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Abstract: A 0.8 ps flat top pulse is generated using a long-period fibre grating and used as control pulse for the first time in a 320 Gb/s demultiplexer. The effect is an increased error-free timing tolerance.

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1. Introduction

At high-speed serial rates (above electronic rates, i.e. >100 Gb/s), there may be an advantage or indeed a need to perform the signal processing optically. Functionalities such as regeneration or wavelength conversion or even add/drop multiplexing may be beneficial to perform all-optically, in order to avoid cumbersome and power consuming down and o/e conversion. Optical signal processing, however, imposes very strict requirements on the timing stability of the optical laser sources, i.e. timing jitter becomes a serious detrimental factor. Timing jitter of data pulses should in general be less than about 5% of the high rep-rate timeslot, but at bit rates of 160 Gbit/s (timeslot: 6.25 ps) and above, it gets increasingly difficult to find pulse sources that can fulfill these requirements. Therefore it can be very advantageous to have a switch with a high tolerance to timing jitter. Such a switch may be obtained by generating a square-like (flat-top) switching window. This way, small displacements of the data pulse within the window will result in an equal amount of switched power, i.e. a low dependence on the data jitter. A flat-top switching window may be obtained by the use of flat-top control pulses in a fibre-based switch relying on the ultra-fast (fs-response) Kerr-effect in non-linear fibres.

In this paper, we use a flat-top pulse shaper (FTPS) based on a novel linear signal processing scheme [1] that exploits an optical differentiator [2] based on a specially tailored long-period fibre grating (LPG) to generate an 0.8 ps flat top pulse. This pulse is subsequently used to gate a fibre-based ultra-fast demultiplexer, resulting in an 0.7 ps timing tolerant error free demultiplexing of a 320 Gb/s optical time division multiplexed (OTDM) data signal. The demultiplexer is a non-linear optical loop mirror (NOLM) with only 50 m of highly non-linear fibre (HNLF), and this paper is the first demonstration of using flat-top pulses for bit rates as high as 320 Gb/s.

2. Principle and experimental set-up

Figure 1 shows a schematic of the experimental set-up.

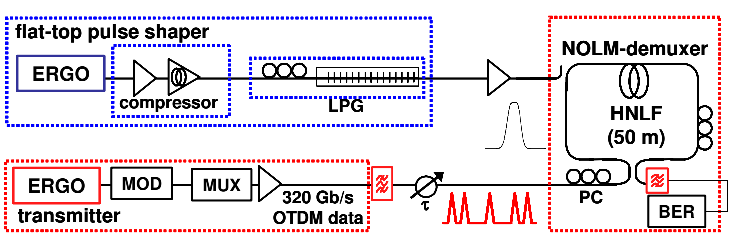

Fig. 1. Schematic set-up.

Referring to figure 1, a 2 ps pulse with a 3.5 nm 3-dB broad spectrum centred at 1543 nm (derived from an Erbium glass oscillating pulse source, ERGO) is soliton compressed through a fibre with gain (basically an EDFA) to a pulse with a Gaussian shape and a FWHM width of 900 fs (or 700 fs). The pulse is sent through the LPG which has a characteristic transfer function with a strong dip (see figure 2, lower middle), which will carve this dip into the spectrum of the input pulse. The effect of this is to create a superposition of the original pulse shape with the differential of the pulse shape [1], balanced by the detuning of the dip with respect to the central spectral carrier. For the mentioned pulse widths, the detuning is about 2 nm. By properly balancing the output of the LPG, a flat top pulse is created. This pulse is subsequently used as control in a NOLM with only 50 m of HNLF (dispersion slope ~ 0.018 ps/nm^{2}km, zero dispersion at 1554nm, and non-linear coefficient of γ ~ 10.5 W^{-1}km^{-1}). A second ERGO is used in an OTDM transmitter producing a 320 Gb/s serial data signal (2^7-1 PRBS, single-polarisation), which is demultiplexed down to 10 Gb/s for subsequent bit error rate (BER) characterisation. The temporal displacement between data and control pulses is controlled by an optical time delay (τ).

3. Experimental results: Characterizations and BER performance

Figure 2 (top, left) shows the obtained flat-top pulses for the two different input pulse widths, as measured with a cross-correlator (resolution: 500 fs). The first pulse obtained has a FWHM of 2.1 ps and a flat top ranging over 800 fs. This pulse is ideal for 320 Gb/s bit rates. To show the versatility of this technique, it is also seen that a 700 fs input pulse results in a 1.8 ps FWHM and 600 fs flat top pulse, which would be adequate for 640 Gb/s data rates.

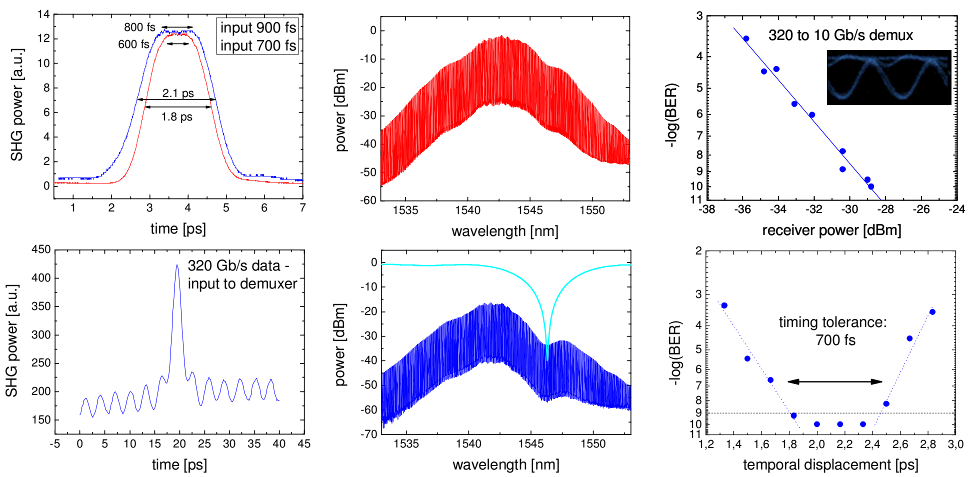

Fig. 2. Left: Flat-top pulse cross-correlation (top) and data pulses auto-correlation (bottom). Middle: Spectrum of compressed input pulse to LPG (top) and filtered (differentiated) output spectrum of LPG with LPG transfer function (bottom). Right: BER curve of demued data (top) and the BER timing tolerance achieved with flat-top pulse.

Figure 2 middle shows how the input spectrum is shaped by the filter. The 320 Gb/s data signal is successfully demultiplexed with the 800 fs flat-top pulse, with clear open eyes (inset) and no error floor (Figure 2, top right). The data pulses are a bit too wide for ideal 320 Gb/s operation, as can be seen by the sub-optimum auto-correlation trace, but the data channels are adequately isolated to obtain error-free performance. The data channels are displaced slightly with respect to the control pulse and the BER is monitored (at 3 dB above sensitivity), and the timing tolerance obtained corresponds well to the flat part of the LPG pulse (namely 700 fs), figure 2, right bottom.

4. Conclusion

We have presented the first use of flat top pulses for 320 Gb/s data signals. The pulses are created by a novel pulse shaping technique based on optical differentiation by an LPG. The same LPG may be used for various bit rates, and we demonstrated a 600 fs flat top pulse, with potential for demultiplexing 640 Gb/s data.

5. References

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