Neutron scattering studies for spin dynamics in terbium iron garnet

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Spin Seebeck Effect (SSE) is one of the representative phenomena which generates a spin current by applying a temperature gradient to a junction array of *ferro*magnetic or *ferri*magnetic materials and a paramagnetic metal. Unlike the usual Seebeck effect, the signal can be detected even in insulators. Carriers of spin currents in insulators are magnons, which are collective excitations of ordered spins. The spin current is detected in the paramagnetic metal layer by the inverse spin Hall effect via spin-orbit interaction [1].

The ferrimagnetic insulator $Y_3Fe_5O_{12}$ (YIG) is frequently used in SSE studies. The SSE signal in YIG is known to decay above room temperature up to Curie temperature (~ 550 K) [2]. This reduction of the SSE signal is due to the thermal excitation of the optical modes, which can interrupt the contribution from acoustic modes. A recent report on polarized neutron inelastic scattering successfully elucidates this mechanism [3]. It revealed that the acoustic and the optical modes in magnons of YIG have different rotation directions of the precession motion of magnetizations (magnon polarization).

In $RE_3Fe_5O_{12}$ (RE = Gd, Dy), the temperature dependencies of the SSE signals are drastically changed from YIG. These show a sign change around the magnetic compensation temperature (T_M) [4,5]. This behavior should be due to the sign reversal of magnetizations whereas the net magnetization is kept parallel to applied magnetic fields. For research on spin dynamics, neutron scattering is a powerful probe. We then focused on the $Tb_3Fe_5O_{12}$ (TbIG) as the best materials for the study of magnetic excitations with terbium being a much smaller neutron absorber than gadolinium and dysprosium.

In this study, we performed inelastic unpolarized and polarized neutron scattering experiments to study magnons in TbIG. At first, we show results from time-of-flight measurements with unpolarized neutrons. We observed that magnetic excitations and their temperature dependence in a wide ($\boldsymbol{Q}$, E) range. Our experimental findings reveal that magnetic excitations of TbIG have two gapped optical modes; low-energy and high-energy optical mode. Second, we show results of P_x-polarized neutron scattering experiment to observe magnon polarizations in these optical magnon modes. The optical modes have opposite magnon polarizations from each other, and we confirmed the sign reversal of magnon polarization in the low-energy optical mode at two temperatures across T_M. Here we report our recent unpolarized and polarized neutron scattering studies on TbIG.

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