Spin torque driven Skyrmion resonance technique in magnetic bulk crystals

(In-depth report)

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Skyrmions are attractive candidates for ultra-dense magnetic data storage and distribution applications. Conventionally, Dzyaloshinskii-Moriya interaction (DMI) is responsible for the Skyrmion's topological protection. Recently, frustration in ferromagnetic (FM) crystals was predicted of also being capable of providing the topological protection of the Skyrmion [1] without relying on the DMI and the effect was immediately discovered in Fe_3Sn_2 crystals [2]. Surprisingly, these Skyrmions survive at temperatures well above room temperature and are controllable by electrical currents illustrating the exceptional technological potential of the Fe_3Sn_2 systems.

Here were present a new technique for studying the skyrmion ferromagnetic resonance (FMR) in a bulk Fe_3Sn_2 crystal where the dynamical response is excited by an AC spin-torque in a fashion that is reminiscent of the spin-torque FMR experiment (Fig. 1(a)). Using phase-locked optical pulses that probe the Skyrmion resonance response in the time, we identify the counter-clockwise and breathing skyrmion modes. From the evolution of the modes, we further map the magnetic skyrmion phase transitions (Fig. 1(b)). The measurements are complemented with dynamical object oriented micromagnetic framework (OOMMF) simulations that reveals a phase transition from a disordered phase to the stripe phase and eventually a uniform crystal lattice forms.

The generality of the presented technique paves way towards resolving the spin dynamics in nonconventional magnetic crystals.

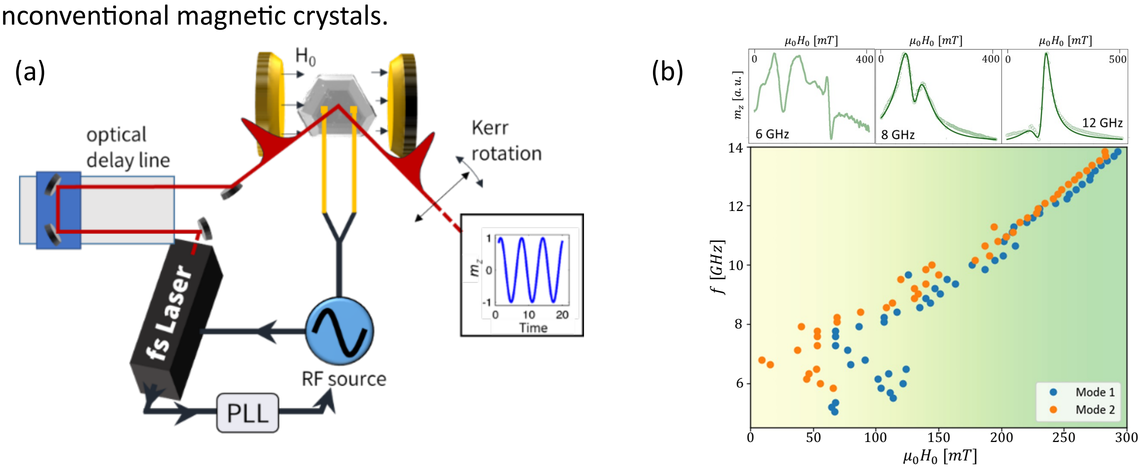

Fig. 1. (a) The optically probed spin torque FMR technique. An AC charge current is passed through the sample and excites the FMR. The FMR response was probed using an 80 MHz Ti:Sapphire laser emitting 35 fs pulses at 800 nm that was phase locked to a microwave signal oscillating. The polar magneto-optical Kerr effect probes the out-of-plane component of the AC magnetization. (b) Top panel: measured FMR spectra at 6, 8 and 12 GHz. bottom panel: evolution of resonance frequency of the breathing and CCW modes with applied magnetic field.

[1] A. O. Leonov and M. Mostovoy, *"Multiply periodic states and isolated skyrmions in an anisotropic frustrated magnet"*, Nature Communications 6, 8275 (2015).

[2] Z. Hou, W. Ren, B. Ding, G. Xu, Y. Wang, B. Yang, Q. Zhang, Y. Zhang, E. Liu, F. Xu, W. Wang, G. Wu, X. Zhang, B. Shen, and Z. Zhang, *"Observation of Various and Spontaneous Magnetic Skyrmionic Bubbles at Room Temperature in a Frustrated Kagome Magnet with Uniaxial Magnetic Anisotropy"*, Advanced Materials 29, 1701144 (2017).