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Anisotropy of dielectric permittivity in optical gain modelling of MIR quantum cascade lasers

Nikola Vuković[1], Jelena Radovanović[1], Vitomir Milanović[1]

(1) *University of Belgrade, School of Electrical Engineering, Bulevar kralja Aleksandra 73, 11120 Serbia*

Contact: N. Vuković (nvukovic@etf.bg.ac.rs)

Abstract. An enhanced numerical model for calculation of population densities and optical gain in quantum cascade laser (QCL) [1] that takes into account anisotropy of dielectric permittivity [2] of the layered quantum-well based structure is presented. Our results indicate that the layering induced anisotropy leads to significant changes in electron-longitudinal (LO) phonon scattering rates [3] on account of the existence of additional resonant frequencies for LO phonons, each altering the total scattering rate between the relevant subbands. Namely, instead of taking LO phonon frequency as a constant [4], we have included dependence on phonon wavevector in the vicinity of the LO phonon modes: one dependence originates from the material system that is used and the others on the transition energies of the structure's active region. Subsequently, carrier distribution between the subbands and the degree of population inversion in the mid-infrared QCL active region are substantially changed in comparison to the predictions of an isotropic permittivity model widely used in the literature [5]. Numerical calculations presented in this contribution are based on solving the system of rate-equations iteratively and then evaluating carrier densities, scattering rates, and optical gain.

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