Photocontrol of spins in chiral lattice magnets and topological insulators

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Ultrafast and directional control of spin-carrier is one of the major topics in the field of opto-spintronics. Here we introduce several time-resolved spectroscopic studies on the spin-waves and spin-polarized charge currents.

Chiral lattice magnets exhibit a variety of spin structures and dynamics via the Dzyaloshinskii-Moriya interaction. Examples include the formation of skyrmions [1] and non-reciprocal propagation of spin-waves [2]. Magnetic skyrmions, nano-scale spin vortices of topological origin, can be driven under an extremely small charge current or by spin-waves, and are expected to realize future magnetic information devices. To reveal their dynamics in the ultrafast time-scale, we performed all-optical spin-wave spectroscopy in an insulating chiral lattice magnet Cu_2OSeO_3 [3]. The spins in the helical, conical, and skyrmion phases were excited by the impulsive magnetic field of the inverse Faraday effect, and subsequent precessional relaxations were detected through conventional magneto-optics. Clear dispersions of the helimagnon were observed, which was accompanied by a transition into the skyrmion phase when sweeping temperature or magnetic field. In the skyrmion phase, three collective excitations were identified, distinct from those in the surrounding conical phases. These spin dynamics can be readily assigned to the clockwise/counter-clockwise rotations and breathing of the skyrmions.

Nonreciprocal spin-wave propagation emerges in the chiral lattice magnets as a result of the magneto-chiral interaction. We directly evaluated the spin-wave dispersion of Cu_2OSeO_3 by using Brillouin light scattering spectroscopy. A large difference in the spin-wave frequency for the oppositely propagating volume spin-waves, exceeding 1 GHz, was confirmed in the field-induced ferromagnetic phase. Surprisingly, other magnetic phases, conical and possibly skyrmion phases, also show non-reciprocal transports. These directional spin dynamics can be utilized as information carriers in spintronics, and also as heat carriers in spin caloritronics.

Dirac-like surface-states of topological insulators (TIs) are ideal playgrounds for the charge-to-spin conversion due to their spin-momentum locking. However, circular photogalvanic effect, to test the photoexcited electron-to-spin conversion there, was found to be not so efficient to realize large spin currents. Doping TIs with magnetic elements brings about essential modifications in their originally *k*-linear (mass-less) dispersion, providing a new way to materialize dissipation-less electronics/spintronics as exemplified in quantum anomalous Hall effects and giant Kerr/Faraday rotations [4]. We have experimentally revealed that a large zero-bias photocurrent can emerge in the magnetically modified TI thin films, due to the band asymmetry induced by the magnetic interactions in the spin-split surface-states [5].

References

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