Generation of Wavelength Tunable Optical Pulses with SMSR Exceeding 50 dB by Self-Seeding a Gain-Switched Source Containing Two FP Lasers

P. J. Maguire, P. Anandarajah, L.P. Barry and A. Kaszubowska
Research Institute for Networks and Communications Engineering, School of Electronic Engineering, Dublin City University, Dublin 9, Ireland. Phone: + 353 1 700 5883, Fax: + 353 1 700 5508, Email: liam.barry@dcu.ie

SUMMARY

The development of transform-limited optical pulse sources with broad wavelength tunability and short pulse widths is extremely important for use in future high-speed communication systems, especially in applications such as Wavelength Division Multiplexing (WDM), Optical Time Division Multiplexing (OTDM), Hybrid WDM/OTDM and soliton systems [1]. One of the simplest, and most reliable, techniques available to generate wavelength tunable, picosecond optical pulses involves the self-seeding of a gain-switched Fabry-Perot (FP) laser, and many experimental schemes have been reported [2-4]. Self-seeding entails the use of a wavelength selective external cavity to re-inject a small fraction of the output light back into the gain-switched laser at only one longitudinal mode frequency. Provided that the optical signal re-injected into the laser arrives during the build-up of an optical pulse in the FP laser, then a single-moded output pulse is obtained.

Recent reports have revealed wavelength tunable Self-Seeded Gain-Switched (SSGS) pulses with widths of about 90-130 ps and Side Mode Suppression Ratios (SMSR) of 32 dB that are tunable between 19 and 26 nm [5, 6]. Their tunability was limited by various factors such as the tunable range of the Fibre Bragg Grating (FBG). In this letter, we show the generation of shorter pulses (~ 20 ps) that exhibit SMSR's greater than 50 dB and wider tuning range (48.91 nm). Our technique is based on the self-seeding of a gain-switched source containing two FP lasers.

Figure 1 illustrates our experimental set up used. The FP lasers used were commercial 1.5 μm InGaAsP devices, with threshold currents of about 26 mA, and a longitudinal mode spacing of 1.12 nm. Gain-switching of both lasers was carried out by applying a DC bias current of 17 mA, and a sinusoidal modulation signal with a power of 29 dBm. The sinusoidal modulation signal had a frequency around 2.5 GHz. Self-seeding of the gain-switched lasers was achieved by using an external cavity containing a polarization controller (PC), a 3 dB coupler, a Tunable Bragg Grating (TBG) with a bandwidth of 0.23 nm and an Erbium Doped Fibre Amplifier (EDFA). The external cavity for self-seeding FP 2 also contained a tunable optical delay line to ensure simultaneous self-seeding of FP 1 and FP 2.

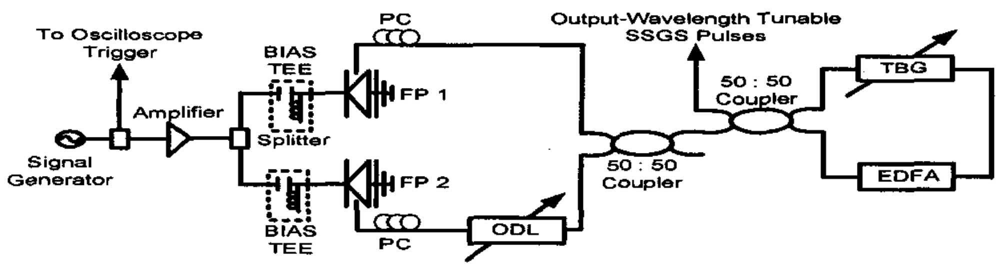

Figure 1: Experimental set up used for the generation of widely tunable SSGS pulses

To achieve optimum SSGS pulse generation, the grating was initially tuned to one of the longitudinal modes of the two gain-switched lasers. The frequency of the sinusoidal modulation was then varied to ensure that the signal re-injected into the laser, from the external cavity, arrives as an optical pulse is building up in the laser. An operating frequency of 2.498 GHz was found to be suitable. The bias current of FP 1 and FP 2 was also changed (reduced to about 12 mA) in order to obtain the minimum pulsewidth. The output pulses, from the return arm of the second 50:50 fiber coupler, were characterized in the temporal domain using a 50 GHz photodiode in conjunction with a 50 GHz HP digitizing oscilloscope. Pulse characterization in the spectral domain was carried out using an optical spectrum analyzer with a resolution of 0.07 nm.

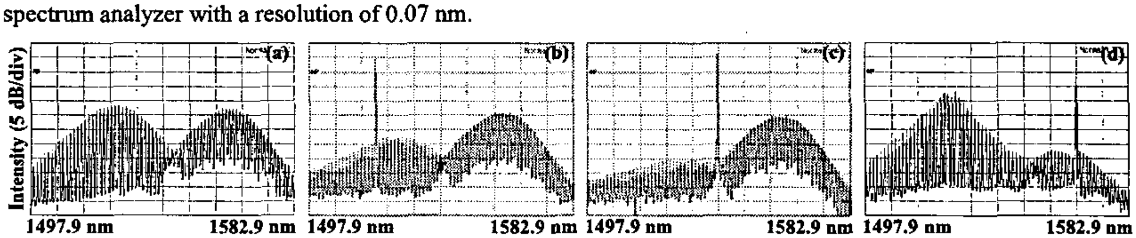

Figure 2: Optical spectra (a) Dual wavelength signal (b) 1517.73 nm (c) 1540.4 nm (d) 1566.6 nm

0-7803-7888-1/03/$17.00©2003 IEEE

The optical spectrum of the dual wavelength signal from the gain-switched lasers without self-seeding is shown in Figure 2 (a). Different longitudinal modes of each FP laser were selectively excited when the seeding wavelength was tuned near the centre of the desired mode. Figure 2 (b, c, & d) shows in respective order the shortest, central and longest wavelengths that could be seeded. The seeded spectra shown are the composite output of the two self-seeded gain-switched lasers before passing through the amplifier and optical filter. By taking the output pulses as the signal that is fed back into the lasers we thus pass this signal through the filter again, which greatly improves the SMSR of the generated optical pulses (as shown below in Fig. 3 (b) and (d)).

The output pulses, and their associated spectra, generated at two specific wavelengths (1524 and 1560 nm) are shown in Figure 3. The pulse duration and spectral width of the signal at 1524 nm are 16 ps and 27 GHz respectively, while for the 1560 nm pulse the temporal duration and spectral width are 18.5 ps and 26 GHz respectively. The measured pulsewidth remained almost constant right through the entire tuning range, with slight increases at the limits of tunability, and the time-bandwidth product of the generated pulses remains in the range 0.43 to 0.49 over the tuning range (which is close to that of a transform limited Gaussian pulses (0.44)). The main limitation on the tuning was imposed by the gain-bandwidth of the EDFA used in our experimental set-up. It is important to note that the spectra of the pulses after going through the filter for the second time, eliminates any effect from the unseeded laser while enhancing the SMSR of the seeded laser (generated pulses). We can thus achieve an SMSR greater than 50 dB for the generated optical pulses over the entire tuning range.

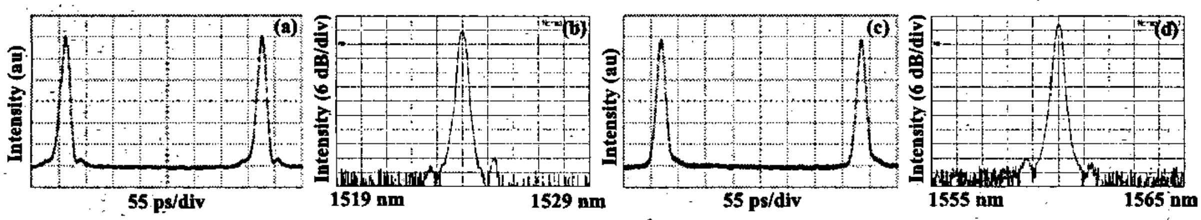

Figure 3: (a) SSGS Pulse FP 1 @ 1524 nm (b) Spectrum of pulse @1524 nm with SMSR of 54 dB (c) SSGS Pulse FP 2 @ 1560 nm (d) Spectrum of pulse @1560 nm with SMSR of 56 dB

The dependence of the SMSR on the seeding wavelength was plotted and is shown in figure 4. It can be clearly seen that we were able to obtain a SMSR of 50 dB and above within a range of 48.91 nm. Also shown in the same plot is the pulse width variation as the wavelength is tuned. The point where the pulse width increases slightly is the juncture when the seeded wavelength is moved from FP 1 to FP 2. As the seeding power was increased, due to higher pump powers from the EDFA, the achievable SMSR was enhanced and the possible tuning range became wider, however pulse deformation and instabilities were observed.

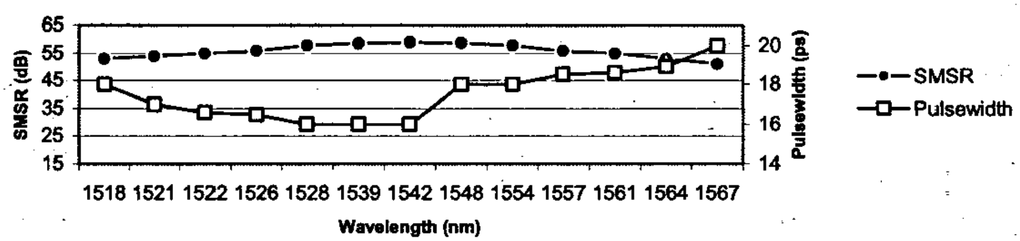

Figure 4: SMSR (left axis) and Deconvolved pulsewidth (right axis) against tunable range in wavelength

The generation of widely tunable (~ 50 nm) self-seeded gain switched short optical pulses that exhibit very high SMSR in the order of 50 dB has been demonstrated. Such pulses (widely tunable and high SMSR) play a vital part in ensuring the optimal performance of high-speed WDM/OTDM optical communication networks [7]. By using an integrated dual laser source it may be possible to develop a compact and highly stable tunable pulse source based on this technique.

[1] S. Kawanishi, *IEEE J. Quantum Electron.*, vol. 34, pp. 2064-2079, 1998.
[2] M. Cavelier et al, *Electron. Lett.*, vol. 28, pp. 224-226, 1992.
[3] L.P. Barry et al, *IEEE Photonics Technol. Lett.*, vol. 5, pp. 1132-1134, 1993.
[4] D. Huhse et al, *IEEE Photonics Technol. Lett.*, vol. 7, pp. 351-353, 1995.
[5] J. W. Chen et al, *Electron. Lett.*, Vol. 39, pp. 679–681, 2003.
[6] X. Fang et al, *IEEE Photon Technol. Lett.*, vol. 15, pp. 855-857, 2003.
[7] P. Anandarajah et al, *IEEE Photon Technol. Lett.*, vol. 14, pp. 1202-1204, 2002.