ).

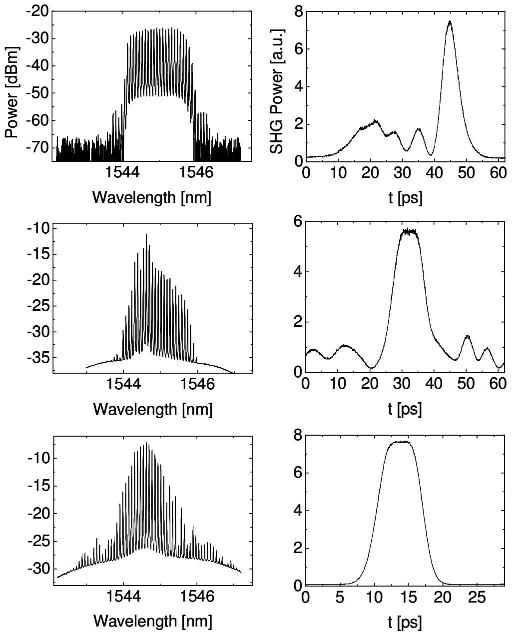

Figure 2. Top: Output of FBG (left: spectrum, right: pulse shape). Middle: Output of chirp-dispersion unit. Bottom: Output of LILM.

Square pulse generation and characterisation

Figure 2 shows results on the generation of the square pulses in terms of spectra and temporal cross-correlations with a 1.7 ps pulse. A 2 ps Gaussian pulse with a 3.5 nm Gaussian spectrum is injected into a fibre Bragg grating filter. The output of the FBG is shown in figure 2 (top) in terms of spectral and temporal shapes. As seen, the spectrum is a square with a 3-dB bandwidth of about 2 nm. The corresponding pulse is sinc-like with a central peak and a “ringing” tail of trailing pulses.

Figure 2 (middle) shows the output of the chirp-dispersion unit. The modulator runs at 10 GHz with the whole pulse envelope ranging over 50 ps (figure 2 top, right) roughly being linearly chirped with a 1.5 π shift from one end of the pulse envelope to the other. At the output of the dispersive medium, the added chirp is compensated so that the square spectral shape has now been transferred onto the temporal shape, yielding a square pulse (figure 2 (middle, right)). There are some residual pulses due to imperfectly compensated chirp, which are suppressed by the LILM. The output of the LILM is shown in figure 2 (bottom), and a clear square pulse is obtained. There is more than 15 dB extinction ratio on the square pulse, and it has a 3 ps wide flat top. Its FWHM is ~6.5 ps (cross-correlated with 1.7 ps sampling pulse) and its spectral envelope (now appearing more sinc-like) has a 3-dB bandwidth of ~1 nm and a 20-db bandwidth of ~4 nm.

Dynamic characterisation – switching

In order to demonstrate the use of the generated square pulse in a system, it is used as control pulse to a NOLM-demultiplexer, demultiplexing a 160 Gb/s data signal at 1557 nm to 10 Gb/s. The NOLM uses as active medium a 500 m highly non-linear fibre with zero dispersion at 1551 nm and a dispersion slope of 0.017 ps/nm^2/km, enabling low walk-off and low pulse broadening, thus assuring the switching window shape to be determined by the control pulse shape. Figure 3 shows that all 16 channels are successfully demultiplexed and error-free with clear and open eyes. This is possible because the switching window is narrower than the cross-correlation indicates, as this is convoluted with the sampling pulse. The average sensitivity is -34.5 dBm, which is only 2.5 dB less than for the 10 Gb/s back-to-back (b-b) baseline. For all the channels there is a sensitivity spread of about 3 dB, which is due to some variations in the multiplexed signal and undesired drifts in the phase modulation.

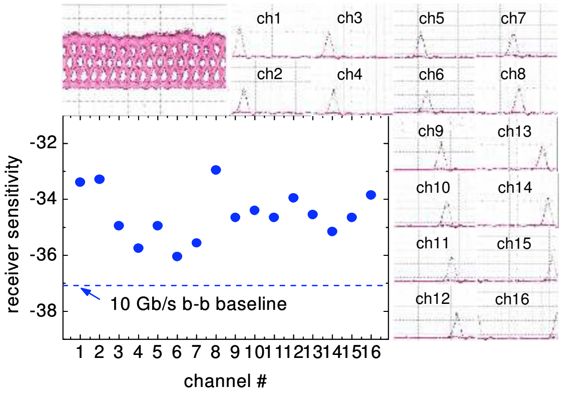

Figure 3. Square pulse demultiplexing. Bottom left: receiver sensitivity for all 16 channels. Top left: 160 Gb/s data. Right: demultiplexed eye diagrams.

To characterise the flat-top feature of the pulse, the data signal is displaced in time relative to the position of the square pulse and hence the switching window. Figure 4 shows the results of this characterisation, where channel 10 is demultiplexed with the square pulse and for comparison with a Gaussian 2 ps wide pulse. The measurements are carried out at a receiver power of 5 dB above the receiver sensitivity for both pulse types to allow for some margin. The square pulse is seen to maintain error-free (BER < 10^{-9}) performance with a 2.6 ps tolerance to temporal displacement, whereas the Gaussian pulse only ensures error-free operation within a 1 ps tolerance.

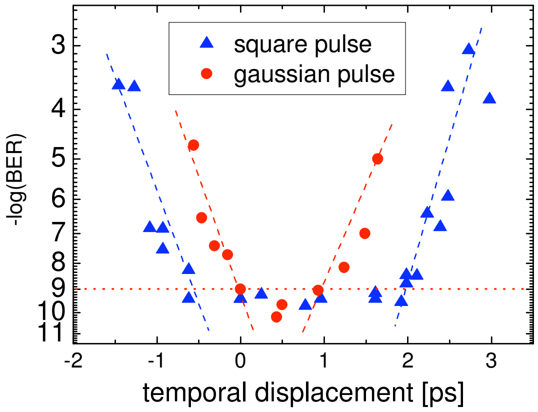

Figure 4. BER at different control-data displacements (power=5dB + receiver sensitivity).

Conclusions

We have demonstrated a novel concept for generating jitter tolerant control signals for high-speed demultiplexing. By virtue of the optical Fourier transform technique, a square-shaped spectrum was transformed into a square-shaped pulse. This was used to demultiplex from 160 to 10 Gb/s with increased jitter tolerance from 1 to 2.6 ps.

Acknowledgements

To OFS Fitel Denmark, and the Danish Research Council through the project Ultra-Net.

References

1 D. Zibar et al, OFC2006, paper OTuB2
2 S. Watanabe et al, OFC2003, paper PD 16-1
3 J.H. Lee et al, J LT, 21(11) (2003), pp 2518
4 M. Nakazawa et , PTL, 16(4) (2004), pp 105