Numerical Analysis of Pulse Pedestal and Dynamic Chirp Formation on Picosecond Modelocked Laser Pulses after Propagation through a Semiconductor Optical Amplifier

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***Abstract*-A numerical analysis, based on a modified Schrödinger equation, of the formation of pulse pedestals and dynamic chirp formation on picosecond pulses after propagation through a semiconductor optical amplifier is presented. The numerical predictions are confirmed by an experiment that utilises the frequency resolved optical gating technique for the amplified pulse characterisation.**

I. INTRODUCTION

*Semiconductor Optical Amplifiers (SOAs) are attracting much interest in applications in all-optical signal processing such as clock recovery and optical time division demultiplexing. In such applications SOAs are used to amplify high-energy optical pulses with pulse widths of the order of picoseconds. Common optical pulse sources used in ultrafast optical communications include modelocked lasers, gain-switched lasers, and CW lasers followed by electro-absorption modulators. These sources can all generate high quality pulses that exhibit low chirp and jitter and high temporal and spectral purity. It is necessary to investigate the propagation of optical pulses originating from different optical sources though SOAs. This paper presents numerical simulations and experimental results on the propagation of 2 ps pulses, generated by a modelocked laser source, through an SOA. The experimental characterisation of the optical pulses is carried out using the Frequency Resolved Optical Gating (FROG) technique and the numerical analysis is based on a modified Schrödinger equation (MSE) [1-3].

II. EXPERIMENT

The experimental setup is shown in Fig. 1 where 5 ps optical pulses are generated using a commercial mode-locked laser (Gigatera). The pulses are compressed to 2 ps using dispersion compensating fiber (DCF) and injected into an SOA (tensile-strained bulk material). The output pulses from the SOA are analysed by the FROG technique. The resulting temporal profiles of the input and output pulse from the SOA are shown in Fig. 2. The output pulse width increases to 4.2 ps. There is also a very large increase in the pedestals on the leading and trailing edges of the pulse, which increases as the input pulse peak power increases. The increase in the pedestal power can cause significant interchannel crosstalk in optical time division multiplexed systems.

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III. NUMERICAL ANALYSIS

A numerical analysis of the pulse propagation in the SOA was carried out using the MSE given by

$$\frac{\partial V(z,\tau)}{\partial z} = \left[\frac{1}{2} g_N(\tau,\omega_0)(1+i\alpha_N) + \frac{1}{2}\Delta g_T(\tau,\omega_0)(1+i\alpha_T) - \frac{i}{2}\frac{\partial g(\tau,\omega)}{\partial \omega}\bigg|_{\omega_0}\frac{\partial}{\partial \tau} - \frac{1}{4}\frac{\partial^2 g(\tau,\omega)}{\partial^2 \omega}\bigg|_{\omega_0}\frac{\partial^2}{\partial \tau^2} - \frac{\gamma}{2} - \left(\frac{\gamma_2}{2}+ib_2\right)|V(z,\tau)|^2 \right] V(z,\tau)$$

$V(z,\tau)$ is the time-domain complex envelope of the optical pulse, z is the propagation direction and τ is the local time of the pulse. The terms on the right hand side of the equation represent carrier density induced non-linearly saturating gain and self-phase modulation, non-linear gain and phase modulation due to carrier heating (via stimulated emission, free carrier absorption and two-photon absorption), gain spectrum slope and curvature, the material loss coefficient, two photon absorption and the non-linear Kerr effect. The various constants in the equation are a measure of the strength of the processes in the SOA contributing to the evolution of the pulse temporal and spectral characteristics. The MSE is solved numerically using the efficient split-step Fourier method. The input pulse is modelled as a linearly chirped main high-power $sech^2$ shaped pulse with $sech^2$ shaped leading and trailing pedestals with power less than the FROG sensitivity. Fig. 3 shows the predicted output pulse temporal profile, which shows reasonably good agreement with the measured profile of Fig. 2. The enhanced pulse pedestals in the experimental results are partly due to the pulse retrieval algorithm used in the FROG technique. The model is useful in designing all-optical processing subsystems based on SOAs. Further results including analysis of the output pulse chirp and spectrum, and a description of the numerical algorithm will be presented at the conference.

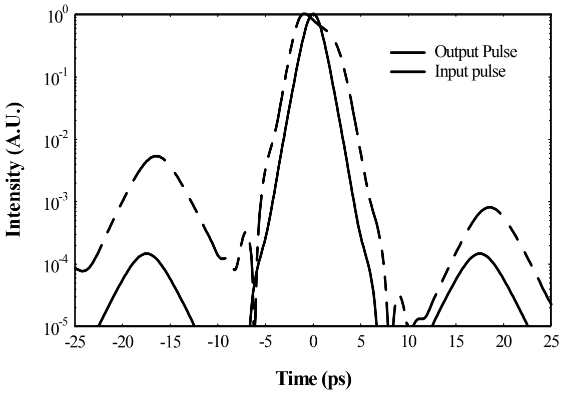

Fig. 3: Assumed input pulse and modelled output pulse temporal profiles.

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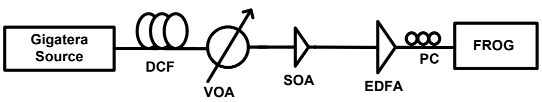

Fig. 1: Experimental setup. DCF: dispersion compensating fibre, VOA: variable optical attenuator, PC: polarisation controller.

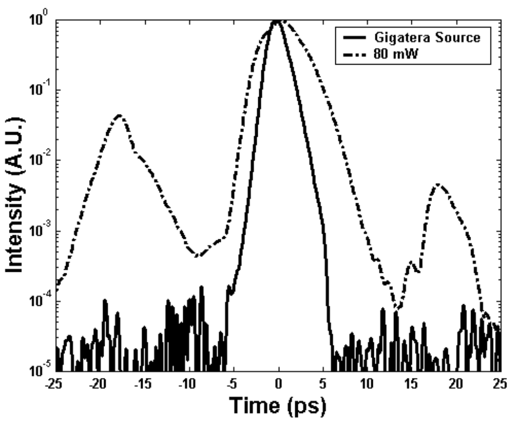

Fig. 2: Temporal profiles of the input pulse and output pulse from the SOA.