Cooper pair splitting as a source of entangled electrons

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One of the foundations of quantum communication is a quantum entanglement between two qubits. Until now entanglement of photons was obtained. The next step is to get entangled state of spatially separated electrons,in particular its spins, in a solid state electronic system that can be important for practical applications. The ground state of conventional superconductors is a singlet state of electron Cooper pairs that can provide a natural source of entangled electrons. One of the proposals to obtain the nonlocal entanglement of electrons is to use the Cooper pairs split in the Double Quantum Dot (DQD) system using the Coulomb interaction between electrons [1]. We have analyzed an efficiency of the separation of Cooper pairs in systems, where the DQD is connected to the two superconducting leads, or to the superconducting and normal leads [2,3]. We considered a flow of electrons in cotunneling regime, where a simultaneous tunneling of electron pairs occurs through the whole system. In this way,we obtained correlated electrons tunneling, what is an advantage in comparison to sequential tunneling, since it allows easily identify particular electron pairs. The Cooper pair splitting (CPS) efficiency was calculated for three ground states (singlet, triplet, and empty dots) of the DQD.

Addressing the idea of quantum communication with entangled electrons in a solid state, where ferromagnetic detectors allow for spin correlation detection, we provide, using quantum information theory, a lower bond on the spin polarization of detectors [4]. In ferromagnetic detectors the spin information is transformed into charge information, however, any real magnetic materials feature imperfect spin polarization due to presence of both spin component in density of states at the Fermi surface. We find that lower bond for the spin polarization is $p > 58\%$ for detection of entanglement using an optimal entanglement witness [4]. It provides the minimal spin polarization of ferromagnetic materials that can be useful in quantum communication.

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