NORMAL MODES OF SOLID-STATE PLASMA IN CONDITIONS OF BLOCH GAIN

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Theoretical predictions suggest that by using specially designed semiconductor structures, it is feasible to develop an inversionless Bloch laser, commonly known as a THz emitter [1]. This capability can be realized using semiconductor superlattices, which, in contrast to bulk semiconductors feature remarkably extended lattice periods. The high-frequency gain in superlattices is associated with negative differential conductivity [1,3], eliminating the need for population inversion and enabling the device to function at room temperature. However, comprehensive theoretical research is needed to fully understand the underlying mechanisms facilitating the extension of emitted frequencies into the terahertz range.

To grasp the working mechanism behind such a system, we employ a model first suggested by Ignatov et al. [2]. Despite its age, this is still a poorly understood model that underlines the importance of plasma effects. The high-frequency conductivity of the superlattice can be calculated from a Boltzmann transport equation with Bhatnagar-Gross-Krook (BGK) operator and thus the eigenmodes of the emission can be found. If one considers the dielectric function of a superlattice in the limit of no spatial dispersion, when high-frequency conductivity is reduced to one calculated in the classical work [3], the description of the system is governed by a relatively simple cubic equation.

Our investigation of the cubic equation shows that there is good correspondence, at all frequencies except ones corresponding to the global extrema of the solutions, between the approximations found in [2] and full analytical solutions calculated in our work. Furthermore, we find interesting correlations between decay/amplification rates of different normal modes (low-frequency “relaxation mode” and high-frequency “hybrid Bloch-plasma mode”). These effects can potentially be applied to create plasmonic devices based on superlattices, such as THz amplifiers, detectors, and switchers.

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