TT 34: Focus Session: Dynamical Probes for Topological Magnetism

Non-equilibrium phenomena are attracting a great deal of interest. One of the main reasons for this intense research effort is to establish the coherent control of quantum states. Magnetic systems constitute promising platforms in this respect because they display quantum properties already in the groundstate. Moreover, several manifestation of coherent spin dynamics in a wide variety of materials and in different regimes (linear, nonlinear, transport, THz frequencies) have been reported. Topological protection of their quantum states adds to the advantageous properties. In view of these aspects, the proposed focus session is intended to present experimental and theoretical advances ranging from ab initio calculations over model simulations to experiments demonstrating the generation, control and detection of spin dynamics.

Organizers: Davide Bossini (University of Konstanz), Götz Uhrig (TU Dortmund University)

Time: Wednesday 9:30–12:15 Location: H 0104

Invited Talk TT 34.1 Wed 9:30 H 0104

A phononic route to ultrafast control of magnetic order — •Andrei Kirilyuk — FELIX Laboratory, Radboud University, 6525 ED Nijmegen, The Netherlands

Strong light-matter interaction constitutes the basis of all photonic applications, empowering material elements to create and mediate interactions of light with light. Among others, phonon-amplified interactions were shown to bring a specific twist into this. In this case, light couples to the spins indirectly by exciting coherent vibrations of the crystal lattice (phonons) that transfer angular momentum to the magnetic ions. The optically driven chiral phonons were shown to possibly produce giant effective magnetic fields. The mechanism allows for bidirectional control of the induced magnetisation through phonon chirality that in turn can be controlled by the polarisation of the laser pulse.

Here we show that through the resonant excitation of circularly-polarized optical phonons in paramagnetic substrates, one can permanently reverse the magnetic state of the substrate-mounted heterostructure. With the handedness of the phonons steering the direction of magnetic switching, such effect offers a selective and potentially universal method for ultrafast non-local control over magnetic order.

Moreover, a different behavior, characterized by displacive modification of magnetic potentials, can be observed when exciting materials at phonon frequencies with linearly-polarized light. The magnetic switching was shown to create very peculiar patterns, confirming the mechanism.

Invited Talk TT 34.2 Wed 10:00 H 0104

Spectroscopic signatures of spin dynamics in spin-orbit-coupled magnets: resolving quantum spin liquids versus magnetically ordered phases — •Roser Valenti — Institute of Theoretical Physics, Goethe University Frankfurt, Frankfurt a.M., Germany

In the search for material realizations of quantum spin liquid phases, spin-orbit coupled magnets – such as the so-called Kitaev materials – have been intensively studied for the last decade. Quantum spin liquid states are characterized by the absence of long-range order even at zero temperature and the presence of exotic fractionalized excitations, in contrast to spin-wave excitations found in conventional magnets. Experimentally probing and theoretically modelling the signatures and topology of these excitations is a challenging task.

In this talk we will first review and discuss the microscopic modelling of spectroscopic signatures (Raman, INS, THz) of spin dynamics in spin-orbit coupled magnets, and we will then move to nonlinear spectroscopy. Nonlinear spectroscopy has been recently suggested as a potentially powerful tool to distinguish coherent fractionalized excitations from effects of disorder or finite lifetime, which are difficult to distinguish in linear response excitation continua. In this spirit, we will introduce methods to efficiently calculate nonlinear response functions numerically, and will present results for extended Kitaev models that are relevant for the description of real materials.

Work done in collaboration with David Kaib, Marius Möller and Wolfram Brenig and funded by the DFG /TRR288.

Invited Talk TT 34.3 Wed 10:30 H 0104

Probing spin dynamics by Hall effect and emergent inductance — •Max Hirschberger[1,2], Jan Masell[2,3], and Rinsuke Yamada[1] — [1]Dept. of Applied Physics, Univ. Tokyo, Tokyo, Japan — [2]RIKEN Center for Emergent Matter Science, Wako, Japan — [3]Karlsruhe Institute of Technology, Karlsruhe, Germany

For helimagnetic textures, an ongoing interest is the investigation of spin dynamics driven by current, or generated by thermal fluctuations. We study thermally induced spin chirality using the Hall / Nernst effects [1,2], and aim to develop inductance measurements, that is the detection of a phase-shifted voltage in response to a current excitation, as a tool to probe the low-lying excitations of spirals and cycloids, supporting thermodynamic and neutron scattering techniques.

Nagaosa (2019) first proposed that current-induced spin tilting of a proper screw or cycloid texture in metallic helimagnets generates an emergent electric field $\mathbf{e}_{em}$ that is time delayed with respect to the excitation current; namely, an inductive response. This $\mathbf{e}_{em}$ can be understood as spin winding in a two-dimensional plane spanned by time and space axes [3]. We have studied $\mathbf{e}_{em}$ in spiral magnets, such as $Gd_3Ru_4Al_{12}$, and found a sizable response that is linear in frequency, but nonlinear in the excitation current [4,5].

[1] K. Kolincio, M. Hirschberger *et al.*, PNAS **118** (2021) e2023588118
[2] K. Kolincio, M. Hirschberger *et al.*, PRL **130** (2023) 136701
[3] N. Nagaosa, Jpn. J. Appl. Phys. **58** (2019) 120909
[4] T. Yokouchi, F. Kagawa, M. Hirschberger *et al.*, Nature **586** (2020) 232
[5] R. Yamada, M. Hirschberger, *et al.*, in preparation (2024)

15 min. break

Invited Talk TT 34.4 Wed 11:15 H 0104

Dissipative Spin-wave Diode and Nonreciprocal Magnonic Amplifier — •Jelena Klinovaja, Ji Zou, Stefano Bosco, Even Thingstad, and Daniel Loss — Department of Physics University of Basel Klingelbergstrasse 82 4056 Basel, Switzerland

We propose an experimentally feasible dissipative spin-wave diode comprising two magnetic layers coupled via a non-magnetic spacer. We theoretically demonstrate that the spacer mediates not only coherent interactions but also dissipative coupling. Interestingly, an appropriately engineered dissipation engenders a nonreciprocal device response, facilitating the realization of a spin-wave diode. This diode permits wave propagation in one direction alone, given that the coherent Dzyaloshinskii- Moriya (DM) interaction is balanced with the dissipative coupling. The polarity of the diode is determined by the sign of the DM interaction. Furthermore, we show that when the magnetic layers undergo incoherent pumping, the device operates as a unidirectional spin-wave amplifier. The amplifier gain is augmented by cascading multiple magnetic bilayers. By extending our model to a one-dimensional ring structure, we establish a connection between the physics of spin-wave amplification and non-Hermitian topology. Our proposal opens up a new avenue for harnessing inherent dissipation in spintronic applications.

[1] Ji Zou, S. Bosco, E. Thingstad, J. Klinovaja, D. Loss, arXiv:2306.15916

Invited Talk TT 34.5 Wed 11:45 H 0104

Floquet magnons in a periodically-driven magnetic soliton — •Helmut Schultheiss — Helmholtz-Zentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung, Dresden, Germany — Fakultät Physik, Technische Universität Dresden, Dresden, Germany

Magnetic vortices are prominent examples for topology in magnetism with a rich set of dynamic properties. They exhibit an intricate magnon spectrum and show a special eigen-resonance of the vortex texture itself, the gyroscopic motion of the vortex core. While there has been studies about magnon assisted reversal of the vortex core polarity, the impact of the vortex core motion on the magnon spectrum wasn't addressed so far. Both excitation types are clearly separated by one order of magnitude in their resonance frequencies, where magnons are in the lower GHz range and the vortex typically gyrates at a few hundred MHz. This clear separation allows for experiments studying the temporal evolution of the magnon spectrum when the motion of the vortex core is driven by an external stimulus. We present experimental and numerical studies on how the magnon eigenstates are transformed into Floquet bands, when the vortex ground state is periodically modulated in time by the gyroscopic motion of the vortex core. The existence of the Floquet bands is evidenced by the appearance of magnon frequency combs, where the comb spacing is determined by the frequency of the gyroscopic motion.