MA 16: Magnonics I

Time: Tuesday 9:30–12:30 Location: EB 107

MA 16.1 Tue 9:30 EB 107

Propagating spin-wave spectroscopy in a liquid-phase epitaxial nanometer-thick YIG film at millikelvin temperatures — •Sebastian Knauer[1], Kristýna Davídková[2], David Schmoll[1,3], Rostyslav O. Serha[1,3], Andrey Voronov[1,3], Qi Wang[1], Roman Verba[4], Oleksandr V. Dobrovolskiy[1], Morris Lindner[5], Timmy Reimann[5], Carsten Dubs[5], Michal Urbánek[2], and Andrii V. Chumak[1] — [1]Faculty of Physics, University of Vienna, A-1090 Vienna, Austria — [2]CEITEC BUT, Brno University of Technology, 612 00 Brno, Czech Republic — [3]Vienna Doctoral School in Physics, University of Vienna, A-1090 Vienna, Austria — [4]Institute of Magnetism, Kyiv 03142, Ukraine — [5]INNOVENT e.V. Technologieentwicklung, Prüssingstraße 27B, 07745 Jena, Germany

Realising large-scale integrated magnonic circuits for quantum applications requires propagating spin-wave spectroscopy in nanostructures at low temperatures. In this work, we demonstrate all-electrical spin-wave propagation in a 100 nm-thick yttrium-iron-garnet (YIG) film at temperatures down to 45mK. The extracted spin-wave group velocity and the YIG saturation magnetisation agree well with the theoretical values. We show that the gadolinium-gallium-garnet (GGG) substrate influences the spin-wave propagation characteristics only for the applied magnetic fields beyond 75mT, originating from a GGG magnetisation up to 62kA/m (45mK). Our results demonstrate that the developed fabrication and measurement methodologies enable the realisation of integrated magnonic quantum nanotechnologies at millikelvin temperatures.

MA 16.2 Tue 9:45 EB 107

Resonant excitation of vortex gyrotropic mode via surface acoustic waves — •Abbas Koujok[1], Alejandro Riveros[2], Davi R. Rodrigues[3], Giovanni Finocchio[4], Mathias Weiler[1], Abbass Hamadeh[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Escuela de Ingeniería, Universidad Central de Chile, 8330601 Santiago, Chile — [3]Department of Electrical and Information Engineering, Politecnico di Bari, 70126 Bari, Italy — [4]Department of Mathematical and Computer Sciences, Physical Sciences and Earth Sciences, University of Messina, 98166, Messina, Italy

With the increasing demand to miniaturize data processing devices while reducing power consumption and enhancing performance, magnonic circuits have been identified as a promising candidate in the framework of non-conventional computing. However, energy-efficient conversion from the magnonic to the electronic domain and vice versa remains a challenge for magnonics. Here, we propose a method of vortex core gyrotropic excitation relying solely on electric fields rather than on the flow of electric current, hence minimizing Ohmic losses resultant of Joule heating. Our method employs surface acoustic waves (SAWs) to excite vortex dynamics via inverse magnetostriction. We present an analytical model validated by micromagnetic simulations to demonstrate the ability of resonant SAWs to drive the gyrotropic motion of the vortex core. Varying the amplitude of the SAW, we can control the radius of the trajectory underwent by the vortex core.

MA 16.3 Tue 10:00 EB 107

Tunable topological magnon-polaron states and intrinsic anomalous Hall phenomena in 2D ferromagnetic insulators — •Alireza Qaiumzadeh and Jostein Kløgetvedt — QuSpin, Department of Physics, NTNU

We study magnon-polaron hybrid states, mediated by Dzyaloshinskii-Moriya and magnetoelastic interactions, in a two-dimensional ferromagnetic insulator. The magnetic system consists of both in-plane and flexural acoustic and optical phonon bands, as well as acoustic and optical magnon bands. Through manipulation of the ground-state magnetization direction using a magnetic field, we demonstrate the tunability of Chern numbers and (spin) Berry curvatures of magnon-polaron hybrid bands. This adjustment subsequently modifies two intrinsic anomalous Hall responses of the system, namely, the intrinsic thermal Hall and intrinsic spin Nernst signals. Notably, we find that by changing the magnetic field direction in particular directions, it is possible to completely suppress the thermal Hall signal while maintaining a finite spin Nernst signal. Our finding reveals the intricate interplay between topology and magnetic ordering, offering compelling avenues for on-demand control over emergent nontrivial topological states and quantum transport phenomena in condensed matter systems by potential applications in both classical and quantum information technology.

MA 16.4 Tue 10:15 EB 107

Spatiotemporal magnon propagation dynamics in ultrathin iron garnets — •Volker Wiechert, Julian Bär, Moritz Cimander, Maurus Mrotzek, and Davide Bossini — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

Recently, ferrimagnetic iron garnets have emerged as a potential material system to study the dynamics and manipulation of spin waves on their fundamental temporal and spatial scales [1]. Today's manufacturing processes also make it possible to produce nanometer-thick layers with variable rare-earth doping that exhibit new dynamic properties [2].

Until now, the spatiotemporal control of magnon propagation on fundamental scales has been barely addressed and, almost exclusively, in a linear spin wave regime. We set out to tackle spatiotemporal magnon dynamics in a nonlinear regime with an all-optical approach. The high tunability of the laser system also allows the individual sublattices of the ferrimagnet to be probed and provides further insights into the dynamics of these compounds [3]. Preliminary measurements of local spin dynamics in Gd-doped iron garnet already displayed nonlinear spin dynamics [4].

[1] T. Satoh et al., *Nat. Photon.* **6**, 662 (2012). [2] L. Soumah et al., *Phys. Rev. Lett.* **127**, 077203 (2021) [3] M. Deb et al., *J. Phys. D: Appl. Phys.* **45**, 455001 (2012) [4] V. Wiechert et al., *in preparation*

MA 16.5 Tue 10:30 EB 107

Femtosecond coupled spin and charge dynamics in an antiferromagnet — •Moritz Cimander, Volker Wiechert, Julian Bär, and Davide Bossini — Universität Konstanz, Konstanz, Germany

The research field adressing spin dynamics in magnets has gained recently a remarkable popularity. Especially antiferromagnets are of interest in view of high magnon frequencies in the THz regime, the lack of stray field and aboundant availibility in nature[1]. However fundamental questions regarding the control of coherent spin dynamics and a possible coupling of charges have still to be solved.

As previously demonstrated, coherent magnons can be excited in a nickel oxide single crystal via optical pumping of an exciton-magnon transition[2]. However, the resulting dynamics of the electronic system has not yet been explored. In particular, we set out to establish the possibility of a coupling between the photoinduced coherent magnons and the optical properties of the electronic system.

For this purpose, we developed a cryogenic magneto-optical pump-probe spectrometer in the VIS-NIR region. This apparatus enabled the detection of optical and magneto-optical dynamics, triggered by resonant and off-resonant excitation of the exciton-magnon and allows the coherent manipulation of the transient transmissivity by magnons. A systematic investigation of the observed effect as a function of several experimental parameters will be presented and discussed.

[1] M. B. Jungfleisch. et al.: Phys. Lett. A 382, 865 (2018)
[2] D. Bossini et al.: Phys. Rev. Lett. 127, 077202 (2021)

MA 16.6 Tue 10:45 EB 107

Unraveling the magnon-phonon hybridization in Fe3GeTe2 — •Namrata Bansal[1], Qili Li[1], Paul Nufer[1], Lichuan Zhang[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 explore the dynamic interplay between magnons and phonons in Fe3GeTe2 (FGT) single crystals using inelastic scanning tunneling spectroscopy (ISTS) at 35 mK. ISTS has been widely employed to investigate the inelastic scattering of hot carriers off phonons or magnons, and in our study, we reveal magnon-phonon coupling in

FGT. We find a significant interaction between magnons and acoustic phonons, giving rise to the formation of van Hove singularities through avoided level crossings and the hybridization of magnon and phonon bands within the material. We identify the hybridization points in the dispersion relations and contrast their energies with density functional theory calculations. These discoveries provide a foundation for tailoring the dynamic magnon-phonon coupling properties in two-dimensional materials.

Reference: Bansal, et al., arXiv: 2308.10774 (2023)

15 min. break

MA 16.7 Tue 11:15 EB 107

Fine-Tuning Spin-Wave Transducers for Improved Efficiency and Sensitivity — •Felix Kohl, Björn Heinz, and Philipp Pirro — Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Current research in magnonics is addressing the transition from potential feasibility to functional applicability, with a particular focus on improving the efficiency of integrated spin-wave transducers, including spin-wave excitation as well as detection. Although spin-wave transducers relying on spin-wave excitation by dynamic Oersted fields are widely used, their inefficiency raises the need for significant enhancements. In a comprehensive study, we evaluate the achieved levels of efficiency under consideration of various key parameters such as the shape of the transducer antenna, magnetic material properties and spin-wave dispersion. By means of propagating spin-wave spectroscopy we measure spin-wave transmission and interpret results, providing valuable insights into the system's behavior. The acquired results, coupled with theoretic modelling of the systems, serve as a guiding framework for the optimization of transducers. Utilizing this framework, optimized transducers are fabricated and tested for their efficiency. This work represents a crucial step towards realizing the full potential of magnonics in practical applications. This research is funded by the European Union within HORIZON-CL4-2021-DIGITAL-EMERGING-01 (No. 101070536,MandMEMS).

MA 16.8 Tue 11:30 EB 107

Investigation of parallel parametric signal amplification in YIG nanostructures — •Akira Lentfert[1], Björn Heinz[1], David Breitbach[1], Carsten Dubbs[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]INNOVENT e.V. Technologieentwicklung, Jena, 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 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 metallic waveguides has already been demonstrated in previous works. In this work, we focus on the phase dependence of the parallel parametric pumping processes in Damon-Eschbach (DE) geometry in yttrium iron garnet (YIG) nanowaveguides. 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 obtain the pumping threshold and to study the 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 16.9 Tue 11:45 EB 107

Magnon spin capacitor — •Pieter M. Gunnink[1], Tim Ludwig[2], and Rembert A. Duine[2,3] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Staudingerweg 7, Mainz 55128, Germany — [2]Institute for Theoretical Physics and Center for Extreme Matter and Emergent Phenomena, Utrecht University, Leuvenlaan 4, 3584 CE Utrecht, The Netherlands — [3]Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

We show that a magnon spin capacitor can be realized at a junction between two exchange coupled ferromagnets [Gunnink et al., arXiv:2310.09064]. In this junction, the buildup of magnon spin over the junction is coupled to the difference in magnon chemical potential, realizing the magnon spin analogue of an electrical capacitor. We analyse the junction in detail by considering spin injection and detection from normal metal leads, the tunnelling current across the junction and magnon decay within the ferromagnet, showing that such a structure realizes a magnon spin RC circuit. Choosing platinum and yttrium iron garnet as the normal metal and ferromagnet, we numerically calculate the RC time, which ranges from picoseconds to microseconds, depending on the area of the junction. We therefore conclude that the magnon spin capacitor has clear experimental signatures and could directly be of use in applications.

MA 16.10 Tue 12:00 EB 107

Giant Surface Acoustic Wave Nonreciprocity in CoFeB/Ru/CoFeB Synthetic Antiferromagnets — •Matthias Küss[1], Stephan Glamsch[1], Mariam Hassan[1], Yannik Kunz[1], Andreas Hörner[1], Mathias Weiler[2], and Manfred Albrecht[1] — [1]Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — [2]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Surface acoustic waves (SAWs) have made their way into many everyday devices. These "nano earthquakes" can be efficiently launched and detected on piezoelectric substrates with periodic metallic gratings. Resonant coupling of SAWs with spin waves (SWs) is the basis for an energy-efficient approach towards SW manipulation. In addition, magnetoacoustic interaction affects the properties of the SAW, which in turn can be used to devise new types of microwave devices.

Here, we investigate the SAW-SW interaction in a synthetic antiferromagnet (SAF) composed of two ferromagnetic layers separated by a thin nonmagnetic spacer layer. The low-frequency SW mode shows a large nonreciprocal SW dispersion $f(+k) \neq f(-k)$. Because of efficient coupling between this SW mode and the SAW, we observe large nonreciprocal SAW transmission in the piezoelectric/SAF hybrid device. We demonstrate that the SAW transmission nonreciprocity can be optimized to be giant ($>$ 100 dB) in CoFeB/Ru/CoFeB SAFs made out of low-damping CoFeB magnetostrictive layers, which holds potential for the realization of acoustic isolators [M. Küß et al., ACS Appl. Electron. Mater. 5, 5103 (2023)].

MA 16.11 Tue 12:15 EB 107

Nonlinear erasing of propagating spin-wave pulses — •David Breitbach[1], Moritz Bechberger[1], Björn Heinz[1], Bert Lägel[1], Carsten Dubs[2], Roman Verba[3], Abbass Hamadeh[1], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]INNOVENT e.V. Technologieentwicklung, Jena, Germany — [3]Institute of Magnetism, Kyiv 03142, Ukraine

Nonlinear phenomena are key for magnon-based information processing and have led to the realization of numerous building blocks for spin-wave-based computing. The nonlinear interaction between two spin-wave signals requires their spatio-temporal overlap which can be challenging for directional processing devices. We study a nearly compensated, gallium-substituted-YIG film. This system exhibits an exchange-dominated dispersion relation and PMA, resulting in a particularly wide range of group velocities compared to YIG. Using time-resolved BLS microscopy, we demonstrate the excitation of two delayed spin-wave pulses at different frequencies from the same source, where the delayed pulse catches up with the previously excited pulse and outruns it due to its higher group velocity. Depending on the excitation power, the delayed pulse nonlinearly interacts with the first pulse, hindering its propagation and erasing the prior signal. Our work achieves a temporal logic operation with potential application for inhibitory neuromorphic functionality. This research is funded by the DFG - Project No. 271741898, by TRR 173-268565370 (B01), and by the ERC Grant No. 101042439 'CoSpiN'.