(1e,1h) states of carbon nanotube quantum dots

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The idea of single electron spin manipulation in carbon nanotube (CNT) quantum dots has been exploited recently in many experimental and theoretical works [1-3]. CNTs provide very attractive medium for that kind of manipulation due to the presence of the spin-orbit interacion [4], arising from the curvature of graphene plane, as well as an absence of the important decoherence source - the nuclear field. That makes the CNT quantum dots a good candidate for e.g. qubits for future quantum information.

In this work we investigate a few-carriers ambipolar (n-p) quantum dots defined electrostatically in carbon nanotubes. We focus on (1e,1h) electron configuration, since that is the only system in which the Pauli spin-valley blockade has been observed experimentally. The blockade has been used to observe manipulation of spin and valley states of the carriers due to electric dipole spin resonance (EDSR).

We model the system of carbon nanotube n-p quantum dot using the exact diagonalization within the tight-binding approximation. We use single electron energy states and configuration interaction method to calculate few-electron energy spectra. In the model we take into account external fields - electric and magnetic, the spin-orbit coupling, the electron-electron interaction and intervalley scattering. By solving the time-dependent Schroedinger equation we simulate spin-valley dynamics of the system due to EDSR.

We describe the lowest energy states of the (1e,1h) system and compare them with other electronic configurations of the n-p quantum dots. The transitions between Pauli blocked and non-blocked states due to EDSR are calculated and compared explicitly with the experimental data. The magnetic field magnitude and orientation dependence of the presented transitions are discussed. We show also the effect of the nanotube bending on the transition spectra and demonstrate that we can significantly improve the agreement with the experiment by bending the nanotube locally over the gates.

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