Theory of Quantum Dot Intraband Optoelectronic Devices

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Abstract. In the last two decades, semiconductor nanostructures, such as quantum wells, wires and dots, have been recognized as sources and detectors of radiation in the mid- and far-infrared region of the spectrum. Much of a success has been obtained with quantum well based intraband devices, such as quantum cascade lasers and quantum well infrared photodetectors. However due to longer carrier lifetimes in quantum dots, it is expected that optoelectronic devices based on intraband transitions in self-assembled quantum dots would have superior performance to their quantum well counterparts. In order to fully exploit this prospect, appropriate theoretical models describing electronic, optical and transport properties of the active region of these devices need to be developed, which will be the main subject of this presentation.

It will be shown how symmetry of the dot shape can be exploited to efficiently calculate the energy levels within the framework of the multiband envelope function method [1]. The implementation of the method in the plane wave representation of the Hamiltonian eigenvalue problem and the results of its application to square based pyramidal InAs/GaAs quantum dots and hexagonal III-nitride quantum dots will be given [1, 2]. A model of intraband carrier dynamics in quantum dots will be presented and its application to the design of an optically pumped long wavelength mid-infrared laser based on intersublevel transitions in InAs/GaAs quantum dots [3]. Next, a theory of transport in quantum dot infrared photodetectors starting from the energy levels and wave functions obtained by solving the envelope Hamiltonian [4], yielding as output the device characteristics such as dark current and responsivity will be described [5]. Finally, the most recent results on the electron transport through arrays of closely stacked quantum dots, where coherent and polaronic effects become important, therefore requiring the treatment within the formalism of nonequilibrium Green's functions, will be presented.

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