Continuous Repetition Rate Tuning with Timing Window Independent Self-Seeding of a Gain-Switched Fabry-Perot Laser

P. Anandarajah, R. Maher and L.P. Barry
Research Institute for Networks and Communications Engineering (RINCE),
School of Electronic Engineering, Dublin City University, Ireland.

SUMMARY

The development of a source of picosecond optical pulses is of paramount importance for an increasing number of photonic applications, such as optical time division multiplexing (OTDM) or hybrid wavelength division multiplexing/OTDM systems [1]. One of the simplest and most reliable techniques of generating picosecond optical pulses involves gain-switching a Fabry-Perot (FP) semiconductor laser [2]. Gain-switching of FP lasers, as opposed to DFB lasers, is more attractive since these lasers are more cost efficient and they yield pulses with lower jitter [3]. However, a problem associated with employing FP lasers in such a gain-switched configuration is the multi-moded output that would lead to the pulses suffering from a large amount of dispersion when transmitted through standard single mode fibre (SSMF). External injection or self-seeding at an appropriate wavelength, into the gain-switched FP laser is a simple solution that could be used to achieve single moded pulse generation. By varying the injected wavelength to select out different modes, the FP laser could potentially be used as a source of wavelength tunable pulses [4]. Other advantages that light injection brings are an improvement in the pulse temporal jitter and a reduction in chirp.

Self-seeding of gain-switched lasers is a simple technique since it negates the need for an additional CW source by using a wavelength selective element placed in an external cavity. A small fraction of the output light, at a chosen wavelength, is re-injected into the gain-switched laser. However, to ensure optimum operation (pulses with reduced jitter and chirp and enhanced SMSR) the light must be re-injected into the laser cavity during the pulse build up time (within a given time window). This could be achieved in two ways namely: by tuning the repetition rate to a multiple of the inverse of the light roundtrip time in the cavity, or by using an optical delay line to change the external cavity length [5]. Such an imposition reduces the flexibility of the self-seeding technique, as a minor alteration in the cavity length would require tuning of the repetition rate or vice versa.

In this work, we propose a novel self-seeding technique that yields timing window independent operation allowing continuous repetition rate tuning of the self-seeded gain-switched (SSGS) laser. This is achieved by employing a highly linearly chirped fiber Bragg grating (LC FBG) as a wavelength selective element. The reflected gain-switched pulses are dispersed to such an extent, that temporal overlap occurs between them. This overlap creates a pseudo CW like signal that is re-injected into the gain-switched laser.

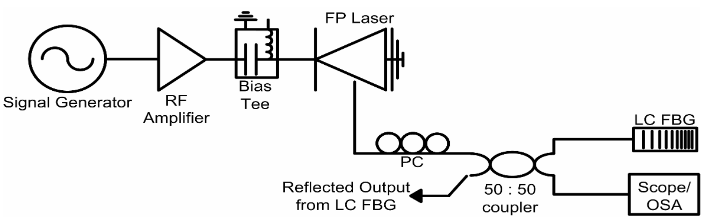

Figure 1: Experimental set-up

The FP laser used was a commercially available 1.5 µm InGaAsP device manufactured for use in 10 Gb/s systems, with a threshold current of 10 mA and a longitudinal mode spacing of 1.2 nm. The laser output power, at a bias of 50 mA, was measured to be 6 mW after being coupled via a GRIN lens fiber pigtail. Gain-switching of the FP laser was achieved by applying a DC bias of 50 mA in conjunction with a 28 dBm sinusoidal signal at a repetition rate of 10 GHz (using a bias tee). Self-seeding of the gain-switched laser diode was accomplished using an external cavity containing a polarization controller (PC), a 3 dB splitter and a LC FBG. As shown in Fig. 2, the LC FBG had a central wavelength of 1545.13 nm, with a 3 dB reflection bandwidth of 0.128 nm and a peak reflectivity of 85.1 %. The grating was 131 mm in length with a rejection ratio greater than 30 dB and portrayed a dispersion coefficient of 4957.8 ps/nm.

In order to achieve optimum SSGS pulse generation, the peak emission wavelength of the FP laser was temperature tuned to the corresponding reflection wavelength (1545.13 nm) of the grating. The SSGS pulses were characterized using an optical spectrum analyzer (OSA) and a high-speed photodetector in conjunction with a 50 GHz digitizing oscilloscope. The reflected pulses that are dispersed and fed back to the gain-switched laser were monitored at the second input arm of the 3 dB coupler (as shown in Fig. 1).

1-4244-0925-X/07/$25.00 ©2007 IEEE

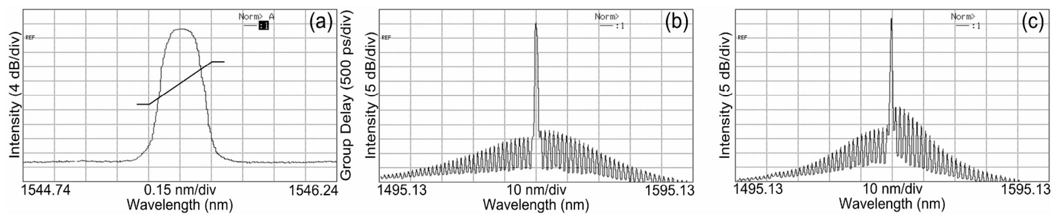

Figure 2: (a) Fibre Bragg grating reflection profile and group delay characteristic, and Single moded optical spectra at varied repetition rates of (b) 10 GHz (c) 2.5 GHz

The repetition rate was tuned from 10 GHz down to 2.5 GHz (500 MHz steps) in order to verify the timing window independence under self-seeding with the highly linearly chirped FBG. Fig. 2 (b) and (c) show the spectra of the SSGS pulses at two different repetition rates (10 and 2.5 GHz). These figures clearly illustrate the fact that the SSGS pulses still portray an acceptable SMSR of about 30 dB at each of the repetition rates. In all previous work carried out on self-seeding of gain-switched lasers, the repetition frequency or the cavity length was altered in order to keep within the limits of the feedback time window that ensures optimum pulse generation. Combined with a constant SMSR, the temporal duration of the gain-switched pulses remained almost constant over the entire repetition rate tuning range of 7.5 GHz. Fig. 3 (a) and (b) display the output SSGS pulses at repetition rates of 10 and 2.5 GHz. The measured widths (full width half maximum - FWHM) of the pulses at 10 and 2.5 GHz repetition rates were 30 and 31 ps respectively. The 3 dB spectral width was measured to be around 0.58 nm which when combined with a pulse width of 30 ps yields a time bandwidth product (TBP) of 2.2. Such a large TBP indicates that the pulses are heavily chirped. This chirp should enable the pulses to be compressed to durations less than 10 ps [6].

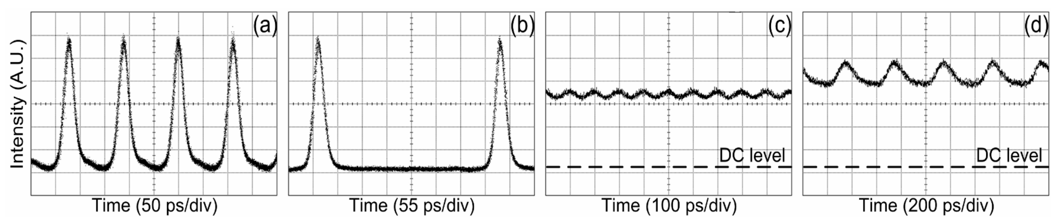

Figure 3: SSGS pulses at repetition rate of (a) 10 (b) 2.5 GHz, and Optical feedback from LCFBG (c) 10 (d) 2.5 GHz

Oscilloscope traces of the reflected (feedback) signal from the highly LC FBG at two different repetition rates of 10 and 2.5 GHz are shown in Fig. 3 (c) and (d) respectively. The high dispersion factor associated with the LC FBG used is responsible for the broadening of the pulses which causes temporal overlap between them. As can be seen in Fig. 3 (c & d), this overlap yields a CW like feedback into the gain-switched laser cavity. The degree of overlap between these dispersed pulses is much higher when the repetition rate is at 10 GHz rather than 2.5 GHz. This is essentially due to the 10 GHz period being much smaller (100 ps) than the 2.5 GHz period (400 ps).

The ripples in the CW feedback signal cause minor fluctuations in the width and SMSR of the output pulses. However, within the range of the repetition rates used (10 to 2.5 GHz), it is important to note that the SMSR is > 30 dB at all times and the pulse width is < 32 ps. This could be attributed to the feedback signal having sufficient CW power (adequate overlap due to broadening).

We have demonstrated a novel self-seeding technique that incorporates a linearly chirped fibre Bragg grating that disperses the output gain-switched pulses. The dispersed pulses provide a CW like feedback into the gain-switched laser cavity. This CW feedback, mimicking an external injection scenario, overcomes the limitation associated with the self-seeding technique. Hence, using the proposed method, we have the potential of continuously tuning the repetition rate and maintaining optimum pulse generation without tuning the cavity length. Experimental results obtained show that pulses exhibiting greater than 30 dB SMSR and less than 30 ps widths are generated over a wide range of modulating frequencies. Further development of this pulse source may be achieved by using a wavelength tunable grating, to achieve wavelength tunable pulse generation. The cost and footprint of such devices could also be reduced by integrating the FBG and FP laser.

References

1 T. Morioka et al., Electron. Lett., vol. 32, pp. 906-907, 1996.
2 L.P. Barry et al., IEEE Photon. Technol. Lett., vol. 5, pp. 1132-1134, 1993.
3 A. G. Weber et al., IEEE J. Quantum Electron., vol. 25, no. 2, pp. 441-446, 1992.
4. P. Anandarajah et al., IEEE Photon. Technol. Lett., vol. 16, no. 2, pp. 629-631, Feb. 2004.
5. S. Li et al., IEEE Photon. Technol. Lett., vol. 12, no. 11, pp. 1441-1443, 2000.
6. P.M. Anandarajah et al., IEEE J. of Selected Topics in Quantum Electron., vol. 12, no. 2, pp. 255-264, 2006.