13B3-4

160 Gb/s retiming using rectangular pulses generated using a superstructured fibre Bragg grating

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Abstract *A 160 Gb/s retiming scheme incorporating a superstructured fibre Bragg grating for pulse shaping is demonstrated. Retiming is performed in a single step without wavelength conversion, and a substantial bit error rate improvement is achieved.*

Introduction

At high-speed serial data rates, timing jitter becomes a serious detrimental factor. Timing jitter of data pulses should in general be less than about 5% of the high repetition 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 fulfil these requirements, in particular after transmission. Therefore retiming in a regenerator is a crucial functionality for high-speed systems. Most optical regenerator schemes also imply wavelength conversion, though it is often desirable to maintain the wavelength, without extra wavelength conversion [1].

In this paper, we demonstrate a 160 Gb/s pulse retiming scheme, which maintains the original wavelength and retimes the data in a single step. The retiming scheme contains a polarisation-insensitive superstructured fibre Bragg grating (SSFBG) [2, 3] with a sinc-shaped transfer function, to shape the incoming data pulses into rectangular pulses, and a polarisation-rotating Kerr switch based on 200 m highly non-linear fibre (HNLF). Using this scheme, a 160 Gb/s data signal with an error floor limited by rms timing jitter, is successfully retimed to become error free.

Experimental procedure

The experimental set-up is shown in Figure 1.

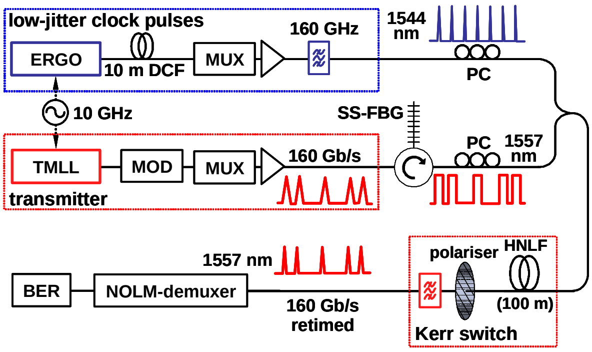

Figure 1. 160 Gb/s retiming set-up.

The heart of the set-up is the SSFBG and the Kerr switch. The SSFBG is used to shape the 160 Gb/s data pulses into ~5 ps rectangular pulses [2]. These are then aligned in polarisation so as to be attenuated in the Kerr switch. A short clock pulse then rotates the polarisation of the part of the rectangular data pulse that overlaps with the clock pulse, thereby allowing this part of the original data pulse to be transmitted through the polariser. This configuration ensures that the switched retimed pulse maintains its original wavelength, since it is actually part of the original data pulse. That is to say, the retimed pulses are *carved out* by the short clock pulses, which have low timing jitter, and hence, the retimed data pulses adopt the low jitter of the clock pulses. The clock pulse being narrower than the flat-topped signal generated by the SSFBG ensures that the switching is insensitive to mistiming in the data signal.

For the data signal, a 10 GHz semiconductor tuneable mode-locked laser (TMLL) is used – the wavelength is set to 1557 nm, the FWHM pulse width is 1.8 ps and the rms timing jitter is ~410 fs. These pulses are data modulated (MOD) with a 2^7-1 PRBS and subsequently multiplexed in a PRBS and polarisation maintaining fibre-based pulse-interleaving multiplexer (MUX). The data is amplified, injected into the SSFBG generating the rectangular pulses and, through a polarisation controller (PC), aligned at 90° to the Kerr switch polariser.

For the clock pulses, an Erbium-glass mode-locked laser (ERGO) with low rms timing jitter (~210 fs) is used – the wavelength is 1544 nm and the FWHM is 1.3 ps when linearly compressed in dispersion compensating fibre (DCF). The pulses are synchronised to the data pulses via the same synthesiser in this back-to-back set-up, and are multiplexed in an additional fibre-based polarisation maintaining multiplexer. The 160 GHz clean pulse train is amplified and filtered and its state of polarisation is aligned at 45° to the Kerr switch polariser.

The Kerr switch contains a 200 m HNLF with dispersion slope ~ 0.017 ps/nm^{2}km, zero dispersion at 1551 nm, and non-linear coefficient of $\gamma \sim 10.5$ W^{-1}km^{-1}. These fibre properties ensure negligible pulse-to-pulse walk-off and pulse broadening.

The 160 Gb/s retimed data pulses have adopted the clock FWHM and jitter (i.e. ~1.2 ps and ~250 fs, respectively). In order to perform BER characterisation, the retimed data signal is demultiplexed to 10 Gb/s in a non-linear optical loop mirror (NOLM) demultiplexer with a 50 m HNLF (slope 0.018 ps/nm^{2}km, zero dispersion wavelength at 1554 nm, $\gamma \sim 10.5$ W^{-1}km^{-1}).

Experimental results

Figure 2 shows the response of the SSFBG to the input pulse from the TMLL – in this case at 10 GHz.

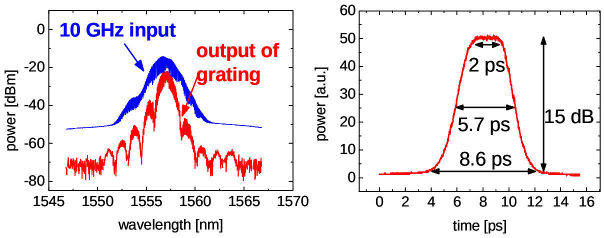

Figure 2. Grating characteristics. Input pulse FWHM ~ 1.8 ps.

The input spectral FWHM is ~2 nm, and the output spectrum is clearly sinc-like. Note that the slight spectral asymmetry originates from a corresponding slight asymmetry in the SSFBG spectral *response*. The FWHM of the measured temporal pulse is ~5.7 ps, though the flanks are not as steep as expected (due to the limited width of the input spectrum). The temporal width is measured with a cross-correlator with a 600 fs sampling pulse, so the de-convoluted trace has slightly steeper flanks. The flat top of the pulse extends over 2 ps, which is enough to eliminate most of the ~410 fs rms timing jitter of the data pulses.

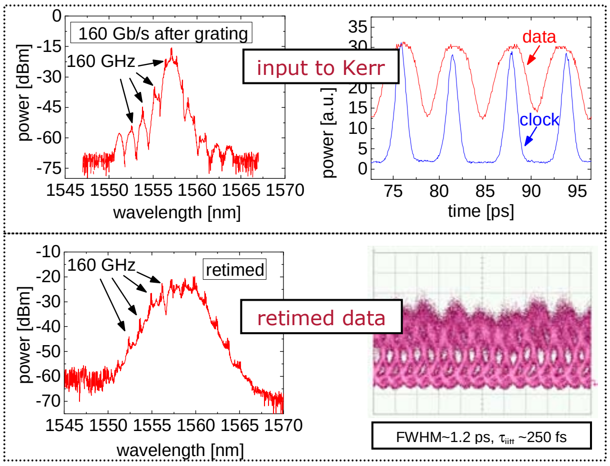

Figure 3. Switching results. Top: Input to Kerr switch – sinc'ed data pulses with ~5.7 ps FWHM and ~2 ps flat-top, and clock pulses with ~1.3 ps FWHM. Bottom: Output of Kerr switch, i.e. retimed data – FWHM ~1.2 ps, and timing jitter ~250 fs.

Figure 3 shows results before and after the retiming system at 160 Gb/s. The input to the Kerr switch is 1.3 ps clock pulses and 5.7 ps rectangular data pulses. The spectrum shows the 160 GHz tones on the sinc-like spectrum. The clock pulses are aligned to the nominal centre of the data pulses, and thus sample this part of the waveform. As only the central part of the data pulse is sampled, and the clock pulses are so short, the retimed pulses are only 1.2 ps wide, and the rms timing jitter is drastically reduced to ~250 fs (as measured at 40 Gb/s). Accordingly, the sampled data pulses have a broader spectrum but are still centred on the original wavelength.

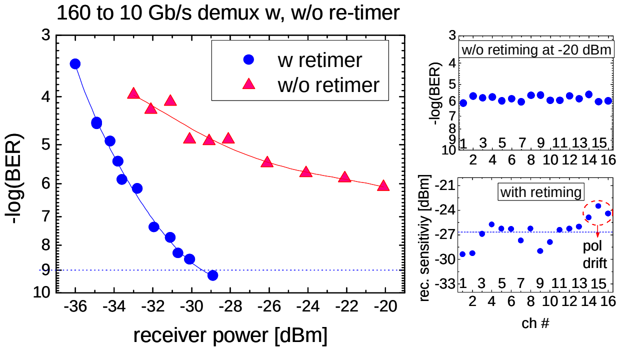

Figure 4. BER characteristics of all 16 channels.

Figure 4 shows the BER characteristics with and without retiming. All 16 channels are successfully retimed and error free operation is achieved for all of them. This is in sharp contrast to the case when retiming is not applied – in that case, the 410 fs rms jitter creates a severe error floor for all channels, and a BER of 1E-6 is the best that can be obtained (at the maximum receiver power, -20 dBm). This clearly reveals the benefit of the retimer. Among the retimed channels with an average sensitivity of -27 dBm, there is a 5 dB sensitivity spread, which is due to uneven multiplexed pulses in the data and clock arms, and to polarisation drifts in the used Kerr switch.

Conclusions

We have presented a retiming scheme and successfully demonstrated its use in a full 160 Gb/s experiment. The technique relies on linear pulse shaping in a SSFBG and subsequent sampling in a HNLF-based Kerr switch. The clock pulses used to gate the Kerr switch have low timing jitter, and this is adopted by the data signal, thus rendering the data signal error free, something which was not possible without the retiming.

Acknowledgements

To the Danish Research Council funded project Ultra-Net, and to the COST-291 programme.

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