Charge and spin injection in a quantum well–quantum dot system

Adam Mielnik–Pyszczorski, Krzysztof Gawarecki, Paweł Machnikowski

Department of Theoretical Physics, Faculty of Fundamental Problems of Technology, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland

The system composed of a quantum well and a quantum dot (QW–QD) has been studied in experiment and theory [1,2]. It turns out that the high density of states in the QW increases efficiency of injection of carriers into QDs. The observed efficient tunneling of carriers combined with techniques of optical orientation and coherent spin control suggest that the QW could also serve as an effective spin injector for the QD structures.

In this contribution we theoretically investigate the process of electron tunneling from a QW to a nearby QD. In order to study the charge and spin dynamics we first determine the strain distribution in the system [3]. The lattice deformation is important in the consideration of a realistic structure since it has strong influence on the band edges, generates a piezoelectric field, which results in additional localization of electrons in the vicinity of the QD, and also, in an external magnetic field, contributes to the effective g–factor. We calculate electronic wave functions within 8–band $k \cdot p$ Hamiltonian including the strain field and the spin–orbit interaction, reduced to a 2–band ($|e \uparrow\rangle$, $|e \downarrow\rangle$) model by Löwdin perturbation theory. We then use the resulting single electron spinor wave functions to calculate the electron evolution within the correlation expansion approach.

We study phonon–induced system relaxation to its ground state localized in the QD (carrier injection), as well as the spin dynamics during this process (spin injection). For carrier injection, we obtained non–monotonic dependence of the relaxation rate on the distance between the QD and the QW. We found an exponential evolution of the average number of electrons in the dot and a non–exponential evolution of the state occupations in the well [1]. We study also the spin evolution during tunneling in order to estimate the spin–flip probability and assess the efficiency of spin injection. We compare spin flip processes generated by various spin–phonon coupling mechanisms.

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