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Collinear and Noncollinear Antiferromagnetic Insulators for Spintronics Applications

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Ability to control spin is important for probing many spin related phenomena in the field of spintronics. Spin-orbit torque is an important example in which spin flows across magnetic interface and helps to control magnetization dynamics. As spin can be carried by electrons, spin-triplet pairs, Bogoliubov quasiparticles, magnons, spin superfluids, spinons, etc., studies of spin currents can have implications across many disciplines. In this talk, I first review the most common ways to generate spin flows and then concentrate on how spin can be controlled in insulating materials. In the first part of the talk, I will discuss a linear response theory based on the Luttinger approach of the gravitational scalar potential and apply this theory to magnon transport in antiferromagnetic insulators, ranging from collinear antiferromagnets [1,2,3] to breathing pyrochlore noncollinear antiferromagnets [4,5]. The theory also applies to noncollinear antiferromagnets, such as kagome, where we predict both the spin Nernst response [4] and generation of nonequilibrium spin polarization [5] by temperature gradients, the latter effect constitutes the magnonic analogue of the Edelstein effect of electrons. In the second part of this talk, I will discuss the spin superfluid transport in exchange interaction dominated three-sublattice antiferromagnets. The system in the long-wavelength regime is described by an SO(3) invariant field theory (nonlinear sigma model). Additional corrections from Dzyaloshinskii-Moriya interactions or anisotropies can break the symmetry; however, the system still approximately holds a U(1)-rotation symmetry. Thus, the power-law spatial decay signature of spin superfluidity is identified in a nonlocal-measurement setup where the spin injection is described by the generalized spin-mixing conductance [6,7]. We suggest iron jarosites as promising material candidates for realizing our proposal. Both magnons and spin superfluidity flows are examples of spin flows with low dissipation and as a result our studies pave the way for the creation of novel electronic devices for classical and even quantum information processing where the signals can propagate with almost no dissipation. If time permits, I will also discuss realizations of skyrmion lattices in noncollinear antiferromagnets.

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