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Short Optical Pulses Generation by Gain Switching of a DFB Laser Diode

A. Nolasco Pinto [1,2], P. S. André [1,3], J. L. Pinto [1,3], F. da Rocha [1,2]

1 - Instituto de Telecomunicações - Pólo de Aveiro, Campus Universitário, 3810 Aveiro, Portugal

2 - Departamento de Electrónica e Telecomunicações da Universidade de Aveiro, Campus Universitário, 3810 Aveiro, Portugal

3 - Departamento de Física da Universidade de Aveiro, Campus Universitário, 3810 Aveiro, Portugal

Abstract

Direct current modulation of semiconductor lasers generally produces optical pulses which width is about the same as the applied current pulses. This technique can produce optical pulses as short as 100 ps by modulating the laser at 10 Gbit/s, but it becomes increasingly difficult to obtain shorter pulses because of the laser bandwidth and current pulses, shorter than 100 ps, are not readily available.

Soliton communication systems working in the range of 2.5-10 Gbit/s require shorter pulses. In this work we generate optical pulses suitable for soliton systems with repetition rate as high as 10 Gbit/s by optical gain switching of a DFB semiconductor laser cavity.

I. INTRODUCTION

Gain switching consists of changing the semiconductor optical cavity gain rapidly from a low to a high value. The laser is bias in a way that the modulation current changes the injection current from a value well below threshold to a value well above threshold. When the injection current is bellow threshold the carriers and photons density is small, when the current is switched to a value above threshold the carriers density increases rapidly, while the photons density remains small until the stimulated emission process becomes dominant. At that point, the optical gain in the cavity is very high making the photons density to increase rapidly [1], this saturates the cavity gain and originates the first relaxation frequency peak. If the duration of the injection current pulse is chosen such that the current is turned off before the second relaxation frequency peak, the output consists of a short optical pulse.

II. EXPERIMENTAL RESULTS

By operating the laser on a non-linear regime of gain switching, it is possible to obtain very short optical pulses, suitable for high-speed lightwave telecommunication systems, from a quasi-sinusoidal modulation current. In these operation regime the small signal laser model, cannot be used and we have to solve numerically the rate equations to obtain the optical power and the phase of the electrical field at the laser output [2].

Defining the modulation index as the ratio of the modulation current and the difference between the bias and the threshold current, we can obtain different pulses width just by adjusting the bias current. In figures 1 - 4 we can see the experimental and simulated pulses for different modulation indexes.

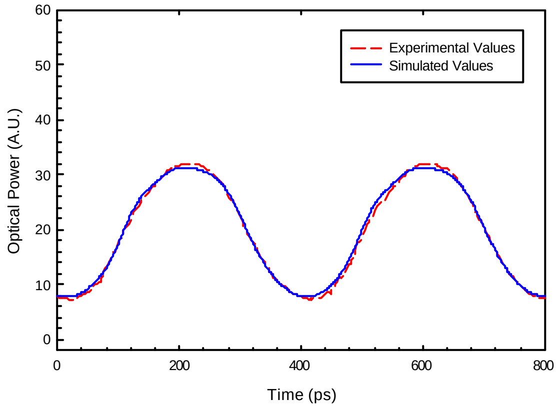

Fig. 1 Experimental and simulated optical pulses for a modulation index of 0.87

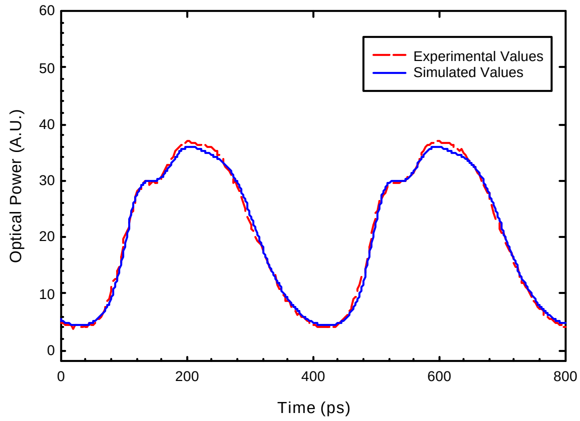

Fig. 2 Experimental and simulated optical pulses for a modulation index of 1.1

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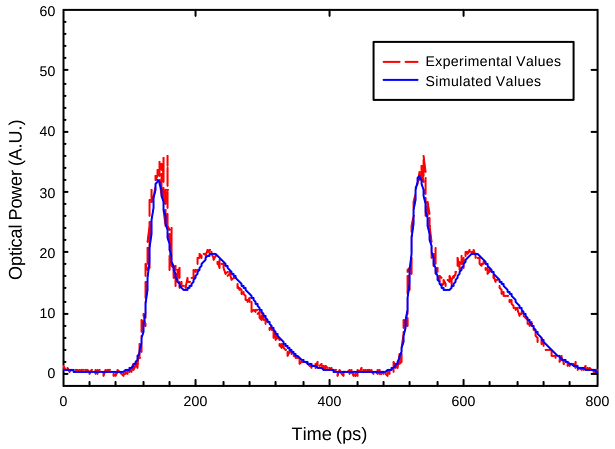

Fig. 3 Experimental and simulated optical pulses for a modulation index of 1.5

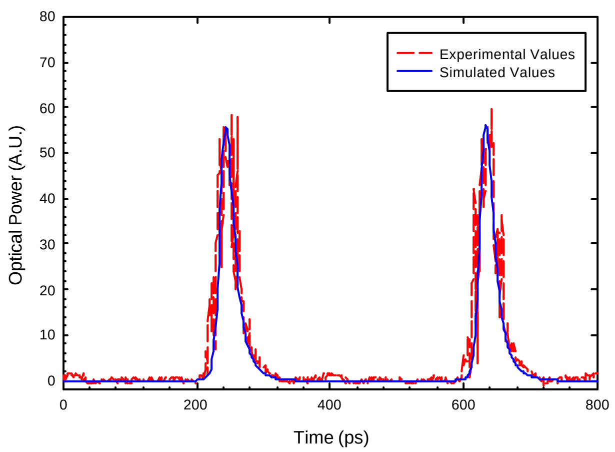

Fig. 4 Experimental and simulated optical pulses for a modulation index of 6.6

A shortcoming of the gain switching method is that optical pulses are considerably chirped. The chirp is intrinsic to the process of direct modulation of a semiconductor laser and is due to the change in the refractive index of the laser cavity. The optical frequency chirp produces a considerable broadening in the pulse spectrum that is translated into a time broadening after fiber propagation due to the chromatic dispersion. For a 20 ps soliton width we should expect a spectrum width of about 11 GHz, around the laser central frequency. However, as we can see in figure 5, we measured in the laboratory a spectrum width of about 34 GHz, for the pulse show on figure 4. Besides that for a chirp free soliton we should expect a symmetric secant hyperbolic spectrum shape. The spectrum presented in figure 5 is far way from a symmetric spectrum and we clearly see the broadening of the left side due to the frequency chirp.

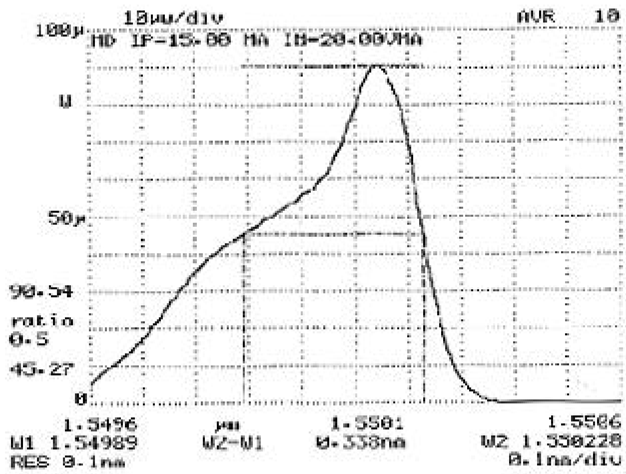

Fig. 5 Optical spectrum for a 20 ps generated pulse

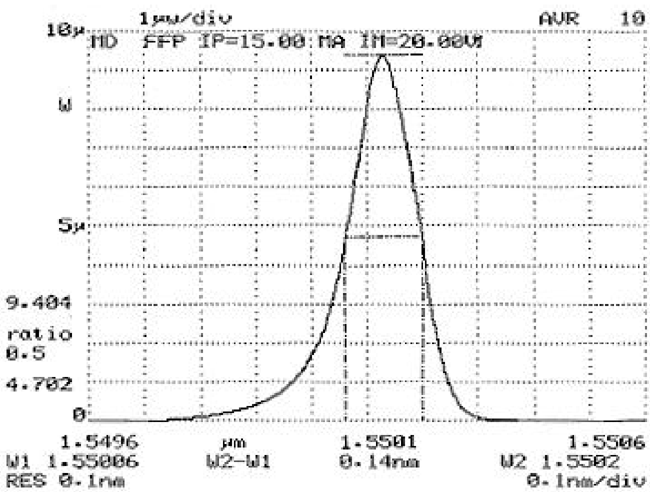

Fig. 6 Optical spectrum for a 20 ps generated pulse, filterd with a Fabry-Perot filter.

In order to reduce the frequency chirp we try to filter the pulse width a narrow optical filter.

We use a Fabry-Perot filter with a bandwidth of 0.16 nm, and as we can see in figure 6, the filter reduces considerably (by a factor of 2) the pulse spectrum. The optical filter also produces same effect in the pulse time domain. However, this effect is small, as we can see in figure7.

We measured a pulse width after the filter of about 23 ps, which is suitable for a 10 Gbit/s soliton system.

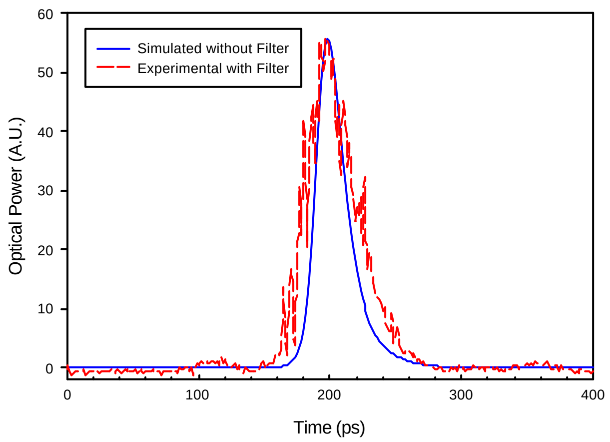

Fig. 7 Pulse width with and without optical filter

III. CONCLUSIONS

In this work we have shown that by gain switching is possible to generate short optical pulses suitable for using in soliton communication systems with bit-rates as high as 10 Gbit/s. We also have shown that by optical filtering the pulses we can reduce considerably the frequency chirp, keeping the pulse width as short as 23 ps.

We can see good agreement between the simulated results and the measurements obtained in the lab. The shorter pulses obtained in figure 7, are to be used in a soliton telecommunication system working at 10 Gbit/s.

IV. REFERENCES

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