# Ultrafast optical excitation of magnetic materials

Naoki Ogawa
Emergent Photodynamics Research Unit, RIKEN CEMS, Wako, Saitama 351-0198, Japan

The field of ultrafast opto-spintronics has emerged with a pioneering work on ferromagnetic Ni[1). As one of the recent topics, we introduce our time-resolved spectroscopic studies on topological spin textures.

Magnetic skyrmions, spin vortices of topological origin, have been identified in several magnetic materials and at interfaces[2). Their lateral extent depends on the magnetic interactions involved; some chiral magnets with the Dzyaloshinskii-Moriya interaction produce skyrmions with the size of 1-200 nm, which are suitable for magnetic information devices. These skyrmions show various emergent electromagnetic interactions, such as topological and Skyrmion Hall effects[2), and can be driven under an extremely small charge current or by magnons. The optical response/control of this nano-magnetic structure, in an ultrafast manner, will be of practical importance.

We report real-time dynamics of skyrmions in an insulating ferrimagnet $Cu_2OSeO_3$ [3), studied by all-optical spin-wave spectroscopy. The spins in the helical, conical, and skyrmion phases were excited by the impulsive magnetic field of the inverse Faraday effect[4) at non-absorbing photon energies, 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 and magnetic field. In the skyrmion phase, three collective excitations were identified, distinct from those in the surrounding conical phases (Fig. 1). These spin dynamics can be readily assigned to the clockwise/counter-clockwise rotations and breathing modes of the skyrmion crystal.

In addition to identifying the dynamics of topological spin textures, we are able to infer the spatial propagation and interaction of the magnetic excitations in these nano-magnetic spin structures by using variety of optical/microscopy techniques. As an example, we demonstrate an optical-drive of magnetic bubbles, which can be topologically equivalent to the skyrmion. In this case, magnetoelastic waves, coupled propagations of magnon and phonon, were photoexcited in iron garnet films. These magnetic excitations were found to interact with magnetic domains and domain walls more efficiently when the domain wall has steeper curvature[5) (Fig. 2).

If time allows, we will also discuss the spin-polarized photocurrent generation in ferromagnetic topological insulators, in which the mass-gap in the Dirac dispersion can be controlled by an external magnetic field.

Reference
1) E. Beaurepaire *et al.*, Phys. Rev. Lett. **76,** 4250 (1996).
2) N. Nagaosa and Y. Tokura, Nature Nanotechnol. **8,** 899 (2013).
3) N. Ogawa, S. Seki, and Y. Tokura, Sci. Rep. **5,** 9552 (2015).
4) A. Kirilyuk, A.V. Kimel, and T. Rasing, Rev. Mod. Phys. **82**, 2731 (2010).
5) N. Ogawa *et al.*, Proc. Natl, Acad. Sci. **112,** 8977 (2015).

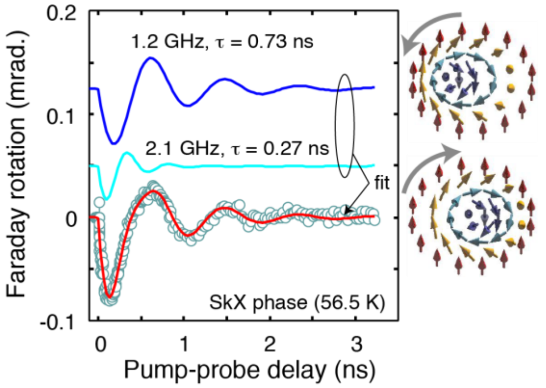


Fig.1 Spin precessions in skyrmion crystal phase.

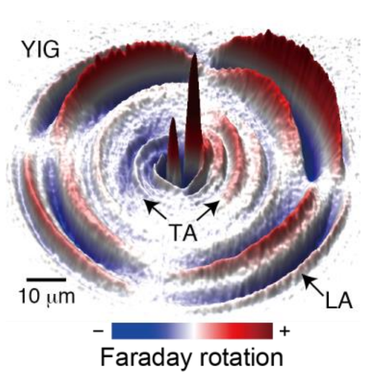


Fig.2 Optically-excited magnetoelastic wave.