MA 3: Magnonics I

Time: Monday 9:30–13:00 Location: H18

MA 3.1 Mon 9:30 H18

Floquet Magnons in a Periodically-Driven Magnetic Vortex — •Christopher Heins[1,2], Luaks Körber[1,2,3], Joo-Von Kim[4], Thibaut Devolder[4], Johan Mentink[3], Attila Kákay[1], Katirn Schultheiss[1], Jürgen Fassbender[1,2], and Helmut Schultheiss[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Radboud University, Institute of Molecules and Materials, Nijmegen, The Netherlands — [4]Centre de Nanosciences et de Nanotechnologies, CNRS, Université Paris-Saclay, Palaiseau, France

Magnetic vortices are prominent examples of topology in magnetism with a rich set of dynamic properties. They exhibit an intricate magnon spectrum and show an eigen-resonance of the vortex texture itself, the gyration of the vortex core. The fundamental modes of both excitation types are separated in their resonance frequencies. While the vortex typically gyrates at a few hundred MHz, the magnon modes typically have frequencies in the lower GHz range. Under the influence of a periodic driving field, Floquet states emerge due to a temporal periodicity imposed on the system's ground state by the gyration, much like the formation of Bloch states in the periodic potential of a crystal lattice. While Bloch states are shifted in momentum space, Floquet states are shifted in energy by multiples of the drive frequency.

MA 3.2 Mon 9:45 H18

Nanoscale YIG-Based Magnonic Crystals — •Khrystyna Levchenko[1], Kristýna Davídková[1], Mathieu Moalic[2], Carsten Dubs[3], Michal Urbánek[4], Qi Wang[5], Maciej Krawczyk[2], and Andrii Chumak[1] — [1]University of Vienna, Austria — [2]A. Mickiewicz University, Poland — [3]INNOVENT, Germany — [4]CEITEC Nano, Czech Republic — [5]Huazhong University, China

Magnonic crystals (MCs) are a spin-wave (SW) based class of artificial magnetic materials characterised by a spatially periodic variation of their properties. The combination of design flexibility and SW intrinsic advantages makes MCs promising candidates for RF applications, although multi-mode SW propagation disturbs the operating characteristics. To overcome this, it is necessary to work with nanostructures in the single-mode regime. Leveraging recent progress in materials science and fabrication techniques, we have realised 1D MCs from 100 nm thick epitaxial yttrium iron garnet (YIG) films. The MCs were developed using electron beam lithography, ion etching and evaporation, with periodicities of 1 μm and optimised notches (100-250 nm depth) or antidots (100-150 nm diameter). Microstrip antennae were used for SW excitation and detection. Experimental characterisation using micro-focused Brillouin light scattering and propagating spin-wave spectroscopy, supported by simulations (TetraX), confirmed efficient single-mode SW transport over a distance of 10 μm and bandgap formation. These results pave the way for further advances, such as 2D arrays with magnon guidance and topologically protected magnon transport - a milestone yet to be achieved experimentally.

MA 3.3 Mon 10:00 H18

The impact of local exchange bias on the dyanmics in chiral antiferromagnetic Mn_3Ir heterostructures with a $Ni_{80}Fe_{20}$ — •Rouven Dreyer[1], James M. Taylor[1], Stuart Parkin[2], and Georg Woltersdorf[1,2] — [1]Martin Luther University Halle-Wittenberg, 06120 Halle, Germany — [2]Max Planck Institute for Microstructure Physics, 06120 Halle, Germany

Non-collinear antiferromagnets (AFs) have been found to exhibit the intrinsic spin Hall effect (SHE) and to provide exchange bias (EB) in multilayer system, rendering these AFs interesting candidates for spintronic applications. However, the role of the chiral domain structure in this process and the transmission of the resulting spin current across interfaces with ferromagnets (FMs), remain open questions. Using a combination of integrative spin-torque ferromagnetic resonance (ST-FMR) and super-Nyquist-sampling magneto-optical Kerr effect (SNS-MOKE) measurements, we investigate the impact of the non-collinear spin texture of the Mn_3Ir on the magnetization dynamics in heterostructures with $Ni_{80}Fe_{20}$. Here, we show a strong discrepancy between local and integrative techniques due to interfacial exchange coupling between the AF and the FM. As a result of this, only SNS-MOKE studies allow for a local detection of the SHE. Furthermore, we obtain modifications of the magnetization dynamics strongly depending on the direction of applied EB. Moreover, we demonstrate that a combination of small bias fields and current-induced heating acts as an efficient control mechanism for setting of the exchange bias und thus for changing the magnetization dynamics during the measurements.

MA 3.4 Mon 10:15 H18

Evoution of coherence in magnonic BECs — •Malte Koster[1], Matthias R. Schweizer[1], Vitaliy Vasyuchka[1], Dmytro Bozhko[2], Burkard Hillebrands[1], Mathias Weiler[1], Alexander A. Serga[1], and Georg von Freymann[1,3] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Department of Physics and Energy Science, University of Colorado Colorado Springs, CO 80918 USA — [3]Fraunhofer Institute for Industrial Mathematics ITWM, 67663 Kaiserslautern, Germany

The process of formation of a coherent magnon-Bose-Einstein condensate (BEC) in an over-populated, hot magnon gas has recently been intensively studied. We have already demonstrated an electromagnetic detection scheme that allows direct evaluation of the phase correlation in the BEC. We have now extended the setup to study the evolution of the phase coherence during and after the formation of a homogeneous excitation of the magnon system - a BEC. In our experiments we use a perpendicularly magnetized yttirumiron-garnet film, which is parametrically pumped. This allows us to further demonstrate that coherence arises even though the magnon gas is still heated by the pumping. Furthermore, due to the phase sensitivity of our technique, we observe the spontaneous emergence of a random phase of the BEC without any influence of external factors.

This research was funded by the Deutsche Forschungsgemeinschaft in frame of TRR 173/2*268565370 Spin+X (Project B04).

MA 3.5 Mon 10:30 H18

Ultra-long magnon lifetime in the quantum limit — •Rostyslav O. Serha[1], Kaitlin H. McAllister[2], Fabian Majcen[1], Sebastian Knauer[1], Timmy Reimann[3], Carsten Dubs[3], Gennadii A. Melkov[4], Alexander A. Serga[5], Vasyl S. Tyberkevych[6], Dmytro A. Bozhko[2], and Andrii V. Chumak[1] — [1]University of Vienna, Vienna, Austria — [2]University of Colorado, Colorado Springs, USA — [3]INNOVENT e. V. technology development, Jena, Germany — [4]National Taras Shevchenko University, Kyiv, Ukraine — [5]RPTU, Kaiserslautern, Germany — [6]Oakland University, Rochester, USA

Quantum magnonics seeks to harness the quantum mechanical properties of magnons for quantum information technologies. A major bottleneck in this field is the limited magnon lifetime, which constrains the performance of quantum magnonic systems. In this study, we investigated yttrium iron garnet (YIG) spheres with varying impurity levels using ferromagnetic resonance (FMR) spectroscopy to examine magnon lifetimes at millikelvin temperatures. For k=0 magnon modes, lifetimes of up to one microsecond were observed. Remarkably, a specialized three-magnon splitting experiment revealed lifetimes of short-wavelength dipole magnons to be up to an order of magnitude longer than their k=0 counterparts. We report a maximum magnon lifetime of 18 microseconds at a frequency of 1.6 GHz. These findings offer crucial insights into the mechanisms influencing magnon lifetimes and pave the way for quantum magnonic devices featuring long-lived propagating magnons.

MA 3.6 Mon 10:45 H18

Exotic Magnon Spectra from Strong Dipolar Interactions and Anisotropy — •Konrad Scharff — KIT, Karlsruhe, Deutschland

Magnetic dipole-dipole interactions on lattices have been known to be the source of non-analytical behaviour of associated spin wave dispersions at and around the Brillouin zone center [1,2]. We investigate the consequences and predicted signatures of said non-analyticity in a 3D hexagonal lattice model that additionally hosts magnetic exchange interaction, as well as an easy-plane on-site anisotropy. Dynamical susceptibilities are theoretically evaluated and compared to available experimental data.

[1] Jensen, J. and Mackintosh, A.R. Rare Earth Magnetism. Clarendon Press - Oxford (1991)

[2] Baehr, M. et al. Effect of magnetic dipolar interactions on the interchain spin-wave dispersion in CsNiF3. Phys. Rev B 54, 12932 (1996)

MA 3.7 Mon 11:00 H18

Machine learning tool for inelastic neutron scattering: The case of CrSBr — •Nihad Abuawwad[1], Yixuan Zhang[2], Hongbin Zhang[2], and Samir Lounis[1,3] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, Jülich, Germany — [2]Institute of Materials Science, Technical University Darmstadt, Darmstadt , Germany — [3]Institute of Physics, University of Halle, Halle, Germany

Spin waves, or magnons, are fundamental excitations in magnetic materials that provide insights into their dynamic properties and interactions. Magnons are the building blocks of magnonics, which offer promising perspectives for data storage, and quantum computing. These excitations are typically measured through Inelastic Neutron Scattering (INS) techniques, which involve heavy and time-consuming measurements, data processing, and analysis based on various theoretical models. Here, we introduce a machine learning algorithm that integrates adaptive noise reduction and active learning sampling, which enables the restoration from minimal INS point data of spin wave information and the accurate extraction of magnetic parameters, including hidden interactions. Our findings, benchmarked against the magnon spectra of CrSBr, significantly enhance the efficiency and accuracy in addressing complex and noisy experimental measurements. This advancement offers a powerful machine-learning tool for research in magnonics and spintronics, which can also be extended to other characterization techniques at large facilities[1].

[1] Abuawwad N. arxiv:2407.04457 (2024)

15 min. break

MA 3.8 Mon 11:30 H18

Thermally Induced Demagnetizing Fields: Effective Potentials for Magnon Bose–Einstein Condensates — •Matthias R. Schweizer[1], Franziska Kühn[1], Victor S. L'vov[2], Anna Pomyalov[2,3], Georg von Freymann[1,4], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern — [2]Department of Complex Systems, Weizmann Institute of Science, Rehovot 76100, Israel — [3]Department of Chemical and Biological Physics, Weizmann Institute of Science, Rehovot 76100, Israel — [4]Fraunhofer Institute for Industrial Mathematics ITWM, Fraunhofer-Platz 1, 67663 Kaiserslautern

We investigate the control of magnon Bose–Einstein condensates (mBEC) by means of reconfigurable potentials. It is shown that the localized decrease of the saturation magnetization leads to strong demagnetizing fields which elevate the resonance frequency of magnons in the mBEC state at the bottom of the spin-wave spectrum. Consequently, spatially varying magnetization and field profiles act as space-modulated potentials, determining the dynamics of the mBEC. For the experimental observation, we create reconfigurable microscopic magnetization profiles using laser heating controlled by optical wavefront modulation. Electromagnetic parametric pumping is used to increase the magnon gas density and Brillouin light scattering spectroscopy is employed to detect the mBEC dynamics. This research was supported by the DFG–TRR 173-268565370 Spin+X (Project B04).

MA 3.9 Mon 11:45 H18

Fluctuations of the inverted magnetic state and how to sense them — •Anna-Luisa Römling[1], Artim Bassant[2], and Rembert Duine[2] — [1]Condensed Matter Physics Center (IFIMAC) and Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Madrid, Spain — [2]Institute for Theoretical Physics, Utrecht University, Utrecht, The Netherlands

Magnons are the low-energy exciations of magnetically ordered materials. While the magnetic moment of a ferromagnet below Curie tempertature aligns with an applied magnetic field, recent theoretical work has demonstrated that the magnetic order can be inverted by pumping spin orbit torque into the magnet. This results in an energetically unstable but dynamically stabilized state where the magnetic moment is antiparallel to an applied magnetic field. The excitations on such a state have negative energy and are called antimagnons, the antiparticle of the magnon. Here, we theoretically study the quantum and classical fluctuations of the inverted magnetic state and their sigatures in experimental set-ups. Our results advance the understanding of fundamental properties of antimagnons as well as experimental data related to the inverted magnetic state. They pave the way for exciting applications in spintronics and magnonics.

MA 3.10 Mon 12:00 H18

Inductive noise spectroscopy of thermally excited magnons — Luise Holder[1], Richard Schlitz[1], Jamal Ben Youssef[2], Christian Runge[1], Akashdeep Kamra[3,4], William Legrand[5], Hans Huebl[6,7,8], •Michaela Lammel[1], and Sebastian T.B. Goennenwein[1] — [1]Universität Konstanz, Konstanz — [2]LabSTICC-CNRS, Université Bretagne Occidentale, Brest — [3]RPTU Kaiserslautern-Landau, Kaiserslautern — [4]Universidad Autónoma de Madrid, Madrid — [5]CNRS, Institute Néel, Université Grenoble Alps, Grenoble — [6]Walther-Meißner-Institut, Garching — [7]Technische Universität München, Garching — [8]Munich Center for Quantum Science and Technology, Munich

For the identification of non-classical (squeezed) magnon states, quantitative knowledge about thermal or vacuum fluctuations of the magnetization is essential. We show that thermal magnetization fluctuations of a ferromagnetic thin film can be sensitively characterized using inductive magnon noise spectroscopy (iMNS). Our broadband approach based on a coplanar waveguide and a commercial spectrum analyzer allows to detect the microwave emission of the equilibrium magnetization fluctuations relative to a cold microwave background. Modeling the response of the whole microwave system and comparing it quantitatively with low-power broadband ferromagnetic resonance measurements in linear response yields excellent agreement, which verifies the equilibrium character of the iMNS. Thus, our work establishes a purely inductive broadband access to the equilibrium properties of magnetization fluctuations.

MA 3.11 Mon 12:15 H18

Threshold of parametric instability of magnons in different magnetization geometries under quasi-continuous pumping — •Tamara Azevedo[1], Rostyslav O. Serha[2], Matthias R. Schweizer[1], Vitaliy I. Vasyuchka[1], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Faculty of Physics, University of Vienna, 1090 Vienna, Austria

Parametric electromagnetic pumping of magnons is a key method for exciting and amplifying spin waves. Measuring the threshold of parametric instability, where energy input overcomes magnon damping, is crucial. Using a sensitive, automated technique with a quasi-continuous wave generated by a vector network analyzer, we measured this threshold in tangentially magnetized yttrium iron garnet films. Two geometries were studied: a microstrip pumping resonator aligned parallel and perpendicular to the external magnetization field $\mathbf{H}_0$. The threshold power as a function of $\mathbf{H}_0$ shows a sawtooth structure, likely caused by wave vector quantization of parametric magnons. In the perpendicular geometry, threshold power peaks suggest magnon-phonon hybridization with longitudinal, transverse, and surface acoustic modes. These results underline the role of magnetization geometry in determining parametric instability thresholds, providing guidance for optimizing spintronic and magnonic devices. This research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)*TRR 173*268565370 Spin+X (Project B04).

MA 3.12 Mon 12:30 H18

Non-reciprocal phonon-magnon interaction in yttrium-iron-garnet/zinc oxide heterostructures — •Yannik Kunz[1], Julian Schüler[1], Kevin Künstle[1], Finlay Ryburn[2], Yangzhan Zhang[2], Katharina Lasinger[1,2], Philipp Pirro[1], John Gregg[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU in Kaiserslautern, Germany — [2]University of Oxford, United Kingdom

Magnon-based devices provide a promising approach for energy-efficient computation due to low intrinsic losses in materials such as yttrium-iron-garnet (YIG). Here we show that surface acoustic waves (SAWs) can be used for the excitation of spin waves in hybrid ferrimagnetic/piezoelectric devices. The SAW thereby couples to magnons under conservation of energy and momentum [1,2].
We studied the excitation and propagation behavior of surface acoustic waves in GGG/YIG/ZnO-heterostructures [3] by electrical and micro-focused optical techniques. The phonon-magnon coupling in YIG is investigated by performing SAW transmission measurement as a function of the magnetic field and orientation. The observed magnetoe-

lastic coupling of phonons and magnons is non-reciprocal and highly dependent on the angle between the propagation direction of the SAW and the applied magnetic field.

[1] Küß et al., Frontiers in Physics 10, 981257 (2022)
[2] Kunz et al., Appl. Phys. Lett. 124 152403 (2024)
[3] Ryburn et al., arXiv 2403.030006 (2024)

MA 3.13 Mon 12:45 H18

Spatial control of hybridization-induced spin-wave transmission stop band — •Franz Vilsmeier[1,2], Christian Riedel[1], and Christian Back[1] — [1]Technische Universität München — [2]Universität Wien

Spin-wave (SW) propagation close to the hybridization-induced transmission stop band is investigated within a trapezoid-shaped 200 nm thick yttrium iron garnet film using time-resolved magneto-optic Kerr effect microscopy. The gradual reduction of the effective field within the structure leads to local variations of the SW dispersion relation and results in a SW hybridization at a fixed position in the trapezoid, where the propagation vanishes since the SW group velocity approaches zero. By tuning the external field or frequency, spatial control of the spatial stop band position and spin-wave propagation is demonstrated.