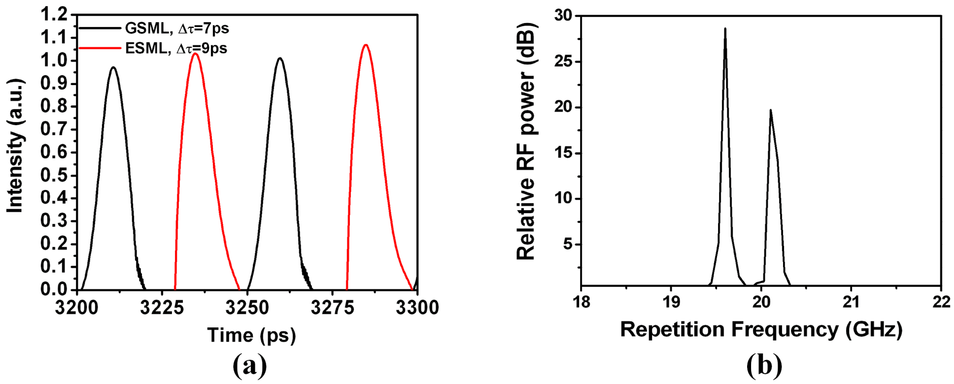

Fig. 5. (a) Time traces for pulses generated from simultaneous GS-ES mode-locking and (b) the corresponding simulated RF spectrum.

In agreement with the experiments, a region with stable dual-wavelength mode-locking occurs at a relatively narrow current range ($I_G = 3.4I_{th} - 3.7I_{th}$) and for bias voltages higher than 7 V. The calculated pulse time traces of this regime are shown in Fig. 5. The GS and ES pulses are shifted to each other in accordance with out-of-phase dynamics between the two states. This effect can be attributed to the asymmetric power exchange during capture/escape carrier transitions which result to nonlinear amplitude-phase coupling [15]. The generated pulses from the stable dual-wavelength mode-locked operation are broadened [Fig. 5(a)] for both GS ($\Delta\tau = 6.5$ ps) and ES pulse ($\Delta\tau = 9$ ps) compared to the GS-ML, due to the high gain current value needed for the appearance of lasing from the ES. The relatively narrow regime of dual-wavelength mode-locked operation can be attributed to the dynamics between the two competitive states due to the carrier intraband capture/escape process between them, giving rise to instabilities. At gain currents beyond $3.8I_{th}$, ES-ML is observed while at even higher current values (i.e. $I > 4.2I_{th}$) ES-CW is observed. In both cases emission from GS is suppressed.

The theoretical computations are in good qualitative agreement with the experimental results. The main trends of the experimental mapping are clearly reproduced by the model. Some differences exist in transitions between distinct operating regions where generally unstable operation occurs. In these regions, the model shows quasi-CW operation with fast fluctuations of the output power, condition that cannot be experimentally observed.

5. Conclusion

In this paper we report the first experimental and theoretical investigation of a dual-wavelength passive mode-locking regime where pulses are generated from both ES (λ = 1180nm) and GS (λ = 1263nm), in a two-section GaAs-based QD laser. The spectral separation (83nm) is the widest ever observed in a dual-wavelength mode-locked non-vibronic laser. Additionally, numerical simulations are presented by means of a theoretical model based on the delay differential equation approximation, which reproduce the dual-wavelength mode-locking regime. The exploitation of this mode-locked regime could enable a range of applications extending from time-domain spectroscopy, through to optical interconnects, wavelength-division multiplexing and ultrafast optical processing.

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