Low-energy magnetic excitations in YIG

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The spin Seebeck effect (SSE) [1] attracts much attention due to possible application to thermal spin generators for driving spintronics devices. The recent discovery of the SSE in magnetic insulators [2] adds essential information for understanding the physics of the SSE. Originally the SSE was phenomenologically formulated in terms of thermal excitation of conduction electrons, in analogy with the conventional Seebeck effect requiring the existence of itinerant charge carriers. The observed SSE in insulators indicates that there are no needed conduction electrons, but it may be directly associated with magnetic properties in ferromagnetic materials. Uchida *et al*. [3] have recently examined temperature dependence of longitudinal SSE at high temperatures in Pt/$Y_3Fe_5O_{12}$ (YIG) systems. They found that the magnitude of the SSE voltage rapidly decreases with increasing temperature and disappears above the Curie temperature of YIG ($T_c \sim 560$ K), implying the necessity of the ferromagnetism for the SSE. But the critical exponent of the SSE voltage in Pt/YIG was estimated to be much greater than that of the magnetization curve of YIG. This discrepancy indicates that the mechanism of the SSE cannot be explained in terms of simple static magnetic properties and rather calls for a dynamical magnetic interpretation of the effect.

Although YIG is the well-known ferrimagnet and a key material for the SSE, research on dynamical magnetism is limited. To our best knowledge, the only detailed neutron scattering experiment on YIG is investigated on a part of spin excitations by a triple-axis spectrometer [4]. We found several magnetic excitations missed in the previous triple-axis measurement. We therefore used lower energy incident neutron with adequate energy resolution to fully determine coupling constants between irons and to decide Q or Q^2 dependence of the acoustic magnon branches.

Inelastic neutron scattering experiment was carried out on the cold neutron triple-axis spectrometer SIKA at ANSTO, Australia. A single crystal (mass: 8 g) grown by an image furnace is oriented so that the [HHL] plane lies within the horizontal scattering plane. We used a cryofurnace to allow the temperature dependence to be studied between 10 and 450 K. The final energy was chosen either 3.5 or 5.0 meV for access to the relevant wave vector transfer and adequate resolution in the $-1 < \hbar\omega < 10$ meV energy range. Magnetic excitations from (220) for [110], [001], and [111] directions were nicely observed at 10, 300 K and 450 K. Figure 1 shows magnon dispersion relation along the P[111] direction taken at 300 K. The obtained spectra is compared with spin wave calculation, and preparation for a manuscript is now under way.

[1] K. Uchida et al., Nature 455, 778 (2008). [2] K. Uchida et al., Nat. Mat. 9, 894 (2010). [3] K. Uchida et al., Phys. Rev. X 4, 041023 (2014). [4] J.S. Plant, J. Phys. C 10, 4805 (1977).

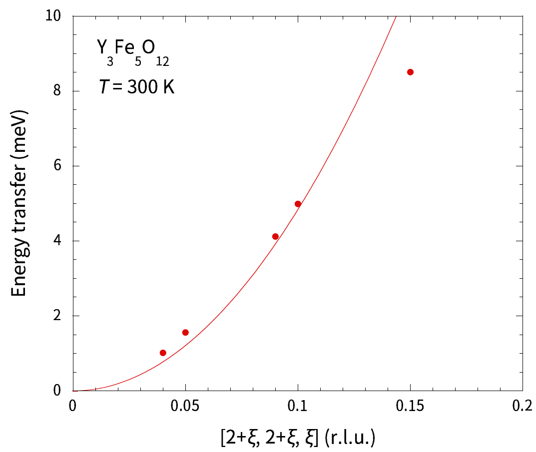

Fig. 1. Magnon dispersion relation along the P[111] direction taken at 300 K.