Nonlinear planar Hall effect in topological insulators: contribution from scattering on magnetic impurities

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We will present results of our theoretical study of a new type of nonlinear Hall effects, that appears in non-magnetic layers with strong spin-orbit coupling (SOC) [1,2]. Assuming the low-energy electronic states on the surface of a 3D topological insulator in terms of Dirac model, and applying the semiclassical Boltzmann formalism, we derive the planar Hall conductivity within the generalized relaxation time approximation. We show that the planar Hall conductivity consist of the linear and nonlinear terms with respect to the external electric field. The linear term scales quadratically with an external magnetic field and presents the conventional planar Hall conductivity, whereas the nonlinear term scales linearly with both the charge current density and in-plane magnetic field. Thus, the latter term reveals the bilinear behavior.

The nonlinear Hall effect in this description is a consequence of electron scattering on spin-momentum locking inhomogeneities [3] in the presence of current-induced spin polarization and external magnetic field. The main objective of the presentation is a detailed analysis of the influence of electron scattering on magnetic impurities in the system on the nonliinear planar Hall effect. Generally, magnetic impurities contribute to scalar scattering (on impurity electrostatic potential) and magnetic scattering (via exchange coupling of electron spin to impurity magnetic momentum). Assuming that magnetic moments of the impurities in the system follow the external magnetic field orientation [4], we show that the nonlinear Hall conductivity becomes remarkably modified by scattering on magnetic impurities. The most pronounced effect of such a scattering is an additional periodicity (in comparison to scattering on scalar impurities) in the dependence of the Hall conductivity on the angle between charge current direction and magnetic field orientation.

References:

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