2nd Transnational Round Table on Magnonics, High-Frequency Spintronics, and Ultrafast Magnetism

Hybrid coherent control of magnons in a ferromagnetic phononic resonator excited by laser pulses

A. V. Scherbakov,[1] A. D. Carr,[2] T. L. Linnik,[1,3] S. M. Kukhtaruk,[1] A. D. Armour,[2] A. Nadzeyka,[4] A. W. Rushforth,[2] A. V. Akimov,[2] and M. Bayer[1]

1: Experimentelle Physik 2, Technische Universität Dortmund, 44227 Dortmund, Germany;

2: School of Physics and Astronomy, University of Nottingham, NG7 2RD Nottingham, UK;

3: Department of Theoretical Physics, V. E. Lashkaryov Institute of Semiconductor Physics, 03028 Kyiv, Ukraine;

4: Raith GmbH, 44263 Dortmund, Germany.

Self-nomination for keynote talk: an in-depth report of a recent discovery.

Phonons are quasi-particles that result from the quantisation of vibrations within a crystal lattice, analogously magnons result from quantising spin waves. Coherent phonons can be used to drive magnons in a similar way as electromagnetic waves drive spin excitations [1]. These experiments were performed on a ferromagnetic, magnetostrictive 20 nm thick Galfenol ($Fe_{0.81}Ga_{0.19}$) film, with a nanograting (grooves are 7 nm deep and 48 nm wide; the period is 120 nm) ion milled into the surface. Since the milling process used Ga^{2+} ions the milled areas have a higher concentration of Ga. This film was excited via femtosecond laser pulse which causes the excitation of magnons by two mechanisms: (1) coherent Rayleigh phonons with frequency 20.1 GHz excited in the nanograting; (2) ultrafast torque pulse acting on the magnetisation vector. Because there are two interacting mechanisms of different origins, inference-based effects can be observed and controlled within the magnon system via the same laser pulse.

In the experiments, we exploit the ultrafast magnetoacoustic technique [2]. We use two synchronised femtosecond lasers as pump and probe beam sources. The ASOPS scheme [3] is used for obtaining temporal signals with 1 ps time resolution. A magnetic field is applied in the plane of the sample at 45° from the normal direction of the grooves in the nanograting. The magnon dynamics is measured by detecting the polarisation rotation (Kerr effect) of the reflected probe beam.

Figure 1 is produced by taking the FFT of the temporal magnon signals for different magnetic fields and plotting the spectra as a colour map. Furthermore, theoretical analysis has been conducted based on the Landau-Lifschitz-Gilbert equation which matches the experimental results and supports the explanation of the observed spectral features in the magnon spectra as the interference of responses from Rayleigh coherent phonons and ultrafast torque induced by the laser pulse.

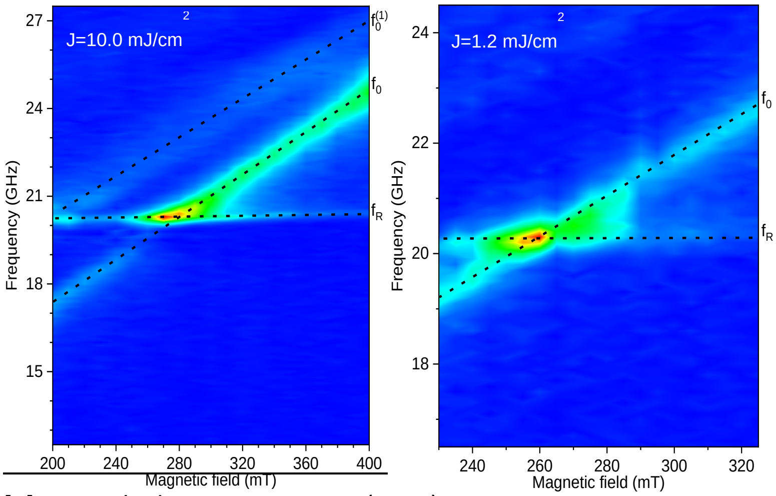

Fig. 1. Colour maps illustrating the increasing magnon frequency with increasing magnetic field (f_0) and the static phonon frequency (f_R). (a) shows the spectrum generated by a laser fluence of 10.0 mJ/cm^2 which results in destructive interference before the magnon-phonon resonance interaction and constructive interference after this interaction (b) shows that at lower laser fluence this interference-based effect is no longer present.

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[2] A.S. Salasyuk et al., Phys. Rev. B, **97**, 060404(R) (2018).

[3] A. Bartelsa etal., Rev. Sci. Instrum. **78**, 035107 (2007).