Research on the new mechanism of a spatial separation of a spin density in a two-electron quantum dot

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Among the several possible physical implementations of a quantum bit, the most promising is its location on the spin of an electron confined within a semiconductor nanodevice. The majority of previous implementations require using strong external magnetic fields in order to separate the energy levels of electrons with different spin orientations. This poses a significant technical difficulty for the construction of a quantum computer. It would be much better if we were able to avoid using a magnetic field. Single-qubit operations on an electron spin can also be performed without a magnetic field. We have proposed and simulated the operation of such a nanodevice in our previous work [1].

The most difficult issue to solve, however, is the intentional spin setup in the beginning without the use of a magnetic field. In the current project, is scheduled to research the possibilities to carry out such a process. Our preliminary research has shown that this is possible. As a structure of the system, we propose a double gate-defined quantum dot system with a tuned interdot barrier. The barrier height is low at the beginning of the system evolution. We shall put two electrons in a potential well. We assume that, in the beginning, the system will be in singlet state, which is the ground state for a double-electron system and may be generated e.g. by thermalisation [2, 3]. It turns out that if a spin-orbit interaction with a periodic variable coupling constant appears in a quantum dot, a pair of electrons can enter the triplet state. For this purpose, we use the Rashba interaction [4, 5], whose amplitude can be controlled with variable voltage applied to electrodes [6, 7, 8]. When the electrons enter a state of balanced linear combination of singlet and triplet state, we interrupt the spin-orbit coupling constant oscillation. The transition between singlet and triplet states will be disturbed. If we then lift the potential barrier inside the well, we can spatially separate both electrons. If we select the time of barrier formation properly, electrons with specific spins will go in both separated regions. In the left side, one with a spin up and in the right, one with a spin down.

If we manage to solve the issue of initializing the spin without a magnetic field, we may be able to build a quantum computer operating on electron spins, controlled only by local voltages and requiring no external fields. The research would provide an insight at some very interesting properties of double-electron systems in semiconductor nanostructures, with particular emphasis on their spin degrees of freedom.

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