CONTROL AND HIGH MAGNETIC FIELD SENSITIVITY OF GEOMETRIC PHASES AND PHONON-MEDIATED SPIN RELAXATION RATES IN QUANTUM DOTS.

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Manipulation of a single electron spin with the application of gate controlled electric fields in confined semiconductor quantum dots (QDs) is a promising way for developing spin based quantum logic gates, spin memory devices for various quantum information processing applications. [1] First, we analyze physical phenomena important under such control for phonon-mediated spin relaxation rates in semiconductor quantum dots, focusing on the analysis Rashba versus Dresselhaus spin-orbit coupling. Magnetic fields, which can be of substantial values, play a key role in this analysis. Indeed, it is well known by now that the cusplike structure in the phonon mediated spin transition rate can be seen for the pure Rashba case. For the pure Dresselhaus case, the spin transition rate is a monotonous function of the magnetic fields and QD radii. Since the Dresselhaus spin-orbit coupling dominates over the Rashba spin-orbit coupling in some materials such as GaAs and GaSb QDs, it is important to find the exact location of the spin hot spot or the cusplike structure even for the pure Dresselhaus case. We consider two-dimensional anisotropic semiconductor QDs in the presence of a magnetic field along the growth direction. We present analytical and numerical results that show that the spin hot spot can also be seen for the pure Dresselhaus spin-orbit coupling case by inducing large anisotropy through external gates. At or nearby the spin hot spot, the spin transition rate increases and the decoherence time decreases by several orders of magnitude compared to the case with no spin hot spot. Contributions of the Rashba and the Dresselhaus spin-orbit coupling to the phonon induced spin-flip rate as a function of magnetic fields are studied in details.

Next, we analyze the Berry phase in III-V semiconductor quantum dots (QDs). We show that the Berry phase is not only highly sensitive to electric fields arising from the interplay between the Rashba and Dresselhaus spin-orbit (SO) couplings, but also this phase is highly sensitive to magnetic fields in QDs. [2] We also demonstrate the importance of several associated physical phenomena. In particular, we show that the accumulated Berry phase can be induced from other available quantum states that differ only by one quantum number of the corresponding spin state and provide characteristics of the Berry phase for three different length scales (spin-orbit length, hybrid orbital length, and orbital radius). In this part, we solve the time-dependent Schrödinger equation by utilizing the Feynman disentangling technique, and we provide the description of the evolution of spin dynamics during the adiabatic transport of QDs in the two-dimensional plane.

[1] S. Prabhakar, R. Melnik and L. L. Bonilla, Phys. Rev. B **87**, 235202 (2013).
[2] S. Prabhakar, R. Melnik and L. L. Bonilla, Phys. Rev. B **89**, 245310 (2014).

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