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X International School and Conference on Photonics

25 - 29 August 2025

Belgrade, Serbia

Editors

Mihailo Rabasović, Uroš Ralević, Marina Lekić, Aleksandar Krmpot
Institute of Physics Belgrade, Serbia

Belgrade, 2025

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of

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Modelling of Terahertz Quantum Cascade Laser Self-Mixing Dynamics

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Quantum cascade lasers operating at terahertz frequencies (THz QCLs) [1, 2] emit in the traditionally hard-to-reach far-infrared part of the spectrum, which has enabled their growing use in fields such as medical diagnostics, chemical detection, and imaging. In this work, we use a theoretical model developed in [3] based on the effective semiconductor Maxwell–Bloch equations (ESMBEs) [4] to study the dynamics of a THz QCL in a Fabry–Perot (FP) configuration. The model incorporates the key features of the semiconductor active medium, such as asymmetric, frequency-dependent gain and refractive index, as well as phase–amplitude coupling described by the linewidth enhancement factor. This approach accounts for standing wave formation in the resonator, resulting in spatial hole burning. We study the self-mixing dynamics of an experimentaly grown GaAs/AlGaAs bound to continuum THz QCL designed for emission at 2.0 THz [5] using transport parameters calculated via the density matrix model. The simulation results show that adding external feedback for a QCL operating at the threshold current density leads to the spectrum of the emitted light changing from a single-mode to a multimode regime as well as a significant increase in both the average output power and steady-state time. The model predicts high sensitivity of the QCL output power to changes in the external resonator length. For numerical calculation of the ESMBEs we use the finite difference method to discretize the variables both in time and space and solve in a travelling wave manner.

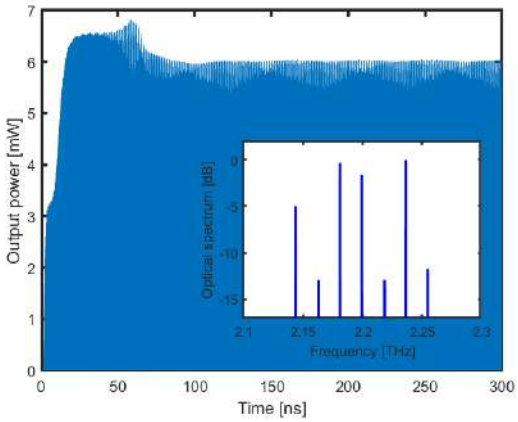

Figure 1. Output power waveform at threshold current for a QCL with external feedback. The inset shows the optical spectrum of the emitted light where the QCL is emitting in a multimode regime.

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