Complete Performance Analysis of a 3.5 ps Pulse Source Consisting of a Gain-Switched Laser Diode Followed by a Non-Linearly Chirped Grating

R. Maher, P.M. Anandarajah and L.P. Barry
Research Institute for Networks and Communications Engineering, Dublin City University, Dublin 9, Ireland
Author e-mail: robert.maher@eeng.dcu.ie

Abstract: The authors demonstrate the performance of an optimized gain-switched pulse source that generates 3.5ps pulses. The transform limited pulses perform excellently when employed in an 80Gb/s OTDM set-up and a 10Gb/s 40km transmission experiment.

OCIS codes: (060.0060) Fiber optics and optical communications; (060.5530) Pulse propagation and temporal solitons

1. Introduction

The continuous increase in demand for media-rich content delivery and the escalation in IP traffic have forced service providers to deploy greater optical backbone transmission capacity to satisfy forecasted demand on current photonic networks [1]. Terabit all-optical communications systems can be realised by reducing the channel spacing in Wavelength Division Multiplexed (WDM) systems or by increasing the per-channel data rate. The latter can be realised through Optical Time Division Multiplexing (OTDM) and implemented in hybrid WDM/OTDM systems. One of the key components for such OTDM systems is the development of a picosecond optical pulse source.

Amongst numerous pulse generation methods, gain-switching of a Distributed Feedback Laser (DFB) diode has proved to be one of the simplest and robust techniques [2]. The inherent simplicity of direct modulation reduces the cost and complexity of the transmitter, which proves to be of great practical significance with regard to market adoption. Although cost and simplicity are among the numerous advantages of this technique, it does suffer from drawbacks, with the generated pulses exhibiting a poor Side Mode Suppression Ratio (SMSR) and a relatively large temporal jitter. These shortcomings could be overcome however, by externally injecting into the laser diode [3].

In this paper, a complete performance analysis of our Externally Injected Gain-Switched (EIGS) pulse source incorporating a Non-Linearly Chirped Fiber Bragg Grating (NC FBG) is demonstrated. A detailed explanation of the source set-up and operation can be seen in [4]. We fully characterise the performance of the gain-switched pulses when employed in an 80 Gb/s OTDM test bed [5], and extend this investigation of system performance by confirming the temporal and spectral purity of the pulses in an optical transmission system consisting of 40 km of Single Mode Fibre (SMF). In both experiments the pulse source performs excellently by yielding error free operation. These results are then bench marked by employing a commercially available Tunable Mode Locked Laser (TMLL) in both the OTDM and transmission set-ups.

2. 80 Gb/s OTDM System

The experimental setup employed to realise the 80 Gb/s OTDM test-bed is illustrated in Fig. 1a. Three different pulse sources were used alternatively as the RZ transmitter block (as in Fig. 1a). In the first instance of system performance characterisation, the EIGS laser diode incorporating the NC FBG (3.5ps) was used, after which, it was replaced by the same EIGS laser diode with a Linearly Chirped FBG (3.6ps). Finally, the commercially available TMLL (2.1ps) was used mainly to act as a reference. Fig. 1b shows the temporal profile of the three pulse sources used in the experiment. The pulses were modulated with data at 10 Gb/s with the aid of a MZM, after which the they were passively multiplexed up to 80 Gb/s. The signal was then demultiplexed using an electroabsorption modulator (20 Gb/s) and an electrical demultiplexer (10 Gb/s). Signal analysis was carried out with an error detector and a high-speed oscilloscope. Fig. 1c illustrates the Bit Error Rate (BER) performance as a function of the received power (measured at the 20 Gb/s stage). It can be observed that to achieve a BER of $1e^{-9}$ a power penalty of 3.5 dB is incurred in the case of the LC FBG (w.r.t. NC FBG). The degraded performance is due to the presence of the pedestals about 20 dB below the peak of the pulse (due to the uncompensated non-linear chirp in the wings of the pulse), as shown in Fig. 1b. These pedestals worsen the extinction of the temporally multiplexed signal thereby leading to intensity fluctuations that causes the BER degradation. A power penalty of 0.5 dB was noticed in the case of the TMLL and the optimized gain-switched pulse source incorporating the NC FBG. This difference could be attributed to the narrower pulse width of the TMLL, providing better receiver sensitivity.

978-1-55752-859-9/08/$25.00 ©2008 IEEE

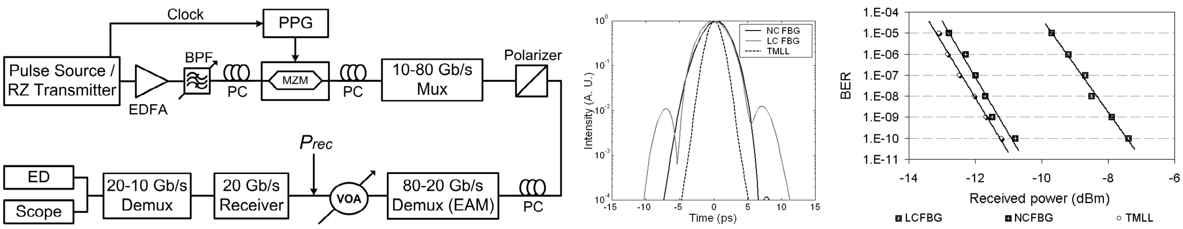

Fig.1. (a) 80 Gb/s OTDM test-bed, (b) temporal profile of transmitted pulses and (c) BER versus receiver sensitivity for three RZ transmitters

3. 10 Gb/s Transmission System

The experimental setup employed to realise the 10 Gb/s transmission test-bed is illustrated in Fig. 2a. As in the OTDM set-up (Fig. 1a), the gain-switched pulse source incorporating the NC FBG (λ_c: 1550nm) was initially tested in the transmission system, followed by the TMLL (λ_c: 1550nm). The 10 GHz pulses are modulated with a MZM before being transmitted through 40 km of standard Single Mode Fibre (SMF). The SMF has a dispersion parameter of 17.2 ps/nm.km at 1550 nm. A Dispersion Compensating Module (DCM) with a dispersion of -681 ps/nm was placed after the SMF in order to fully compensate for the chromatic dispersion experienced by the pulses after propagation. Pulse chirp measurements were recorded before and after the dispersion compensating module, using the Frequency Resolved Electro-Absorption Gating (FREAG) technique, to ensure that the pulse dispersion was correctly compensated.

BER measurements were recorded for a range of received optical powers with the aid of a variable optical attenuator and an in-line power meter (P_{rec} in Fig. 2a). Fig. 2b illustrates the BER versus receiver sensitivity power plots for each of the RZ transmitters. Initial back-to-back measurements are recorded to act as a reference, relative to the performance after the 40 km SMF transmission span. The back-to-back receiver sensitivities at a BER of $1e^{-9}$ for both the TMLL and the optimized gain-switched pulse were -22.38 dBm and -21.85 dBm respectfully. The gain-switched pulse source experienced a power penalty of 0.6 dB at a BER of $1e^{-9}$ after the transmission span with respect to its back-to-back case. A penalty of 0.5 dB is experienced with respect to the commercially available mode locked laser after both pulse sources have passed through the transmission path. The same variation in sensitivity between the two pulse sources is noticed here again and as stated in the 80 Gb/s OTDM set-up, is due to the minor difference in pulse width between the two sources. The excellent transmission performance of the gain-switched pulse source illustrates the spectral and temporal purity of the transform limited pulses.

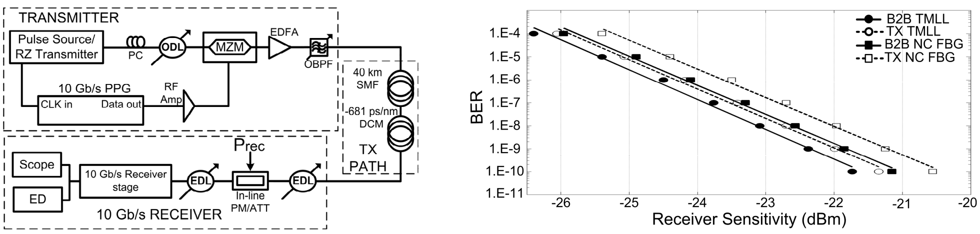

Fig.2. (a) 10 Gb/s transmission test-bed and (b) BER versus receiver sensitivity for both RZ transmitters

4. Conclusion

We have demonstrated the performance of an EIGS pulse source incorporating a NC FBG. Due to the temporal purity of the pulses (very low pedestals) the source performed excellently in an 80 Gb/s OTDM system, when compared to a commercially available TMLL. In addition, the spectral purity of the pulses (transform limited) allowed error free transmission over 40 km of SMF, with negligible penalty in comparison to the TMLL.

5. References

[1] E. Desurvire, "Optical Communications in 2025", ECOC 1, paper Mo2.1.3, 5-6 (2005).
[2] L.P. Barry, "Effect of side-mode suppression ratio on the performance of self-seeded optical pulses in lightwave communications systems", PTL 11, 1360-1362 (1999).
[3] A.M. Clarke, "Generation of widely tunable picosecond pulses with large SMSR by externally injecting a gain-switched dual laser source", PTL 16, 2344-2346 (2004).
[4] P.M. Anandarajah, "Optimized pulse source employing an externally injected gain-switched laser diode in conjunction with a non-linearly chirped grating", JSQE 12, 255-264 (2006).
[5] P.M. Anandarajah, "System-Performance Analysis of Optimized Gain-Switched Pulse Source Employed in 40- and 80-Gb/s OTDM Systems", JLT 25, 1495-1502 (2007).