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A Fast Time Domain Travelling Wave method for simulation of Quantum Dot Lasers and Amplifiers / Gioannini, Mariangela; Bardella, Paolo; Montrosset, Ivo. - ELETTRONICO. - (2013), p. CB_3.2 MON. (Intervento presentato al convegno Conference on Lasers and Electro-optics, CLEO EUROPE 2013 tenutosi a Munich (Germany) nel 12th-16th May,2013).

Availability:
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19 April 2024

A Fast Time Domain Travelling Wave method for simulation of Quantum Dot Lasers and Amplifiers

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The Time Domain Travelling Wave (TDTW) model has been applied to a large number of Quantum Well lasers with complex multi-section structure. Even for the Quantum Dot lasers and amplifiers, the TDTW approach reveals to be a very powerful tool, because it can be used to reproduce with good accuracy several experiments performed in the lab (eg: pump-probe experiments in SOA [1]) or to simulate and interpret the performance of various QD lasers [2,3]. However, when we move to the QD case and we need to include peculiar properties of the QDs (e.g: wide emission spectrum due to ground and excited states emission, multi-population rate equation, phase dynamics…) the TDTW tool becomes practically useless because it requires huge simulation times (see Fig.1). This simulation time is unacceptable particularly when we need to run large number of simulations planned to reproduce for example several different characteristics of the same device (ie: optical emission spectra, power versus current characteristics, small and large signal modulation with electrical or external optical signals etc…) or when we need to design or optimize a new device.

We have developed a Fast TDTW simulator applying, for the first time to the QD case, the method proposed in [4] for the QW lasers. In the standard TDTW approach we must guarantee the constrain $\Delta z = v_g\,\Delta t$ between the spatial and temporal discretization intervals. If Δt must be small (less than 100fs) the number of longitudinal spatial nodes becomes too large. The fast method proposed in [5] consists in reducing of an integer factor M the number of longitudinal grid points ($\Delta z = v_g\,\Delta t \cdot M$) while keeping the same time sampling Δt. We demonstrate that the method can be applied also to the QD case. In Fig. 1 we present the comparison between the standard TDTW approach [2,3] and the new fast approach simulating the propagation of one narrow high power pulse in a 4 mm long QD-SOA. As shown, using a factor M=30 the error on the pulse shape is negligible respect to the reference solution and the error on the small signal chip gain is about 0.7%. As two examples of application of the simulator, we show in Fig.2 the calculated emission spectra of the QD-SOA (including comparison with experimental results) and in Fig. 3 the results of the simulation of the output from a 1 mm long single section QD-FP laser after optical fibre compensation [5]. These two examples where chosen as representative of the need of a fast simulation tool. In the QD-SOA case the simulation of the wide ASE bandwidth (160nm) requires indeed a very small time step (<10fs) necessary to avoid numerical aliasing effects in the solution. The simulation of the QD-FP mode-locked laser requires again a small time step to simulate correctly the FP bandwidth as well as a long simulation time window to assure that the pulses have formed and reached a stationary behaviour. Further details on the two application examples will be given at the conference.

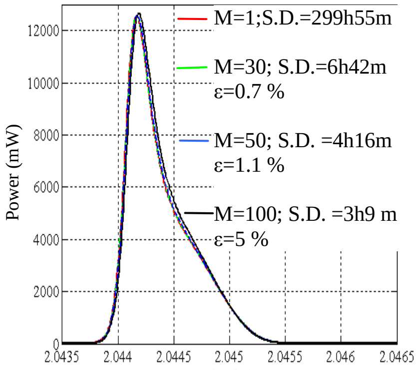

Fig. 1 SOA output pulse calculated for different M; S.D. is the simulation duration on 2 Xeon CPUs at 2.5GHz; ε is the error on the small signal chip gain.

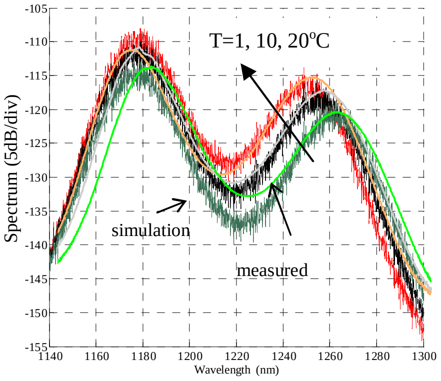

Fig. 2 Calculated (M=30) and measured SOA spectra with 1A current injection at different temperatures.

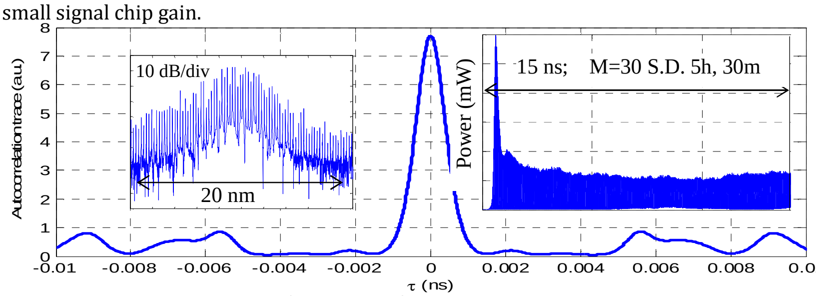

Fig. 3: Autocorrelation trace of the pulses after group delay compensation. Inset: power versus time (right) and optical spectrum (left) out of the FP laser.

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