MA 34: Focus Session: Spin-Phonon Coupling

Recent work on ultrafast demagnetization in ferromagnets has demonstrated that angular momentum can be transferred from the spin system to the lattice on ultrashort time scales. These findings demonstrate that a detailed understanding of the mechanisms that transfer angular momentum between the spin system and the lattice are of key importance in spintronics. The goal of this focus session is to give an overview over spin-phonon coupling effects in solids, ranging from the Einstein-de Haas effect on ultrafast time scales to magnon-phonon coupling and acoustic spin pumping at GHz frequencies. Coordinators: Tobias Kampfrath, Freie Universität Berlin and Uli Nowak, Universität Konstanz.

Time: Thursday 9:30–13:00 Location: HSZ 02

Invited Talk MA 34.1 Thu 9:30 HSZ 02
Polarized phonons carry angular momentum in ultrafast demagnetization — •Peter Baum — Universität Konstanz, Germany

Many laser-excited magnetic materials lose their magnetic order almost completely within femtosecond timescales, but where is the missing angular momentum in such a short time? Here we use ultrafast electron diffraction with THz-compressed electron pulses to reveal in nickel an almost instantaneous, long-lasting, non-equilibrium population of anisotropic high-frequency phonons with an anisotropy plane that is perpendicular to the direction of the initial magnetization. We explain these observations by means of circularly polarized phonons that quickly absorb the angular momentum of the spin system before macroscopic sample rotation. The time that is needed for demagnetization is related to the time it takes to accelerate the atoms. These results provide an atomistic picture of the Einstein-de Haas effect and signify the general importance of polarized phonons for non-equilibrium dynamics and phase transitions.

Invited Talk MA 34.2 Thu 10:00 HSZ 02
Spin-phonon coupling in ordered magnets: origin and consequences — •Akashdeep Kamra — Universidad Autónoma de Madrid, Madrid, Spain

Interaction between the spin and lattice degrees of freedom in magnets underlies a broad range of phenomena from magnetic damping to the Einstein-de Haas effect. Despite its long history and high importance, an adequate understanding of spin-phonon coupling's origin and potential consequences have eluded us. In this talk, we will discuss the microscopic mechanisms and related symmetry-breaking that underlie the spin-phonon coupling thereby achieving guidance on how to engineer it. In this discussion, we will pay special attention to the rotational invariance or total angular momentum conservation and how to account for it in the simulation of coupled spin and lattice dynamics. Then, we will examine some of the direct consequences of this coupling, focusing on magnon-polaron formation in ferro and antiferromagnets as well as the Einstein-de Haas effect in magnetic nanoparticles. If time permits, we will briefly discuss future directions and challenges.

References:
[1] M. Weißenhofer et al., arXiv:2211.02382.
[2] H. T. Simensen et al., Phys. Rev. B 99, 064421 (2019).
[3] A. Kamra et al., Phys. Rev. B 91, 104409 (2015).

Invited Talk MA 34.3 Thu 10:30 HSZ 02
Magnon-mechanics in high overtone acoustic resonators — •Hans Huebl — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — School of Natural Sciences, Technische Universität München, Garching, Germany — 3Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Magnetoelastic coupling between excitation modes of the spin system (spin waves) and the lattice (phonons) is of interest from a fundamental perspective and can enable mode hybridization. For quantum sensing and transduction protocols, excitation exchange between the magnetic and elastic systems is of importance, however typically this requires strong coupling between the modes. In this presentation, I will present our current results on coupling the magnetization dynamics of a Kittel mode to a high-overtone bulk acoustic resonator and discuss this hybrid system in the context of sensing and transduction.

15 min. break

Invited Talk MA 34.4 Thu 11:15 HSZ 02
Cavity Magnomechanics: Harnessing the Magnomechanical Coupling for Applications in the Microwave and Optical Regimes — •Silvia Viola Kusminskiy — Institute for Theoretical Condensed Matter, RWTH Aachen University, 52074 Aachen, Germany — Max Planck Institute for the Science of Light, Staudtstr. 2 91058 Erlangen, Germany

Cavity magnonic systems are ideally suited to explore the range of possibilities opened by tailoring the interactions between photons, phonons, and magnons. In this talk I will discuss the different coupling mechanisms and propose applications ranging from quantum thermometry to wavelength conversion.

Invited Talk MA 34.5 Thu 11:45 HSZ 02
Coherent spin-wave transport in an antiferromagnet — •Andrea Caviglia — Department of Quantum Matter Physics, University of Geneva, 24 Quai Ernest Ansermet, CH-1211 Geneva, Switzerland

Magnonics is a research field complementary to spintronics, in which the quanta of spin waves replace electrons as information carriers, promising lower dissipation. The development of ultrafast, nanoscale magnonic logic circuits calls for new tools and materials to generate coherent spin waves with frequencies as high and wavelengths as short as possible. Antiferromagnets can host spin waves at terahertz frequencies and are therefore seen as a future platform for the fastest and least dissipative transfer of information. However, the generation of short-wavelength coherent propagating magnons in antiferromagnets has so far remained elusive. Here we report the efficient emission and detection of a nanometre-scale wavepacket of coherent propagating magnons in the antiferromagnetic oxide dysprosium orthoferrite using ultrashort pulses of light. The subwavelength confinement of the laser field due to large absorption creates a strongly non-uniform spin excitation profile, enabling the propagation of a broadband continuum of coherent terahertz spin waves. The wavepacket contains magnons with a shortest detected wavelength of 125nm that propagate into the material with supersonic velocities of more than 13kms-1. This source of coherent short-wavelength spin carriers opens up new prospects for terahertz antiferromagnetic magnonics and coherence-mediated logic devices at terahertz frequencies.

MA 34.6 Thu 12:15 HSZ 02
Magnon-phonon coupling in polycrystalline metallic thin films — •Manuel Müller[1,2], Johannes Weber[1,2], Fabian Engelhardt[3,4,5], Victor A. S. V. Bittencourt[3,6], Thomas Luschmann[1,2,7], Silvia Viola Kusminskiy[5,3], Stephan Geprägs[1], Rudolf Gross[1,2,7], Matthias Althammer[1,2], and Hans Huebl[1,2,7] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]TUM School of Natural Sciences, Technische Universität München, Garching, Germany — [3]Max Planck Institute for the Science of Light, Erlangen, Germany — [4]Department of Physics, University Erlangen-Nuremberg, Erlangen, Germany — [5]Institute for Theoretical Solid State Physics, RWTH Aachen University, Aachen, Germany — [6]ISIS (UMR 7006), Université de Strasbourg, 67000 Strasbourg, France — [7]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Magnetoelastic coupling between wave-like excitations of the spin system (spin waves) and the lattice (elastic waves) can result in a hybridization of both modes. This is of interest for future applications, such as microwave-to-optics transducers and phononic spin valve devices. As a finite magnetoelastic coupling affects the magnetization dynamics of the magnetic layer, it can be characterized with high sensitivity using ferromagnetic resonance spectroscopy. By using broadband ferromagnetic resonance spectroscopy, we have studied study the magnetoelastic coupling between silicon and sapphire substrates and ferromagnetic thin films deposited on them via DC sputtering.

MA 34.7 Thu 12:30 HSZ 02

Parametric excitation and instabilities of spin waves driven by surface acoustic waves — •Moritz Geilen[1], Roman Verba[2], Alexandra Nicoloiu[3], Daniele Narducci[4], Adrian Dinescu[2], Milan Ender[1], Morteza Mohseni[1], Florin Ciubotaru[4], Mathias Weiler[1], Alexandru Müller[3], Burkard Hillebrands[1], Christoph Adelmann[4], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern Landau, Germany — [2]Institute of Magnetism, Kyiv, Ukraine — [3]National Institute for Research and Development in Microtechnologies, Bucharest, Romania — [4]imec, Leuven, Belgium

We present our experimental results on the parametric excitation of spin waves by coherent surface acoustic waves in metallic magnetic thin film structures. The involved magnon modes are analyzed with micro-focused Brillouin light scattering spectroscopy and complementary micromagnetic simulations combined with analytical modelling to determine the origin of the spin-wave instabilities. Depending on the experimental conditions, we observe spin-wave instabilities originating from different phonon-magnon and magnon-magnon scattering processes. Our results demonstrate that an efficient excitation of high amplitude, strongly nonlinear magnons in metallic ferromagnets is possible by surface acoustic waves, which opens novel ways to create micro-scaled nonlinear magnonic systems for logic and data processing.

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MA 34.8 Thu 12:45 HSZ 02

Magnetic ordering and spin-lattice interactions in $M\mathrm{CrO}_2$ and $M\mathrm{CrS}_2$ (with M = Li, Na, K, Cu, Ag, Au) — •S. Mankovsky, H. Lange, S. Polesya, and H. Ebert — Department Chemie, Ludwig Maximilian University, Munich, Germany

The triangular lattice antiferromagnets (TLA) are discussed in the literature as materials exhibiting a variety of magneto-elastic and magneto-electric properties determined by a complex magnetic structure driven by magnetic frustrations. In the present work we have investigated two groups of TLA compounds, $M\mathrm{CrO}_2$ and $M\mathrm{CrS}_2$, with M = Li, Na, K, Cu, Ag, Au. Their properties are discussed on the basis of first-principles calculations of their electronic structure as well as exchange coupling and spin-lattice coupling (SLC) parameters. The properties of these two groups are expected to be quite different, among others, because of a different distance dependency of the Cr-Cr exchange interactions. In particular one finds that the Cr layers in $M\mathrm{CrS}_2$ cannot be treated as independent, in contrast to $M\mathrm{CrSO}_2$ with quasi-2D frustrated AFM Cr layers. We discuss different contributions to the magnon-phonon interaction responsible for a modification of the phonon spectra in these materials, as well as a transition to the AFM state in some of them, accompanied by a lattice distortion as observed by experiment. In addition, a contribution of the inverse Dzyaloshinskii-Moriya (DM) interaction mechanism [PRL **95**, 057205 (2005)] to the ferroelectric properties driven by the magnetic ordering is discussed on the basis of the calculated DM-SLC parameters.