Observation of magnon polarization through neutron scattering

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Spin current, a flow of the spin degree of freedom in condensed matter, is a fundamental concept in spintronics research. Many experimental and theoretical investigations are devoted to developing creation/annihilation and control methods of the spin current. As one of the creation methods, the spin Seebeck effect (SSE) attracts much attention recently due to possible applications to thermal spin generators for driving spintronics devices. The SSE is observed via the induced spin current in ferromagnets and ferrimagnets with an application of a temperature gradient. Driving spin currents thermally could lead to the manufacturing of a compact spin current source without using an electric current or magnetic field.

Deep into microscopic views, the spin current in magnetic insulators is carried by the transverse component of spin-waves (quantized magnons). Magnons can be polarized, and the magnon polarization, i.e., the direction of the precessional motion of the electronic spin, affects the thermodynamics of magnetic materials, governing the magnitude and sign of the SSE. However, the magnon polarization of magnon modes has eluded experimental observation. We here show our recent results of the first direct observation of magnon polarization through polarized neutron scattering experiment[1)]. Our results describe electromagnetic responses of magnons in THz regime that are spanned over a wide ($\boldsymbol{Q}$, ω) space.

Target compound, the iron-based garnet $Y_3Fe_5O_{12}$ (YIG), is a ferrimagnetic insulator with a complex structure and is an essential material for microwave and optical technologies and also for basic research in spintronics, magnonics, and quantum information. One reason is that it has the highest quality magnetization dynamics among known magnets—resulting in long magnon lifetimes. There exist major two magnon modes, and the gap separating optical and acoustic modes is of the order of the thermal energy at room temperature. A maximum of the spin Seebeck signal in YIG near room temperature[2)] has been interpreted in terms of the competition between magnon modes with opposite polarization. Our experimental findings are well accounted for by atomistic spin dynamics calculations. The observation of both signs of magnon polarization in YIG (Fig.) also gives direct proof of its ferrimagnetic nature.

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Reference
1) Y. Nambu *et al*., Phys. Rev. Lett. **125**, 027201 (2020).
2) T. Kikkawa *et al*., Phys. Rev. B **92**, 064413 (2015).

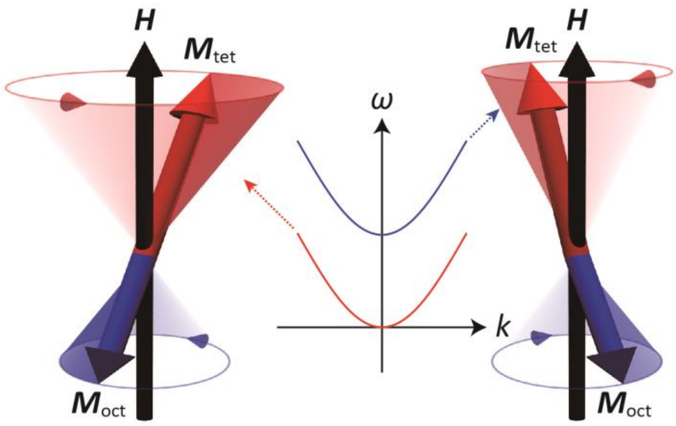

Fig. Illustration of magnon polarization for two magnon modes in YIG[1)]. The positive polarization acoustic (left) and negative polarization optical modes (right) are shown.