A Fast Time Domain Travelling Wave simulator for Quantum Dot Lasers and Amplifiers

Mariangela Gioannini, Paolo Bardella, Ivo Montrosset

Department of Electronics and Telecommunication, Politecnico di Torino, Corso Duca degli Abruzzi, 24, 10129, Torino,Italy

Email: mariangela.gioannini@polito.it

Quantum Dot edge emitting lasers and amplifiers are well accepted as interesting devices for the realization of various kinds of lasers (lasers in mode-locking for ultra-short pulse generation, THz sources …). These lasers have often a complicate multi-section structure including for example a saturable-absorber and gain sections, gratings etc… For simulating complex multi-section lasers the Time Domain Travelling Wave (TDTW) has been applied to lasers based on Quantum Well technology. However, moving to the QD case and including peculiar properties of the QDs, the TDTW tool becomes practically useless because it requires huge simulation time (hundreds of ours). This long time is unacceptable when we need to run a large number of simulations planned to reproduce and understand the several measured characteristics of the same device (ie: optical emission spectra, L-I characteristics, small and large signal modulation with electrical or external optical signals etc…) or when we need to design and optimize new devices. In our Fast TDTW tool we have focused both on the correctness of the representation of the QD physics and on the computational speed. To correctly simulate the QD material we have used a multi-population rate approach with separate equations for electron and hole dynamics, we account for the interplay between homogeneous and inhomogeneous broadening including the polarisation dynamics and we can study the phase and chirp dynamics without the inclusion of the α-parameter (the simulator can indeed be used to reproduce measurements from where an equivalent α is extracted). In order to speed up the simulation time we have applied the fast method proposed in [1] to the QD case. The fast approach consists in reducing of a factor M the number of longitudinal grid points ($\Delta z = v_g\, \Delta t{\cdot}M$) whereas keeping the same time sampling Δt. In our contribution we demonstrate that the method can be applied successfully to the QD case and then we will provide several examples of application. In Fig. 1a we present the comparison between the standard TDTW approach (M=1) and the new fast approach simulating the propagation of one narrow high power pulse in a 4 mm long QD-SOA. The QD-SOA is chosen as a test device, because it allows focusing only on the effect of propagation of the signal without including the effect of multiple round trips as in the laser case. In the same figure we also present a summary of the simulation results obtained applying the program to the analysis of various devices.

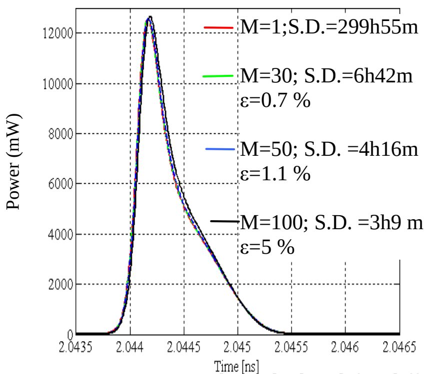

Fig.1a SOA output pulse calculated for different M; S.D. is the simulation duration on 2 Xeon CPUs at 2.5GHz; ε is the error on the small signal chip gain.

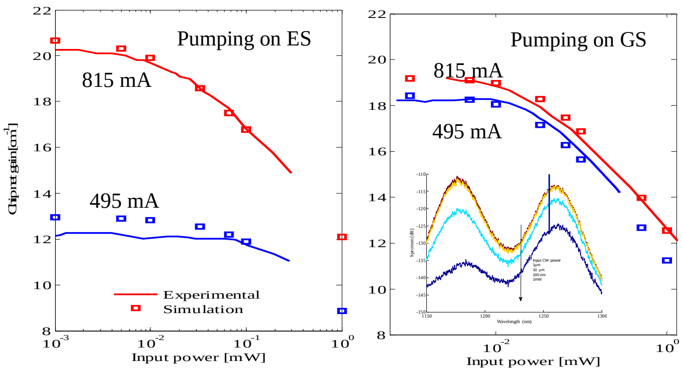

Fig. 1b: Simulation of chip gain of a QD-SOA and comparison with experiments. Inset: calculated optical output spectra when pumping on GS.

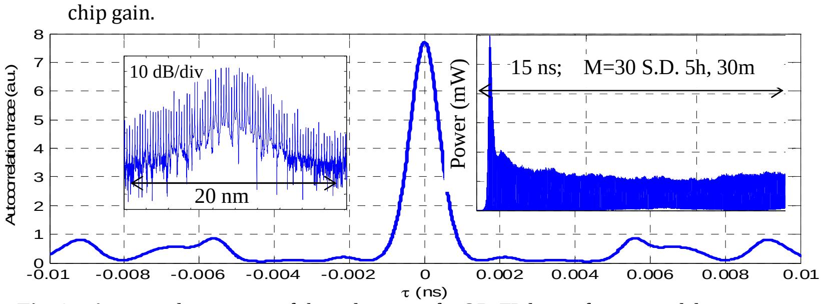

Fig. 1c: Autocorrelation trace of the pulses out of a QD-FP laser after group delay compensation with optical fiber [2]. Inset: power versus time (right) and optical spectrum (left) out of the FP laser.

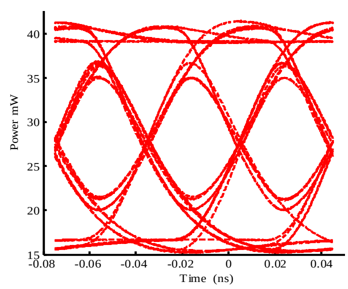

Fig. 1d: eye diagram of QD-DFB laser modulated at 25Gb/s equal to 2.8 time maximum modulation bandwidth of 9GHz

[1] J.Javaloyes, et al, ," *Opt. Express* **20**, 8496-8502 (2012). [2] Rosales,R et al. *Applied Physics Letters*,**101**,.221113-221113-3, 2012.
[3] D. Gready et al. « On the relationship between small and large signal modulation capabilities in highly nonlinear quantum dot lasers» », submitted to APL