Spin transport through a single quantum dot with ferromagnetic electrodes and coherent control of nuclear spins in quantum Hall systems

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Abstract :

Spin injection into semiconductors is one of the most essential techniques in spintronics. In this study, we demonstrate spin-dependent electron transport in laterally fabricated ferromagnetic metal (FM)/InAs quantum dot (QD)/FM double barrier magnetic tunnel junctions (MTJ). The MTJ shows clear Coulomb blockade and hysteretic tunneling magnetoresistance (TMR) effects at low temperatures. The TMR ratio is enhanced by the Coulomb blockade effect and varied by changing source-drain voltage (V_{SD}). We can observe even negative TMR effects, which appear at V_{SD} values where the I-V_{SD} characteristic shows negative differential conductance. The correspondence between the negative TMR and the negative differential conductance suggests the spin accumulation in the QD. The TMR features can be controlled also by tuning the gate voltage. This means that our systems have a possibility to work as a single spin transistor.

We also demonstrate electrical coherent manipulations of nuclear spins in quantum Hall systems based on $Al_{0.3}Ga_{0.7}As$/GaAs heterostructures. Nuclear spins of the host semiconductor material are dynamically polarized through the hyperfine interaction between electron and nuclear spins by exciting electrons to the upper Landau subband with opposite spin polarity in a breakdown regime of quantum Hall effect. A pulsed radio-frequency magnetic field is generated by a built-in micrometal strip, which causes the nuclear-spin state to evolve coherently. Finally, the nuclear-spin state reached after the pulse application is read out through the value of resistance, which oscillates as a function of the pulse duration, i.e. a resistively-detected Rabi oscillation.