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Pulse Source for 80 Gb/s Systems using a Gain-Switched Laser Diode followed by a Nonlinearly Chirped Grating

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SUMMARY

Picosecond pulse generation schemes are of vital importance in meeting the demands of increased bandwidth capacities, operating at line rates 40 Gb/s and beyond [1]. Return-to-Zero (RZ) coding is the more likely candidate to be used for data transmission, as it has many advantages over NRZ format, which include an inherent receiver sensitivity improvement [2] and less susceptibility to nonlinear and dispersion effects which lead to increased transmission distances [3]. Hence the design of an optical transmitter, capable of generating pulses with adequate temporal and spectral purity for acceptable operation in high-speed optical communication systems, is crucial. Gain-switching provides a very simple technique in the generation of picosecond pulses however the generated pulses have a large nonlinear frequency chirp across them. It has been reported how this chirp can be used to compress the pulses using dispersion compensating fibre [4] or linearly chirped gratings [5], to obtain near transform limited pulses. However, due to the chirp being non-linear across the pulse, this compression typically results in pedestals on either side of the pulses that make them unsuitable for use in practical communication systems.

This work, an improvement on previous work [6], presents the generation of 3.5 ps pulses at a repetition rate of 10 GHz and the optimization of the pulse spectrum. The output pulses are near transform limited and have pulse pedestals that are virtually eliminated to 35 dB down from the peak of the pulse, thus providing a source suitable for use in 80 Gb/s OTDM systems.

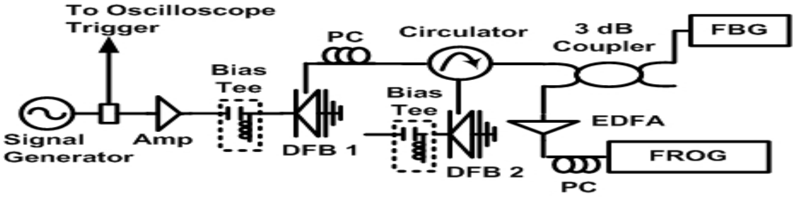

Figure 1: Experimental set up for the generation of compressed externally injected gain switched pulses

The experimental set-up employed in this work is shown in Fig. 1. A high-speed 1550 nm DFB laser diode is gain-switched (GS) at 10 GHz using a signal generator and a high power RF amplifier. To overcome the poor Side Mode Suppression Ratio (SMSR~15 dB) and timing jitter of the GS pulses, we use external injection from a second DFB (2) laser (via an optical circulator). A polarization controller was also used to ensure that the light being fed back was aligned with the optical axis of the laser. External injection improves the SMSR to around 30 dB and reduces the timing jitter to < 1 ps. The generated pulses were characterized using an OSA, a high-speed oscilloscope and a FROG measurement system [7]. From the latter, we can accurately characterize the intensity and chirp profile across the generated optical pulses (as shown in Fig. 2 (a)). We can clearly see how the frequency chirp becomes non-linear in the wings of the 10 ps pulse generated, due to the gain-switching mechanism and results in a TBP of 1.5.

We subsequently use the measured non-linear chirp across the pulse to design and fabricate a Nonlinearly Chirped Fibre Bragg Grating (NC FBG) with a chirp profile opposite to that measured across the pulse. The reflection and group delay profiles of the fabricated filter are shown in Fig. 3 (a). The reflection profile of the grating is made to ensure equalization in such a way that an optimized Gaussian spectrum is achieved. We also fabricated a linearly chirped fibre grating which had a chirp profile that was opposite to a linear approximation of the chirp across the GS pulse. Fig. 2 (b) and (c) show the measured intensity and chirp profile of the GS pulses after compression with the linearly and non-linearly chirped fibre gratings respectively. In both cases we can see that the gratings have eliminated any frequency chirp across the centre of the pulses. However, the linearly chirped grating results in significant pedestals on both sides of the pulse due to the nonlinearity of the input chirp. These pedestals, which are around 23 dB down from the peak of the pulse, would clearly pose significant problems (through inter-symbol interference) for the use of these pulses in high-speed OTDM systems. When the NC FBG is employed, the pedestals are virtually eliminated on both sides of the pulse to below 35 dB down from the peak. The resultant chirp is flat and has a very small order of magnitude across the pulse yielding a TBP of 0.45.

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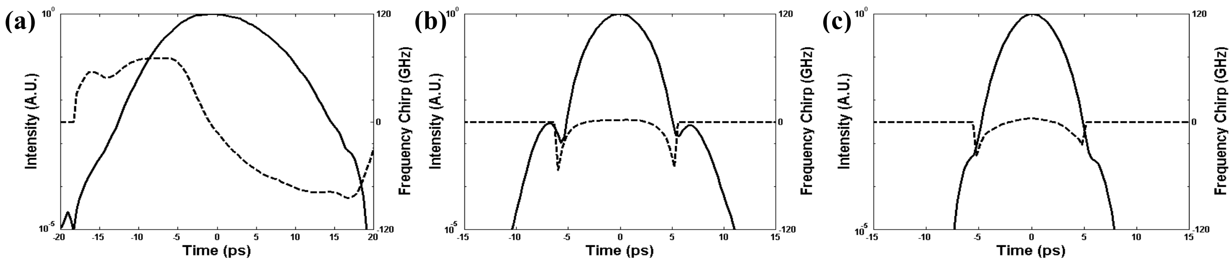

Figure 2: Intensity and chirp of pulses (a) from EI-GSL (b) after linearly chirped FBG and (c) after NC FBG

The spectra and group delay of the input and output pulses are shown in Fig. 3 (b). It is clear that the group delay has been entirely compensated for by the NC FBG. The output spectrum is more Gaussian shaped and symmetric in comparison to the input, which is due to the equalization by the nonlinear reflection profile of the NC FBG.

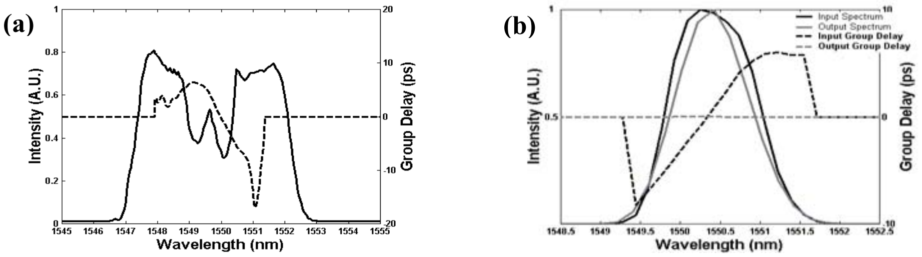

Figure 3: (a) Reflection and group delay of the NC FBG & (b) i/p and o/p spectra to the NC FBG & their corresponding group delays

The system penalties introduced by poor a Temporal Pedestal Suppression Ratio (TPSR) were characterized by carrying out simulations using Virtual Photonics Incorporated (VPI). Two 80 Gb/s OTDM systems were built, one based on linearly compressed 3.5 ps GS pulses and the other employing 3.5 ps transform limited gaussian pulses. The former exhibited a TPSR of ~25 dB due to the uncompensated non-linear chirp in the wings of the pulse (Fig 4 a). The latter on the other hand portrayed an excellent TPSR of over 40 dB (Fig. 4 b). A plot of the BER as a function of received optical power (Fig 4 c) shows that the system employing compressed GS pulses incurs a power penalty of ~ 9 dB (@ BER of 10^{-9}) in comparison to the system that uses transform-limited pulses.

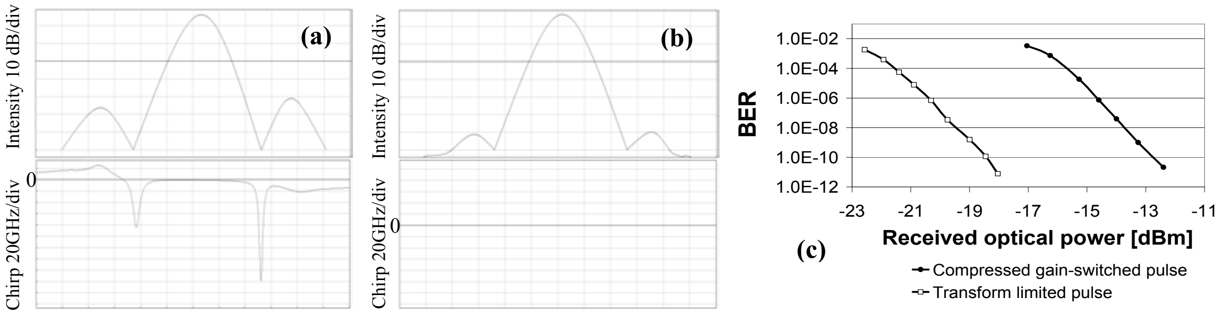

Figure 4: Intensity and chirp of (a) compressed gain switched pulses (b) transform limited pulses (c) BER vs received optical power

We have demonstrated the use of NC FBGs for ensuring a sufficient TPSR of the compressed GS pulses. The resulting 3.5 ps pulse source comprising of an Externally Injected-Gain Switched Laser (EI-GSL) followed by an NC FBG would be suitable for use in 80 Gbit/s transmission systems. The system viability, characterized by simulations, portrays a 9 dB difference in performance between a pulse source with insufficient TPSR and one that exhibits adequate TPSR (> 30 dB).

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