Modeling the generation and control of THz radiation in nanostructures

Alice Regina de Almeida, Teldo Anderson da Silva Pereira
Instituto de Física, Universidade Federal de Mato Grosso, 78060-900 Cuiabá, Mato Grosso, Brasil

Robson Ferreira
Laboratoire Pierre Aigrain, Ecole Normale Supérieure (LPA/ENS). Paris, France

The aims of the present work account for the studying of different aspects of the generation, optimisation and control of THz radiation in semiconductor-based systems. The so-called quantum cascade lasers (QCL) employ quantum transitions between localised electronic energy levels in multiple-quantum-well semiconductor heterostructures. Since the energy of the radiative transition can be engineered by tailoring the quantum well thickness, QCL can now cover the mid-infrared (3\(\mu\)m < \(\lambda\) < 24\(\mu\)m) and part of the THz ranges (70 \(\mu\)m < \(\lambda\) < 200\(\mu\)m) of the electromagnetic spectrum. We have generalized the wave function formalism to describe a different experiment, namely the THz generation in a semiconductor superlattice illuminated by a short optical pulse. The approach was adapted to a c.w. excitation. However, its most important implementation was that necessary to handle the existence of a quantized electromagnetic field in the QCL cavity (whereas all fields were classical in the superlattice studies). This point is of particular importance, since it permits studying the evolution of the IR optical response of the QCL system when the THz-field is made to continuously increase, from the very low intensity case (quantized THz field in the QCL cavity) up to a very strong limit (QCL cavity providing very intense THz light). Indeed, it is well known that the perturbative model applies only in the intermediate limit where the THz field is strong enough to be safely assimilated to a classical field (when the number of THz photons in the cavity fulfils \(n_{THz} + 1 \approx n_{THz} \gg 1\)), while being at the same time weak enough so that the strong-coupling regime (and Rabi-related splitting) does not raise up. The model is a quantum-optics approach, where the field states are characterised by the photon numbers \(n_{THz}\) for the THz field and \(n_{inc}\) (\(n_{out}\)) for the incoming (outgoing) NIR ones. For instance, \(\Delta(n_{THz}) = +1\), \(\Delta(n_{inc}) = -1\) and \(\Delta(n_{out}) = +1\) for the “\(-1\)” replica.