Theory on Spin Conversion Function: Topological Engineering of Magnons

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Recent advances in spintronics have revealed various kinds of conversion of electron spins into other degrees of freedom such as heat, electromagnetic wave, spin wave, and so forth. Theoretically there are several approaches for investigations of new kinds of spin conversion phenomena: (a) new theoretical framework, (b) new materials, (c) nanostructures such as interfaces and thin films.

As an example of exploration of new spin conversion phenomena, we studied magnons in ferromagnet from the viewpoint of Berry curvature in momentum space. The Berry curvature in momentum space is represented by the derivatives of the Bloch wavefunctions in terms of the wavevector. As has been studied in the context of spin Hall effect of electrons in semiconductors[1], the Berry curvature is closely related to the band structure. We find that the Berry curvature of magnons causes various physical phenomena such as thermal Hall effect[2,3]. For example, for the magnetostatic forward volume-wave modes in a ferromagnetic slab, where the magnetic field is out-of-plane, we calculate the Berry curvature and resulting magnon thermal Hall conductivity. Furthermore, at the edge of a magnet this Berry curvature gives rise to the shift of the wavepacket, i.e. the Goos-Hänchen shift, known in optics (Fig.1). We discuss possible measurement of this shift in a magnet with a step, used for the observation of the Snell's law for spin waves in Ref.4).

Furthermore, if one introduces an artificial periodicity into a ferromagnet and makes a magnonic crystal, the band structure is modified accordingly. As a result the Berry curvature changes and in some cases the Chern number, i.e. the integral of the Berry curvature over the Brillouin zone, becomes nonzero, implying that the some magnon band gaps have topological nature. It results in an existence of chiral magnonic edge states within the gap (Fig.2)[5,6].

References

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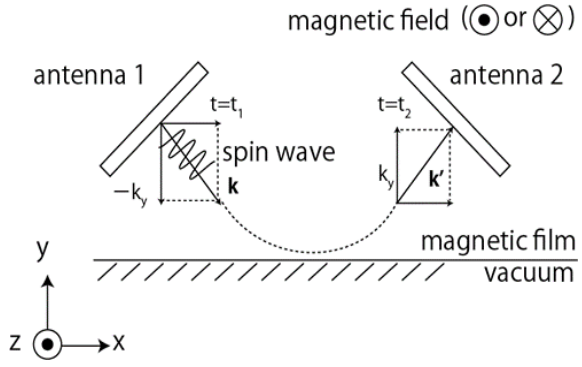

Fig. 1 Schematic illustration of Goos-Hänchen shift of magnons at the edge

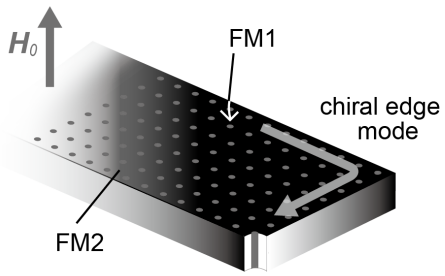

Fig. 2 Topological magnonic crystal and chiral edge mode