Coherent multi-mode dynamics of Terahertz Quantum Cascade Lasers in Fabry-Perot configuration

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Optical frequency combs (OFCs) are coherent regimes defined as set of equally spaced optical lines with low phase and amplitude noise. The experimental demonstration that quantum cascade lasers (QCLs) can spontaneously emit OFCs has brought to a rapid development of the study about the multimode dynamics of these devices, with possible applications in metrology, free space communication and high-resolution spectroscopy [1]. Here we present a numerical investigation concerning the multi-mode dynamics of a Terahertz QCL in Fabry-Perot configuration. For this purpose, we adopt the theoretical model of Effective Semiconductor Maxwell-Bloch Equations, which self-consistently includes the main characteristics of semiconductor materials, such as the dependence of the optical susceptibility on the density of carriers, the presence of the linewidth enhancement factor, and accounts for a carrier grating due to spatial hole burning [2]. Our simulation results correctly reproduce the main experimental observations [3], such as the self-generation of both fundamental OFCs (Fig. 1a) and harmonic frequency combs (Fig. 1b), the alternation of these coherent regimes with unlocked states, and the recently observed pulsations of carriers [4].

[1] J. Faist et al., Nanophotonics **5**, 272-291 (2016).

[2] C. Silvestri et al., Opt. Express **16**, 23846-23861 (2020).

[3] C. Silvestri et al., arXiv:2208.06156v1 (2022).

[4] H. Li et al., Opt. Express **30**, 3215-3229 (2022).

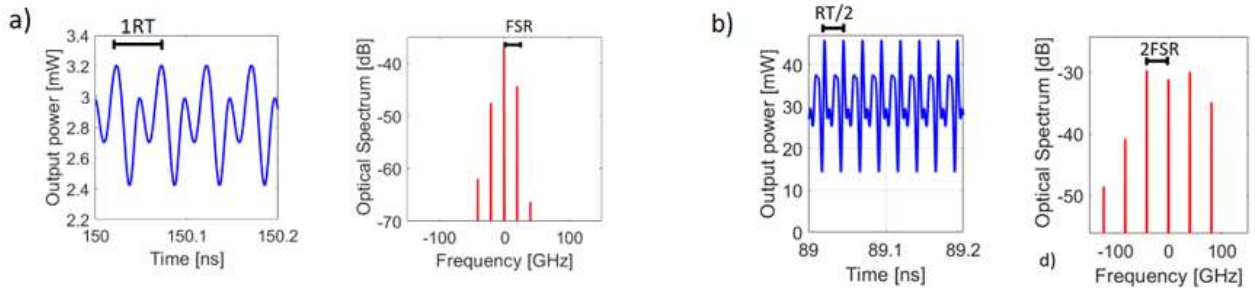

Figure 1: Simulated fundamental (a) and harmonic (b) frequency combs: temporal evolution of the power (left) and optical spectrum (right). FSR: free-spectral range of the laser cavity; RT: roundtrip time in the laser cavity.