Electron-Phonon Interaction in Four-Well Nanostructure Being an Expanded Active Region of Quantum Cascade Detector

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The quantum cascade detectors operating in middle and far range have been recently experimentally and theoretically studied on the contrary to the ones operating in near infra red range, researched in details over the last decade. The rising attention to their investigation is caused by the fact that they can operate at room temperatures as it was experimentally shown in [1]. The varying temperature effects at the magnitude of energy gaps of contacting layers of resonant tunneling structure, being an active region of quantum cascade detector and, thus, the heights of potential barriers are varying too, changing the electron energy spectrum in its turn. Therefore, the electromagnetic field absorption bands are shifting for these nano devices. Besides, the increasing temperature of the system increases the occupation phonon numbers and renormalizes the electron spectrum due to the electron-phonon interaction shifting the operating frequency of quantum cascade detector.

In the present investigation, we develop the quantum mechanical theory of electron-phonon interaction in four-well resonant tunneling structure as expanded active region of separate cascade of quantum cascade detector. The electron energy spectrum is calculated within the solution of Schrodinger equation in the model of effective mass and rectangular potential profile for $In_{0.53}Ga_{0.47}As/In_{0.52}Al_{0.48}As$ nanostructure. The spectra of confined and interface phonons are calculated using the transfer matrix method in dielectric continuum model. The electron-phonon Hamiltonian is obtained in the representation of second quantization over all variables of the system.

Using the Hamiltonian, we calculated the mass operator of electron Green's function at any temperature of the system and expanded energy bands at cryogenic and room temperatures. The partial contributions of different mechanisms of electron-phonon interaction (inter-band and intra-band ones within discrete and continuum spectrum) are obtained.

It is shown that the electron-phonon interaction at bigger temperature causes the weak shift of absorption band into the region of higher frequencies. The decreasing heights of potential barriers, due to the varying widths of contacting layers, bring to the essential expanding and shift of electromagnetic waves absorption bands into the region of smaller frequencies according to the experimental data [1].

1. Hofstetter D. 23GHz operation of a room temperature photovoltaic quantum cascade detector at 5.35μm // Appl. Phys. Let. – 2006. – V.89, P. 061119.