Physical Properties of Three-Barrier Cascade of Terahertz Quantum Cascade Laser

Seti J.O., Tkach M.V., Pan'kiv M.V., Frankiv I.B.

Chernivtsi National University, Chernivtsi, Ukraine

The investigation of semiconductor nanostructures used for the fabrication of nanodevices operating in terahertz range, such as quantum cascade lasers, attract the scientific attention due to their actual advances in the operating frequencies enclosing one of the atmosphere transparency window. It is well known [1], that the quantum cascade laser consists of the series of typical nano size superlattice cascades, each of which generates the electromagnetic wave due to the intersubband electronic transitions. The semiconductor materials of cascade and widths of their potential wells and barriers are chosen depending on the demanded frequency of radiation and constant electric field, driving the structure, coordinates the operation of all cascades.

The theoretical investigation of physical properties of quantum cascade lasers is based at the consisted theory for electronic currents flowing through the multi-layer resonant tunneling structure driven by electromagnetic field and taking into account the interaction between electrons and electromagnetic field and with optical phonons as main dissipative subsystem. In the majority of experimental papers the theoretical evaluation of energy spectrum and probability of quantum transitions between the electronic states have been performed without taking into account of electron-electromagnetic field interaction. This interaction is considered in the simplest Frohlich model.

In the proposed paper, using the expanded into Fourier range the analytically obtained exact solution of complete Schrodinger equation, describing the electronic current through the three-barrier resonant tunneling nanostructure in electric and electromagnetic fields, we study the electron quasi-stationary states and dynamic conductivity of the system.

The theory of electron-phonon interaction is developed in the dielectric continuum model using Feynman-Pines diagram technique and temperature Green's functions. At the base of this theory we investigated the dynamics of electronic currents through the cascade of quantum cascade laser in outer fields and took into account the temperature effect of electron-phonon interaction on the renormalization and expanding of operating electron states.

1. C. Gmachl, F. Capasso, D.L. Sivco, A.Y. Cho. Recent progress in quantum cascade lasers and applications // Rep.Prog.Phys. – 2001. – V. 64. – P.1533.