MA 16: Magnonics

Time: Tuesday 9:30–12:00 Location: HSZ 403

MA 16.1 Tue 9:30 HSZ 403

Resonances in periodically driven magnon systems — •Jan Mathis Giesen, Christoph Dauer, Imke Schneider, Sebastian Eggert, Alexandre Abbass Hamadeh, and Philipp Pirro — Department of Physics and Research Center Optimas, Technical University of Kaiserslautern, 67663 Kaiserslautern, Germany

Parametric resonances in ferro- and ferri-magnetic systems under a periodic drive are known for quite some while. So called parallel pumping, which is for example used to realize Magnon BECs in materials like YIG, is normally achieved by driving the system with twice the frequency of a certain magnon mode. Much less research has been dedicated to lower lying resonances, which in theory should also be possible and give rise to some interesting behaviours.

We establish a method based on Floquet theory to efficiently determine and examine instabilities of the microscopic magnon system. As a central consequence parametric resonances occur if the driving frequency is an integer multiple of two times the energy of the elementary excitation. In particular we examine regions of resonances for frequencies below the energy spectrum and predict different effects depending on the driving amplitude and frequency, like the vanishing of instabilities at high driving fields. We compare our results with phenomenological approaches to investigate the role damping plays in such systems and perform micromagnetic simulations in order to confirm our results.

MA 16.2 Tue 9:45 HSZ 403

Topological Hybrids of Magnons and Magnon Bound Pairs — Alexander Mook[1], •Rhea Hoyer[1], Jelena Klinovaja[2], and Daniel Loss[2] — [1]Johannes Gutenberg-University, Mainz, Germany — [2]University of Basel, Basel, Switzerland

We employ anisotropic and spin-nonconserving Heisenberg models on Bravais lattices to predict the existence of topological quantum spin excitations in ferromagnets. We show that a hybridization of a single magnon and a two-magnon bound state can lead to topological spectral gaps that support quantum-Hall-like edge excitations. Such topological chiral hybrids of magnons and magnon pairs are a quantum phenomenon that vanishes in the classical limit and goes beyond the established theory of magnon topology.

Reference: Mook, Hoyer, Klinovaja, Loss, arXiv:2203.12374.

MA 16.3 Tue 10:00 HSZ 403

Finite-element micromagnetic modeling of spin-wave propagation with the open-source package TetraX — •Lukas Körber[1,2], Gwendolyn Quasebarth[1,2], Alexander Hempel[1,2], Andreas Otto[2], Jürgen Fassbender[1,2], and Attila Kákay[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Bautzner Landstraße 400, Dresden Germany — [2]Fakultät Physik, Technische Universität Dresden

We present a finite-element-method (FEM) dynamic-matrix approach to efficiently calculate the dispersion and spatial mode profiles of spin waves propagating in waveguides with arbitrary cross-section, where the equilibrium magnetization is invariant along the propagation direction. This is achieved by solving a linearized version of the equation of motion of the magnetization numerically only in a single cross-section of the waveguide at hand. To compute the dipolar field, we present an extension of the well-known Fredkin-Koehler method to plane waves. The presented dynamic-matrix approach is implemented within our recently published open-source micromagnetic modeling package TetraX [1], which aims to provide user-friendly and versatile FEM workflows for the magnonics community (not only for the magnonics community but FEM simulations in general), covering several classes of sample geometries and, soon, also antiferromagnets. As a brief introduction, this talk will include a short live demo of TetraX.

[1] https://gitlab.hzdr.de/micromagnetic-modeling/tetrax

MA 16.4 Tue 10:15 HSZ 403

Confinement of Bose-Einstein magnon condensates in adjustable complex magnetization landscapes — •Matthias R. Schweizer, Alexander J.E. Kreil, Georg von Freymann, Alexander A. Serga, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Germany

We demonstrate the capability to control a room-temperature magnon Bose–Einstein condensate (BEC) by spatial modulation of the saturation magnetization. We use laser heating in combination with a phase-based wavefront modulation technique to create adjustable temperature patterns in an yttrium-iron-garnet film. The increase in temperature leads to a decrease of the local saturation magnetization and in turn to the modification of the corresponding BEC frequency. Over time, a phase accumulation between different BEC-areas arises, leading to phase-driven magnon supercurrents.

The BEC is created by microwave parametric pumping and probed by Brillouin light scattering spectroscopy. We observe a strong magnon accumulation effect caused by magnon supercurrents for several distances between heated regions. This accumulation effect manifests itself in the confinement of the magnon BEC, which exhibits an enhanced lifetime due to the continuous influx of magnons.

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – TRR 173 – 268565370 (project B04).

15 min. break

MA 16.5 Tue 10:45 HSZ 403

Time-correlated nonlinear spiking spin waves in Ga:YIG — •David Breitbach[1], Moritz Bechberger[1], Björn Heinz[1], Jan Maskill[1], Bert Lägel[1], Carsten Dubs[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]INNOVENT e.V. Technologieentwicklung, Jena, Germany

Nonlinear spin-wave phenomena are key for magnon-based information processing and have led to the realization of numerous building blocks for spin-wave based computing. For coherent spin waves, the nonlinear frequency shift is one of the most robust nonlinear effects. In this study, we utilize this effect to build a spin-wave reservoir with temporal signal correlation. We apply time-resolved BLS microscopy to investigate the coherent excitation of spin waves by a microantenna in an in-plane magnetized, gallium-substituted yttrium iron garnet film. This system exhibits an exchange-dominated dispersion relation and PMA, resulting in a positive nonlinear frequency shift. We observe a strongly power-dependent nonlinear excitation and show that the nonlinear frequency shift creates an effective interaction between successive spin-wave excitations. This effectively serves as a fading memory in the system which can be used to temporally correlate input signals. Our work provides a foundation for future implementations of reservoir and neuromorphic computing in magnonic systems. This research is funded by the DFG - Project No. 271741898 and TRR 173-268565370 (B01) and by the ERC Grant No. 101042439 'CoSpiN'.

MA 16.6 Tue 11:00 HSZ 403

Simultaneous multitone microwave emission by DC-driven spintronic nano-element — •A. Hamadeh[1], D. Slobodianiuk[2,3], R. Moukhader[4], G. Melkov[2], V. Borynskyi[3], M. Mohseni[1], G. Finocchio[4], V. Lomakin[5], R. Verba[3], G. de Loubens[6], P. Pirro[1], and O. Klein[7] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Taras Shevchenko National University of Kyiv, Kyiv 01601, Ukraine — [3]Institute of Magnetism, Kyiv 03142, Ukraine — [4]Dept. Mathematical and Computer Sciences, Physical Sciences and Earth Sciences, University of Messina, 98166 Messina, Italy — [5]Center for Magnetic Recording Research, University of California San Diego, La Jolla, California 92093-0401, USA — [6]SPEC, CEA, CNRS, Université Paris-Saclay, 91191 Gif-sur-Yvette, France — [7]Univ. Grenoble Alpes, CEA, CNRS, Grenoble INP, INAC-Spintec, 38054 Grenoble, France

The generation of microwave radiation by DC-driven spintronic elements is generally considered a process that generates only one frequency at a time. In our study however, we can show by means of experimental data, micromagnetic simulations, and an analytical model that several frequencies can be generated simultaneously due to nonlinear magnon coupling. This discovery opens the way for entirely new multiplexing techniques and synchronization mechanisms that can be used for communication and neuromorphic computing.

MA 16.7 Tue 11:15 HSZ 403

Sensing magnetic excitations in two-dimensional materials with single NV-centers — •Hossein Mohammadzadeh, Dominik Maile, and Joachim Ankerhold — Institute for Complex Quantum Systems Albert-Einstein-Allee 11 D-89069 Ulm

Magnetism in two-dimensional (2D) van der Waals (vdW) materials has recently emerged as one of the most promising areas in condensed matter research, with a significant potential for applications ranging from topological magnonics to low-power spintronics, quantum computing, and optical communications [1]. In this talk, we theoretically investigate the possibility of sensing magnetic excitations in such materials with nitrogen-vacancy (NV) center in diamond. The NV center in diamond is an excellent platform for noninvasively detecting nanoscale signatures and magnetic domain walls [2]. We present a description of the low-energy magnetic excitations within a Kitaev-Heisenberg model for a honeycomb lattice. Coupling these excitations to the single NV-electronic spin paves the way to use magnetic noise spectroscopy to probe magnons in such a system. Utilizing Fermi*s golden rule and quantum linear response theory, we show how the spin relaxation time of the NV alters in the magnetic field induced by magnons in both bulk and topologically protected edge states. The relaxation time of the NV changes by different NV-sample distances and in various strengths of spin-spin interactions inside the material.

[1] Qing Hua Wang et al., ACS Nano, 16, 5, 6960-7079 (2022)
[2] Jörg Wrachtrup et al. Nat Commun 12, 1989 (2021)

MA 16.8 Tue 11:30 HSZ 403

Magnetic excitations in the conductive altermagnet RuO2: ab initio calculations — •Alberto Marmodoro[1], Sergiy Mankovsky[2], Hubert Ebert[2], Ilja Turek[3], Tomas Jungwirth[1], and Ondřej Šipr[1,4] — [1]Institute of Physics (FZU) of the Czech Academy of Sciences, Prague, Czech Republic — [2]Department of Chemistry, Ludwig-Maximilians- University (LMU), Munich, Germany — [3]Institute of Physics of Materials (IPM) of the Czech Academy of Sciences, Brno, Czech Republic — [4]New Technologies Research Centre, University of West Bohemia, Pilsen, Czech Republic

Altermagnets are materials with zero net magnetization, alike traditional antiferromagnets, as well as a characteristic alternation of spin polarization for the electronic structure in reciprocal space, due to the relative orientation for anisotropic crystal field effects on different magnetic sublattices in direct space. This may have significant implications for possible spintronics and nano-electronics applications [1]. We report about the ab initio study of magnetic excitations in the case of the conducting, colinear antiferromagnetic altermagnet material RuO2 [2].

[1] http://doi.org/10.1103/PhysRevX.12.031042
[2] http://doi.org/10.48550/arXiv.2211.13806

MA 16.9 Tue 11:45 HSZ 403

Investigation of magnon-phonon coupling in two dimensional ferromagnetic Fe_3GeTe_2 — •Namrata Bansal[1], Qili Li[1], Paul Nufer[1], Hung-Hsiang Yang[1], Lichaun Zhang[2], Dongwook Go[2], Amir-Abbas Haghighirad[3], Yuriy Mokrousov[2,4], and Wulf Wulfhekel[1,3] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]Peter Gruenberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1) Forschungszentrum Juelich GmbH, D-52425 Juelich — [3]Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [4]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany

We use inelastic tunneling spectroscopy (ITS) at 35 mK to investigate phonon-magnon coupling in the ferromagnetic van der Waals crystals Fe3GeTe2 (FGT). ITS is a powerful tool for determining the inelastic scattering of hot carriers with magnons or phonons with the second derivative of the tunneling current with respect to the bias voltage being proportional to the density of states of phonons and/or magnons. We observe excitation peaks at low energy which do not correspond to van Hove singularities of the phonon or magnon density of states but to points in their dispersion, where magnon and phonon bands cross, indicative for phonon-magnon coupling.