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Production and Detection of Spin-Entangled Electrons in Mesoscopic Conductors

GUIDO BURKARD, University of Basel, Switzerland

Electron spins are an extremely versatile form of quantum bits. When localized in quantum dots, they can form a register for quantum computation. Moreover, being attached to a charge in a mesoscopic conductor allows the electron spin to play the role of a mobile carrier of quantum information similarly to photons in optical quantum communication. Since entanglement is a basic resource in quantum communication, the production and detection of spin-entangled Einstein-Podolsky-Rosen (EPR) pairs of electrons are of great interest. Besides the practical importance, it is of fundamental interest to test quantum non-locality for electrons. I review the theoretical schemes for the entanglement production in superconductor-normal junctions [1] and other systems. The electron spin entanglement can be detected and quantified from measurements of the fluctuations (shot noise) of the charge current after the electrons have passed through an electronic beam splitter [2,3]. This two-particle interference effect is related to the Hanbury-Brown and Twiss experiment and leads to a doubling of the shot noise $S_I = \langle \delta I \delta I \rangle_{\omega=0}$ for spin-entangled states, allowing their differentiation from unentangled pairs. I report on the role of spin-orbit coupling (Rashba and Dresselhaus) in a complete characterization of the spin entanglement [4]. Finally, I address the effects of a discrete level spectrum in the mesoscopic leads and of backscattering and decoherence.

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