MA 31: Magnonics I

Time: Wednesday 15:00–18:15 Location: H 0110

Topical Talk MA 31.1 Wed 15:00 H 0110

Magnonics, Quo Vadis? — •Volodymyr Kruglyak — University of Exeter, CEMPS, Exeter, United Kingdom

Starting from a brief general introduction to the topic of magnonics, I will present an overview of its state of the art and opportunities for future developments, in mind with questions: What spin wave applications could be realised with what we have? What challenges need to be resolved to enable further spin wave applications? Why is magnonics fun even if one is not bothered by applications? Among other themes, I will discuss and provide demonstrations of exciting new physics and technological opportunities associated with the graded magnonic index and spin wave Fano resonances, promoting them as the next big thing in magnonics research. The research leading to these results has received funding from the Engineering and Physical Sciences Research Council of the United Kingdom (Project Nos. EP/L019876/1, EP/L020696 EP/P505526/1 and EP/L015331/1) and from the European Union*s Horizon 2020 research and innovation program under Marie Skłodowska-Curie Grant Agreement No. 644348 (MagIC).

MA 31.2 Wed 15:30 H 0110

Direct observation of Sub-100 nm spin-wave propagation in magnonic waveguides — •Nick Träger[1], Paweł Gruszecki[2], Filip Lisiecki[3], Johannes Förster[1], Markus Weigand[1], Piotr Kuswik[2,3], Janusz Dubowik[3], Gisela Schütz[1], Maciej Krawczyk[2], and Joachim Gräfe[1] — [1]MPI for Intelligent Systems, Stuttgart — [2]Adam Mickiewicz University, Poznan — [3]Institute of Molecular Physics, Poznan

In magnonics research, capabilities of data processing mediated by spin-waves are of current interest and promise beyond-CMOS technologies, providing efficient guiding of information between logic elements. Here, we investigate 350, 700 and 1400 nm wide, and 50 nm thin Py stripes as spin-wave guides. Continuous wave RF fields were generated in a 2 μm wide antenna to excite spin waves into these Py stripes. Using magnetic scanning x-ray microscopy (MAXYMUS@BESSY) with 18 nm spatial and 35 ps temporal resolution, we directly observe highly oriented emission and propagation of sub-100 nm spin-wave modes in these wave guides. Furthermore, we tested that they are capable of simultaneously carrying multiple modes and explored the dispersion behaviour by burst experiments. Thus, a rich data transmission scenario was created, unveiling the interleaving mode behaviour during these information pulses. Non-dispersive propagation was observed for the wave guide length of 12 μm, indicating high transmission velocity with uniform characteristics that are promising for future technical applications.

MA 31.3 Wed 15:45 H 0110

Spin pinning conditions in nano-scale spin-wave waveguides — Qi Wang[1], Roman Verba[2], Martin Kewenig[1], Björn Heinz[1], Philipp Pirro[1], Thomas Meyer[1], Carsten Dubs[3], •Thomas Brächer[1], and Andrii Chumak[1] — [1]Fachbereich Physik, Technische Universitaet Kaiserslautern, Kaiserslautern, Germany — [2]Institute of Magnetism, Kyiv 03680, Ukraine — [3]INNOVENT e.V., Technologieentwicklung, Prüssingstraße 27B, 07745 Jena, Germany

The research field of magnonics deals with the transport of information via spin waves in ever decreasing spin-wave conduits. As the used spin-wave waveguides approach nanometric scales, the spin-wave mode profiles have to be revisited. In particular, if the lateral sizes of the waveguide approaches the exchange length, dipolar pinning is not dominant anymore. Studying the model system yttrium iron garnet (YIG), we demonstrate that this leads to an exchange-mediated unpinning in waveguides with widths on the order of 100 nm and we discuss the impact of this unpinning on the spin-wave spectra. This research has been supported by ERC Starting Grant 678309 MagnonCircuits and DFG Grant DU 1427/2-1.

MA 31.4 Wed 16:00 H 0110

Broadband Magnetoelastic and Magnetostatic Spin Wave Emission by Magnetic Domain Walls — •Rasmus Holländer, Cai Müller, and Jeffrey McCord — Institute for Materials Science, Kiel University, Kaiserstraße 2, 24143 Kiel, Germany

We investigate the linear dynamic magnetization response of an amorphous CoFeB stripe element in different domain states by homogeneous Oersted-field excitation. Coherent spin waves emitted by the domain walls can be directly observed by component-selective time-resolved magneto-optical wide-field imaging. The system is modeled in a two dimensional micromagnetic model. Magnetoelastic and magnetostatic spin waves can be distinguished by their dispersion and relation to magnetization orientation and domain wall orientation. The emission of spin waves from excited micromagnetic objects is a general physical phenomenon relevant for magnetization dynamics in patterned magnetic thin films.

The authors thank the German Science Foundation (DFG) for the financial support (grant Mc9/9-2 and Mc9/10-2).

MA 31.5 Wed 16:15 H 0110

Taking an electron-magnon duality shortcut from electron to magnon transport — •Alexander Mook[1], Börge Göbel[2], Jürgen Henk[1], and Ingrid Mertig[1,2] — [1]Institut für Physik, Martin-Luther-Universität, D-06120 Halle — [2]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle

The quasiparticles in insulating magnets are the charge-neutral magnons, whose magnetic moments couple to electromagnetic fields. For collinear easy-axis magnets, this coupling can be mapped elegantly onto the scenario of charged particles in electromagnetic fields. From this mapping we obtain the same equations of motion for magnon wave packets as for electron wave packets in metals. Thus, well-established electronic transport phenomena can be carried over to magnons: this 'duality shortcut' facilitates the discussion of magnon transport. We identify the magnon versions of normal and anomalous Hall, Nernst, Ettingshausen, and Righi-Leduc effects. They are discussed for selected types of easy-axis magnets: ferromagnets, antiferromagnets, and ferrimagnets. Besides a magnon Wiedemann-Franz law and the magnon counterpart of the negative magnetoresistance of electrons in Weyl semimetals, we predict that certain low-symmetry ferrimagnets exhibit a nonlinear version of the anomalous magnon Hall effect family.

MA 31.6 Wed 16:30 H 0110

Magnonic crystals with spatial modulation of magnetic anisotropy — •Lukáš Flajšman[1], Ondřej Wojewoda[2], Viola Křižáková[2], Jonas Gloss[3], Igor Turčan[1], Michael Schmid[3], Michal Urbánek[1,2], and Peter Varga[1,3] — [1]CEITEC BUT, Brno, Czech Republic — [2]IPE, BUT, Brno, Czech Republic — [3]TU Wien, Wien, Austria

Artificially patterned periodic magnetic structures - magnonic crystals - are prospective materials for controlling and manipulating spin waves. Most common types of magnonic crystals are based on periodic alternation of saturation magnetization or material thickness. We investigate the possibility of inducing the frequency band-gap by periodic modulation of direction of uniaxial anisotropy. In our approach in order to fabricate structures with periodic spatial modulation of uniaxial anisotropy we use a metastable paramagnetic fcc Fe thin films on Cu(100) substrate, which can be locally transformed by focused ion beam (FIB) to ferromagnetic bcc Fe phase [1]. The transformed areas have highly ordered crystallographic structure which can be to some extend controlled by proper selection of the FIB irradiation procedure. This permits the control of the magnetic anisotropy (type and direction) of the transformed areas. us to prepare magnonic crystals with modulation in direction of uniaxial anisotropy. We further investigate the band-structure of magnonic crystals with modulated uniaxial magnetic anisotropy by micromagnetic simulations.

[1] J. Gloss, S. Shah Zaman, J. Jonner, Z. Novotny, M. Schmid, P. Varga, M. Urbánek, Appl. Phys. Lett. 103 (2013) 262405

15 minutes break

MA 31.7 Wed 17:00 H 0110

Reprogrammable, zero-field spin-Hall nano-oscillators based on domain walls — Nana Nishida[1], Toni Hache[1,3], Sri Sai Phani Kanth Arekapudi[3], Olav Hellwig[1,3], and •Helmut Schultheiss[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung, Dresden, Germany — [2]TU Dresden, Germany — [3]TU Chemnitz, Germany

Spin-Hall nano-oscillators are nano-scale devices for the generation of magnons and rf-signals. They are based on pure spin currents generated by the spin-Hall effect in heavy metals and the subsequent spin-transfer-torque acting on the magnetization of an adjacent ferromagnetic layer. This transfer of angular momentum can compensate the intrinsic damping of the ferromagnetic layer which results in auto-oscillations of the magnetization. For a high efficiency of this transfer of angular momentum in bilayers of a heavy metal and a ferromagnet, the magnetization needs to be perpendicular to the direction of the injected dc current. Typically, this requires the application of large external magnetic fields. We present an approach based on magnetic domain walls in nano-wires which shows strongly confined auto-oscillations without the application of any magnetic field.

MA 31.8 Wed 17:15 H 0110

Spin-Wave Optics in Magnetization Landscapes — Rick Assmann[1], •Marc Vogel[1], Andrii V. Chumak[1], Burkard Hillebrands[1], and Georg von Freymann[1,2] — [1]Department of Physics and State Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Str. 56, 67663 Kaiserslautern — [2]Fraunhofer-Institute for Industrial Mathematics ITWM, Fraunhofer-Platz 1, 67663 Kaiserslautern

Spin-wave propagation in ferrimagnetic films (several micrometers thick yttrium iron garnet) follows the well-known laws of optical propagation, e. g., Snell's law of refraction [Phys. Rev. Lett. 117, 037204 (2016)]. In conventional optics, low divergent light beams are often used in the experimental setup. To do optics with spin waves, the excitation of spin-wave beams is necessary. Therefore, we use specially designed coplanar waveguides or microstrip antennas [Sci. Rep. 6, 22367 (2016)]. The spin-wave propagation can be observed in the experiment with micro-structured induction probes, which are scanned over the sample. We propose to use optically-induced magnetization landscapes [Nature Physics 11, 487 (2015)] to create the building blocks of spin-wave optics, e. g., spin-wave (graded-index) lenses, fibers, beamsplitter or diffraction gratings. Moreover, spin-wave Fourier optics can be realized by exploiting the properties of spin-wave lenses. We compare our experimental results with micromagnetic simulations.

Financial support by DFG collaborative research center SFB/TRR 173 "Spin+X" (project B04) is gratefully acknowledged.

MA 31.9 Wed 17:30 H 0110

Tailoring spin-wave eigenfrequencies in Py films with Co-Fe-FEBID nanodisks embedded into square antidot lattices — •Oleksandr V. Dobrovolskiy[1,2], Roland Sachser[1], Sergey A. Bunyaev[3], Gleb N. Kakazei[3], Felix Stobiecki[4], Janusz Dubowik[4], Piotr Kuswik[4], Maciej Krawczyk[5], Michael Huth[1], and Ruslan V. Vovk[2] — [1]Goethe University, Frankfurt am Main, Germany — [2]V. Karazin National University, Kharkiv, Ukraine — [3]IFIMUP-IN Universidade do Porto, Porto, Portugal — [4]IMP Polish Academy of Sciences, Poznań, Poland — [5]Adam Mickiewicz University in Poznań, Poznań, Poland

The spin-wave eigenfrequencies in 30 nm-thick Py films with Co-Fe nanodisks of different heights embedded in antidots were studied by VNA-FMR spectroscopy in the 10 K to 300 K temperature range and compared with a reference plain Py film. The antidots with 200 nm in diameter were milled by Ga focused ion beam and formed a square lattice with a period of 600 nm. The Co-Fe nanodisks were deposited inside of the antidots by focused electron beam induced deposition (FEBID). The external field H was applied along the edge of the unit cell of the bicomponent magnonic crystal thus formed. In the Py sample with antidots, in addition to the FMR mode of the plain film, modes resulting from the nanopatterning have been observed. In the Py/Co-Fe-FEBID sample, further modes depending on H and the antidot volume fraction filled with Co-Fe-FEBID have been revealed. The role of the Co-Fe-FEBID disks in the broadening of the FMR linewidth is discussed.

MA 31.10 Wed 17:45 H 0110

Bose-Einstein Condensation of Quasi-Particles in a Dynamically Cooled System — •Michael Schneider[1], Thomas Brächer[1], Viktor Lauer[1], Phillip Pirro[1], Alexander A. Serga[1], Bert Lägel[2], Carsten Dubs[2], Andrei Slavin[3], Vasyl S. Tiberkevich[3], Burkard Hillebrands[1], and Andrii V. Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]INNOVENT e.V., Technologieentwicklung, Jena, Germany — [3]Oakland University, Rochester, USA

Recently the formation of magnon Bose-Einstein Condensates (BEC) in extended films attracted large attention. In previous studies the conditions for the formation of the BEC are artificially created by parametric pumping. Here we present a fundamentally new approach. Fast DC current pulses applied to yttrium-iron-garnet (YIG)/Pt microstructures result in a strong heating. Consequently, this leads to an increased number of magnons, distributed over the whole spectrum. Once the current is switched off the micro-sized system cools down rapidly. This results in a strong increase of the magnon density at the bottom of the spectrum. That is observed using time-resolved Brillouin light scattering spectroscopy. Our experiment shows, that the BEC formation depends on the magnon temperature and the timescale of the cooling process. This research has been supported by ERC Starting Grant 678309 MagnonCircuits, ERC Advanced Grant 694709 SuperMagnonics and DFG Grant DU 1427/2-1.

MA 31.11 Wed 18:00 H 0110

Directional couplers for short spin wave generation: magnons and phonons — •Piotr Graczyk, Mateusz Zelent, Jarosław Kłos, and Maciej Krawczyk — Faculty of Physics, Adam Mickiewicz University in Poznan, Umultowska 85, 61-614 Poznan, Poland

New ideas to generate short spin waves and process spin wave signals are very desirable nowadays, due to their potential for high energy efficiency and miniaturization. We present here two mechanisms to achieve this goal: directional dipolar coupling in magnonic crystal and broadband magnetoelastic coupling in the magnonic-phononic system. The former is achieved by grating-assisted resonant dipolar interaction between two ferromagnetic layers separated by some distance. We show by the numerical calculations the efficient energy transfer between layers which may be of co-directional or contra-directional type. Such a system may operate either as a short spin wave generator or a frequency filter. In the latter we investigated the dynamics of magnetoelastic excitations in a system consisting of alternating layers of permalloy and CoFeB. The studied structure is optimized for hybridization of specific spin-wave and acoustic dispersion branches in a broad frequency range. Therefore, a device based on this mechanism may be used for efficient generation of high-frequency broadband spin wave signals.

P. Graczyk, M. Zelent, and M. Krawczyk, arXiv:1710.09138 (2017); P. Graczyk and M. Krawczyk, Phys. Rev. B 96, 024407 (2017); P. Graczyk, J. Kłos and M. Krawczyk, Phys. Rev. B 95, 104425 (2017).

Financial support from NCN Poland grants UMO-2012/07/E/ST3/00538, UMO-2016/21/B/ST3/00452