Controlling of the geometric phase of electron spin in a semiconductor ring device

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Geometrical phases arise in time-dependent wave systems where the parameters of the wave function are cycled around a circuit. Such phase factors can be observed via interference of waves traversing different paths. Berry showed that the electron spin wave function in an adiabatic evolution acquires a geometric phase that depends only on the geometry of the traversed path in the parameter space. As a consequence the geometric phase is robust against dephasing. This is in contrast with the time-dependent dynamical phase of a particle. Experimentally, geometrical phase factors have been observed in various physical systems and previously reported for InGaAs rings [1]. However, a geometric phase of an electron spin wave function has not been directly observed and manipulated independently from the dynamical phase. Here we report measurement and manipulation of the geometric phase of an electron spin in a mesoscopic semiconductor device in which an array of rings forms interference paths. The observed geometrical phase is a non-adiabatic Aharonov-Anandan phase due to the Aharonov-Casher effect. A geometrical phase shift is induced with an in-plane magnetic field and measured in the interference pattern of the electron current. The measured oscillations in the conductance are consistent with theoretical calculations using the perturbation theory and the Recursive Green's Function method (see Figure). In the first order perturbation theory the phase shift is quadratic in magnetic field, which is in good agreement with experiments. Our findings show manipulation of the geometric phase independently of the dynamical phase without resorting to additional geometric phase factors such as the Aharonov-Bohm phase.

[1] F. Nagasawa, J. Takagi, Y. Kunihashi, M. Kohda, and J. Nitta, Phys. Rev. Lett. **108**, 086801 (2012)

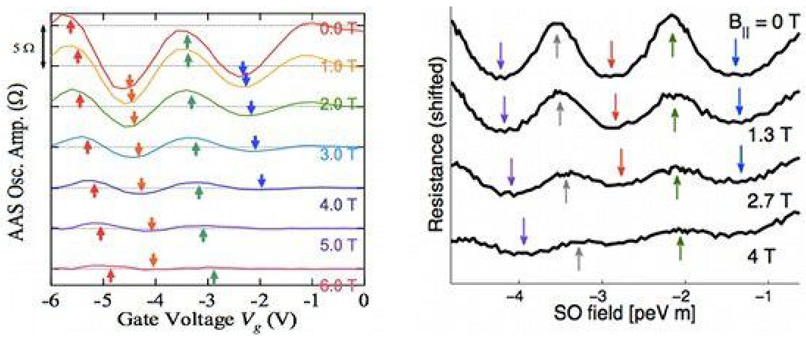

Figure : Interference of geometric phases causes oscillations in conductance through a semiconductor ring device. The oscillation period decreases with increasing in-plane magnetic field which is a sign of the geometric phase shift. Experiments to the left and Recursive Green's function calculations to the right.