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Spin-dependent quantum transport in nanoscaled geometries

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We discuss experiments where the spin degree of freedom leads to quantum interference phenomena in the solid-state. Under spin-orbit interactions (SOI), spin rotation modifies weak-localization to weak anti-localization (WAL). WAL's sensitivity to spin- and phase coherence leads to its use in determining the spin coherence lengths Ls in materials, of importance moreover in spintronics. Using WAL we measure the dependence of Ls on the wire width w in narrow nanolithographic ballistic InSb wires, ballistic InAs wires, and diffusive Bi wires with surface states with Rashba-like SOI. In all three systems we find that Ls increases with decreasing w. While theory predicts the increase for diffusive wires with linear (Rashba) SOI, we experimentally conclude that the increase in Ls under dimensional confinement may be more universal, with consequences for various applications. Further, in mesoscopic ring geometries on an InAs/AlGaSb 2D electron system (2DES) we observe both Aharonov-Bohm oscillations due to spatial quantum interference, and Altshuler-Aronov-Spivak oscillations due to time-reversed paths. A transport formalism describing quantum coherent networks including ballistic transport and SOI allows a comparison of spin- and phase coherence lengths extracted for such spatial- and temporal-loop quantum interference phenomena. We further applied WAL to study the magnetic interactions between a 2DES at the surface of InAs and local magnetic moments on the surface from rare earth (RE) ions (Gd3+, Ho3+, and Sm3+). The magnetic spin-flip rate carries information about magnetic interactions. Results indicate that the heavy RE ions increase the SOI scattering rate and the spin-flip rate, the latter indicating magnetic interactions. Moreover Ho3+ on InAs yields a spin-flip rate with an unusual power 1/2 temperature dependence, possibly characteristic of a Kondo system. We acknowledge funding from DOE (DE-FG02-08ER46532).