MA 20: Magnonics II

Time: Wednesday 9:30–13:15 Location: H16

MA 20.1 Wed 9:30 H16

Wavenumber-dependent magnetic losses in YIG-GGG heterostructures at millikelvin temperatures — •David Schmoll[1], Andrey A. Voronov[1], Rostyslav O. Serha[1], Denys Slobodianiuk[2], Khrystyna Levchenko[1], Claas Abert[1], Sebastian Knauer[1], Dieter Suess[1], Roman Verba[2], and Andrii V. Chumak[1] — [1]University of Vienna, Vienna, Austria — [2]V.G. Baryakhtar Institute of Magnetism of the NAS of Ukraine, Kyiv, Ukraine

With its low magnetic damping, the ferrimagnet yttrium iron garnet (YIG), grown on gadolinium gallium garnet (GGG), is the most promising material for magnon based quantum technologies, wich demand long decoherence times. While such samples are already well established at room temperature, further knowledge needs to be acquired at millikelvin temperatures, due to the paramagnetic character of the GGG substrate. We report on propagating spin-wave spectroscopy studies at temperatures between 4 K to 26 mK and the recorded change of the dissipation rate. Additionally, we compute the dispersion and the dissipation rate of the layered YIG-GGG magnetic system quasi-analytically and with micromagnetic simulations, allowing us to investigate the magnon losses with respect to wavenumber. Contrary to room temperature, we observe a significant increase of the magnetic losses with k at cryogenic temperatures, introduced by the dipolar coupling between the ferrimagnetic YIG film and the partially magnetized GGG substrate. Our theoretical calculations predict a steady decrease of the dissipation for short-wavelength exchange magnons.

MA 20.2 Wed 9:45 H16

Exchange enhanced switching in quantum antiferromagnets with dephasing and relaxation — •Asliddin Khudoyberdiev and Götz S. Uhrig — Condensed Matter Theory, TU Dortmund University, Otto-Hahn-Straße 4, 44221 Dortmund, Germany

One requirement for ultrafast storage devices is that they can be operated in the terahertz (THz) regime. Suitable candidates are antiferromagnets because of their characteristic frequencies range. The efficient control of their order is the focus of a plethora of current studies. Recently, we established a quantum approach, time-dependent Schwinger boson mean-field theory, to reverse the sublattice magnetization in anisotropic quantum antiferromagnets by means of external static and oscillating magnetic fields [1,2]. We also showed that the exchange enhancement for staggered control fields persists on the quantum level so that significantly lower fields are sufficient to switch the order [3]. Our quantum theory incorporates dephasing, i.e., the destructive interference of the contributions of all spin modes at their respective frequencies, which results in a slow, non-exponential decrease of the oscillations after the switching [2,3]. This must be distinguished from spin-lattice relaxation which induces faster decay of oscillations. Our methodological progress including Lindblad dissipators allows us to address the differences between dephasing and spin-lattice relaxation in the switching processes. [1] K. Bolsmann, A. Khudoyberdiev, and G. S. Uhrig, PRX Quantum 4, 030332 (2023) [2] A. Khudoyberdiev and G. S. Uhrig, Phys. Rev. B 109, 174419 (2024) [3] A. Khudoyberdiev and G. S. Uhrig, arXiv:2407.00472.

MA 20.3 Wed 10:00 H16

Non-linear processes in YIG based spin-wave transducers — •Matthias Wagner, Felix Kohl, Björn Heinz, and Philipp Pirro — Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Spin waves are considered as promising candidates for the realization of future signal processing devices. Due to their fundamental equation of motion, spin-wave dynamics are inherently non-linear. For the practical application of spin-wave based devices, this non-linear nature can either be a perspective or a challenge, depending on the desired use case. Therefore, a systematic study on the impact of non-linear dynamics on a potential spin-wave based device is instructive. For this purpose, spin-wave transducers patterned on yttrium iron garnet (YIG) films are investigated. Using micro-focused and time-resolved Brillouin light scattering spectroscopy, the power-limiting non-linear processes as well as their scattering dynamics are analysed. The characterization is complemented by propagating spin-wave spectroscopy measurements to study the corresponding impact of the non-linear processes on the output of the spin-wave transducers. The results of this work provide an important foundation to develop new concepts of signal processing devices using spin waves. This research is funded by the European Union within HORIZON-CL4-2021-DIGITAL-EMERGING-01 (No. 101070536,MandMEMS).

MA 20.4 Wed 10:15 H16

Higher Order Resonances in Periodically Driven Magnon Systems — •Jan Mathis Giesen, Alexandre Abbass Hamadeh, Philipp Pirro, Imke Schneider, and Sebastian Eggert — RPTU, Kaiserslautern, Germany

We analyze resonant excitations of ferromagnetic magnons via microwave pumping below the threshold frequency using Floquet theory. A special feature of parameteric resonance is the possibility to create magnons with higher energy than the driving frequency, which allows for new tuning possibilities. We develop a theoretical framework that analytically predicts the region of resonances and resonance thresholds in thin films of ferro- and ferri-magnetic materials as a function of damping, amplitude and frequency. The results are compared with micomagnetic simulations.

MA 20.5 Wed 10:30 H16

SAW-Induced Spin Wave Excitation in Ferromagnetic Epitaxial Thin Films — •Alfons Georg Schuck, Sebastian Kölsch, and Michael Huth — Institute of Physics, Goethe University, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany

Surface acoustic wave (SAW) excitation of spin waves in ferromagnetic thin films has recently gained significance due to the potential for the realization of novel microwave devices and applications in magnonics. So far, SAW excitation has commonly been accomplished by use of piezoelectric substrate materials, such as $LiNbO_3$, on top of which the ferromagnetic thin film is deposited [1]. This approach has severe limitations with regard to studying SAW-spin wave coupling effects in epitaxial magnetic thin films. For epitaxy to occur, selected substrate materials and crystal orientations have to be used; and these substrate materials tend not to be piezoelectric.

Here we show how textured piezoelectric AlN thin film transducer structures can be fabricated on different substrate materials by means of reactive RF sputtering. By proper selection of the material for the interdigital transducer electrode structures and standard UV lithography, the frequency range up to about 3 GHz becomes available for spin wave excitation. Selected examples of SAW-induced spin wave excitation in epitaxial magnetic thin films are presented and compared to results obtained on Nickel thin films as commonly used reference material. Complementary simulations of the SAW attenuation are shown and the influence of the magnetic anisotropy is described.

[1] M. Weiler et. al., Phys. Rev. Lett. **106**, 117601, **2011**

MA 20.6 Wed 10:45 H16

Integrated hybrid magnonic-spintronic system for tunable broadband signal filtering and microwave generation — •Abbas Koujok[1], Abbass Hamadeh[1,2], Leandro Martins[3], Felix Kohl[1], Björn Heinz[1], Ricardo Ferreira[4], Alex Jenkins[4], Ursula Ebels[3], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Université Paris-Saclay, Centre de Nanosciences et de Nanotechnologies, CNRS, 91120, Palaiseau, France — [3]Univ. Grenoble Alpes, CEA, CNRS, Grenoble INP, IRIG, Spintec, Grenoble, France — [4]International Iberian Nanotechnology Laboratory (INL), 4715-31 Braga, Portugal

Non-conventional beyond-the-state-of-the-art signal processing schemes require parallelism, scalability, robustness and energy efficiency to meet the demands of complex data-driven applications. Magnonic and spintronic circuits are potential candidates that can aid in fulfilling these requirements. Hereby, an experimental proof-of-concept for a novel hybrid magnonic-spintronic device is proposed. Using spintronic auto-oscillations, this device can generate a broad, GHz-wide RF signal and filter this signal in a selective and tunable manner using a magnonic circuit. This research is funded by the European Research Council within the Starting Grant No. 101042439 "CoSpiN" and by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - TRR 173-268565370 (project B01). U.E.

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MA 20.7 Wed 11:00 H16

Spatially Resolved Investigation of Spin Wave frequency Multiplication — •Roméo Beignon[1], Chris Körner[2], Rouven Dreyer[2], Georg Woltersdorf[2], Vincent Jacques[1], and Aurore Finco[1] — [1]Laboratoire Charles Coulomb, Université de Montpellier, CNRS, Montpellier, France — [2]Martin Luther University Halle-Wittenberg, Halle, Germany

Interactions between spin waves and magnetic textures offer promising tools for designing magnonic devices. Among new developments, a frequency multiplication phenomenon has been observed in permalloy microstructures [1]. This generation of a high harmonic frequency has been observed using magnetic resonance measurements on NV center ensembles.

Here, we use scanning NV-center microscopy to investigate this phenomenon further. Our aim is to obtain maps of the harmonic generation with a spatial resolution of about 50 nm, and to correlate them with the magnetic state of the Py microstructures (edges, domain walls, ...).

Our results show that we can detect the spin wave frequency comb with a single NV center in a scanning probe tip. Furthermore, we are able to spatially map the effect of each harmonic on the NV center separately, revealing a non-trivial behavior. These measurements are a first step towards the understanding of the interplay between the non-linear process that generates the harmonics and the magnetic texture.

[1] Köerner et al., Science 375. 1165-1169 (2022)

15 min. break

MA 20.8 Wed 11:30 H16

Tayloring spin-wave transducers for integrated RF application — •Felix Kohl, Björn Heinz, Matthias Wagner, and Philipp Pirro — Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Current advances in magnonics are increasingly targeted at improving the functional applicability of integrated magnonic devices. Despite the widespread use of transducers based on dynamic Oersted field excitation, there are still inefficiencies due in part to a discrepancy between the scientific understanding of magnetic responses and the technical requirements for practical implementation. Using propagating spin-wave spectroscopy, we investigated spin-wave transducers patterned on yttrium-iron-garnet (YIG) films, demonstrating the capability to tailor transducer characteristics, such as non-reciprocity towards a desired use case. Supported by a modelling approach, our measurements provide a useful framework for designing efficient, application-specific transducers and pave the way for integrated and standalone RF devices such as isolators and filters. This work is an important step towards scalable, energy-efficient magnonic application and demonstrates the potential of magnonics to become a future technology. This research is funded by the European Union within HORIZON-CL4-2021-DIGITAL-EMERGING-01 (No. 101070536,MandMEMS).

MA 20.9 Wed 11:45 H16

Investigation of parallel parametric signal amplification in YIG nanostructures — •Akira Lentfert, Björn Heinz, David Breitbach, Burkard Hillebrands, and Philipp Pirro — Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

In the pursuit of advanced information processing beyond traditional CMOS technologies, various magnonic circuits and devices such as magnon transistors, majority gates, and half adders have been developed. However, for an extended magnonic network, a phase-conserving and sensitive amplification of spin waves is required. One of the candidates is the use of the parallel parametric pumping process. A phase-conserving signal amplification in microscopic metallic waveguides has already been demonstrated in previous works. In this work, we focus on the phase dependence of the parallel parametric amplification processes in Damon-Eschbach (DE) geometry in yttrium iron garnet (YIG) nanowaveguides for propagating spin waves. Due to the low spin-wave damping in YIG, other damping mechanisms such as radiative losses have a significant impact on the pumping processes. Time-resolved micro-focused Brillouin light scattering spectroscopy is used to study the phase-dependent amplification of short spin-wave pulses.

This project has been supported by the EU Horizon research and innovation program within the SPIDER project (No. 101070417) and by DFG (TRR 173-268565370: Spin+X).

MA 20.10 Wed 12:00 H16

Nanoscaled Spin-Wave Frequency Selective Limiter (FSL) for 5G Technology — •Kristýna Davídková[1], Khrystyna Levchenko[1], Florian Bruckner[1], Roman Verba[2], Fabian Majcen[1], Qi Wang[3], Carsten Dubs[4], Vincent Vlaminck[5], Jan Klíma[6], Michal Urbánek[6], Dieter Suess[1], and Andrii Chumak[1] — [1]University of Vienna, Austria. — [2]Institute of Magnetism, Ukraine. — [3]School of Physics, China. — [4]INNOVENT e. V. Technologieentwicklung, Germany. — [5]IMT Atlantique, France — [6]CEITEC BUT, Czech Republic

Power limiters are essential devices in radio frequency communications systems to protect the input channels from large incoming signals. Nowadays-used semiconductor limiters suffer from high electronic noise and switching delays when approaching the GHz range, which is crucial for the modern generation of 5G communication technologies aiming to operate at the EU 5G high band (24.25-27.5 GHz). The proposed solution is to use ferrite-based Frequency Selective Limiters (FSLs), which maintain their efficiency at high GHz frequencies, although they have only been studied at the macroscale so far. We demonstrate a proof of concept of nanoscale FSLs based on spin-wave transmission affected by four-magnon scattering phenomena in a 97-nm-thin YIG film. Spin waves were excited and detected using coplanar waveguide transducers of the smallest feature size of 250 nm. The FSLs are tested in the frequency range up to 25 GHz, and the key parameters are extracted (power threshold, power limiting level, insertion losses, bandwidth) for different SW modes and transducer lengths.

MA 20.11 Wed 12:15 H16

Uniaxial strain response of antiferromagnetic magnons — •Manuel Knauft, Arthur von U.-S. Schwark, Yiran Liu, Lichen Wang, Sajna Hameed, Matteo Minola, and Bernhard Keimer — Max Planck Institute for Solid State Research, Stuttgart, Germany

With the suggested paradigm shift away from conventional transistors towards lower loss devices, magnonics has attracted considerable attention in recent years. Generation, manipulation and detection of magnons are prerequisites for successful integration into microstructured chips. We will present ideas and results of using uniaxial strain to control magnon behavior in perovskite antiferromagnets. In particular, recent work on iridates has shown that the magnon energy can be varied by as much as 40 % with small uniaxial strain of about 0.1 % [1]. Building on those findings, we discuss alternative approaches. Furthermore, through spatially inhomogeneous strain environments, we will also demonstrate ideas of guiding magnons as investigated using finite element simulation and confocal Raman scattering.

[1] Kim *et al.*, Nat. Commun. **13**, 6674 (2022)

MA 20.12 Wed 12:30 H16

cavity-enhanced optical manipulation of Antiferromagnetic magnon-pairs — •Tahereh Parvini — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Walther-Meißner-Str.8, 85748 Garching, Germany

The optical manipulation of magnon states in antiferromagnets (AFMs) holds the potential for advancing AFM-based computing devices. In particular, two-magnon Raman scattering processes are known to generate entangled magnon-pairs with opposite momenta. We propose to harness the dynamical backaction of a driven optical cavity coupled to these processes, to obtain steady states of squeezed magnon-pairs, represented by squeezed Perelomov coherent states. The system's dynamics can be controlled by the strength and detuning of the optical drive and by the cavity losses. In the limit of a fast (or lossy) cavity, we obtain an effective equation of motion in the Perelomov representation, in terms of a light-induced frequency shift and a collective induced dissipation which sign can be controlled by the detuning of the drive. In the red-detuned regime, a critical power threshold defines a region where magnon-pair operators exhibit squeezing, a resource for quantum information, marked by distinct attractor points. Beyond this threshold, the system evolves to limit cycles of magnon-pairs. In contrast, for resonant and blue detuning regimes, the magnon-pair dynamics exhibit limit cycles and chaotic phases, respectively, for low and high pump powers. Observing strongly squeezed states, auto-oscillating limit cycles, and chaos in this platform presents opportunities for future quantum technologies.

MA 20.13 Wed 12:45 H16

Predicting the future with magnons — •Zeling Xiong[1,2], Christopher Heins[1,2], Katrin Schultheiss[1], Helmut Schultheiss[1], Thibaut Devolder[3], and Joo-Von Kim[3] — [1]Helmholtz-Zentrum Dresden Rossendorf, Germany — [2]Technische Universität Dresden, Germany — [3]Centre de Nanosciences et de Nanotechnologies, ClderNRS, Université Paris-Saclay, France

The Mackey-Glass (MG) time series data describes how density of mature circulating cells change over time using time delayed differential equations. This is a standard problem to test the performance of physical reservoirs. Here, we used different magnon reservoir systems to carry out such time series prediction task. By connecting several reservoirs together we increase the reservoir depth which yielded very accurate long-time future prediction.

MA 20.14 Wed 13:00 H16

Dynamic Control of Spin-Wave Propagation for Advanced Computing Applications — •Dmitrii Raskhodchikov[1], Kirill Nikolaev[2], Jannis Bensmann[1], Rudolf Bratschitsch[1], Vladislav Demidov[2], Sergey Demokritov[2], and Wolfram Pernice[1,3] — [1]Institute of Physics and Center for Nanotechnology (CeNTech), Muenster, Germany — [2]Institute of Applied Physics, Muenster, Germany — [3]Kirchhoff-Institute for Physics, Heidelberg, Germany

Spin waves, collective excitations of electron spins in magnetic materials, have attracted significant interest for spin-wave and neuromorphic computing applications. A key challenge in utilizing spin waves for these technologies is achieving precise control over their propagation. This study investigates methods to regulate spin-wave dynamics by manipulating parameters like the external magnetic field, excitation frequency, and the integration of external memory elements, including phase-change materials.

Our results show that varying the external magnetic field influences the dispersion relation of spin waves, allowing for tunable propagation velocities and wavelengths. Adjusting the excitation frequency enables selective excitation of spin-wave modes with desired properties. Furthermore, incorporating phase-change materials allows for dynamic modulation of spin-wave propagation through localized changes in magnetic anisotropy or damping. This approach provides a foundation for adaptive control mechanisms essential for spin-wave-based information processing.