Non-Contact Spin Pumping by Microwave Evanescent Fields

The angular momentum of evanescent light fields has been studied in nano-optics and plasmonics, but not in the microwave regime. We predict non-contact pumping of electron spin currents in conductors by the evanescent stray fields of excited magnetic nanostructures. The coherent transfer of the photon to the electron spin is proportional to the g-factor, which is large in narrow-gap semiconductors and surface states of topological insulators.

Efficient transfer of spin information among different entities is a key objective in spintronics. The electromagnetic field at frequency ω carries a spin angular momentum density [1]

$$\mathcal{D} = \frac{1}{4\omega}\mathrm{Im}\left(\varepsilon_0 \mathbf{E}^* \times \mathbf{E} + \mu_0 \mathbf{H}^* \times \mathbf{H}\right) \qquad (1)$$

where μ_0/ε_0 are the vacuum permeability/permittivity, and in the microwave regime the magnetic field component dominates. The evanescent fields at boundaries can have local angular momentum with locked linear and angular momentum. The chiral electrical near-field of a rotating electrical dipole, e.g., unidirectionally excites surface plasmon polaritons [2]. Metallic striplines or coplanar waveguides biased by currents in the GHz regime also emit chiral magnetic near-fields, which is of considerable interest for magnonics, since chiral excitation is a robust and switchable mechanism that pumps a DC unidirectional magnon current by an AC field [3].

Spin pumping by exchange interaction is established when the magnet and conductor form a good electric contact [4], which is difficult to achieve between metals and semiconductors including graphene because of Schottky barriers and electronic structure mismatch. Even when a good contact to a magnet can be established, results may be difficult to interpret due to proximity effects. Spin pumping at a distance by microwaves solves these issues since it does not require direct contact between the magnet and the system of interest.

Here we address the non-contact angular momentum transfer to an electric conductor by stray magnetic fields emitted by an excited magnet, thereby generalizing the concept of spin pumping by a contact exchange interaction. We are motivated by the significant near fields that couple magnetic nanowires and ultrathin magnetic insulating films, causing several chiral magnon transport phenomena. We find that a magnetodipolar field pumps electron spins into a conductor in a non-chiral fashion without the need of an electric contact [4]. We illustrate the physics for a simple yet realistic model system of a magnetic nanowire on top of a two-dimensional electron gas (2DEG) as illustrated in Fig. 1. The latter may be graphene, but the effect is strongly enhanced by spin-orbit interaction, such as a large g-factor in InAs or InSb quantum wells (QWs) or the surface states of 3D topological insulator. The singularity of the spin susceptibility in a one-dimensional situation such as a carbon nanotube and Luttinger liquid recovers the chirality of the spin injection.

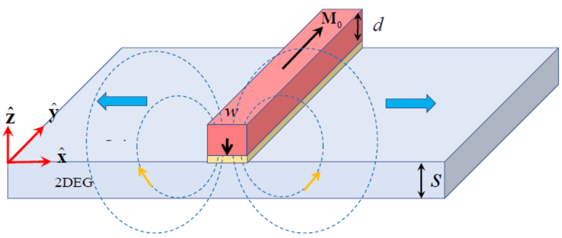

Fig. 1: Snapshot of spin pumping by the microwave dipolar field of an excited magnetic nanowire on top of a 2DEG. A thin tunneling barrier suppresses any exchange coupling. Orange arrows indicate the direction of the stray field.

References

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Keywords: spintronics, electronic structure, spin current
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