# MA 26: Spin Dynamics / Spin Torque IV

Time: Thursday 14:00–17:00 Location: H10

**Invited Talk** MA 26.1 Thu 14:00 H10

**Magnonics - Exploring spin waves on the nanoscale** — •Dirk Grundler — Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, Physik Department, James-Franck-Str. 1, 85747 Garching b. München, Germany

Collective spin excitations in ferromagnets have regained great interest in magnetism research. Recent observations such as spin-wave quantization, localizaton and interference in nanopatterned ferromagnets have stimulated further the field of magnonics where spin waves (magnons) are explored in order to carry and process information.[1] Here, magnonic waveguides and magnonic crystals, i.e. the magnetic counterpart of photonic crystals, are expected to offer intriguing perspectives for the transmission and manipulation of spin waves, respectively. However, the experimental realization is still in its infancy and challenging. We will discuss recent developments and all-electrical spin-wave spectroscopy on magnonic nanodevices based on nanowires as well as antidot lattices. We gratefully acknowledge collaborations and discussions with M. Becherer, B. Botters, G. Dürr, F. Giesen, G. Gubbiotti, D. Heitmann, M. Kostylev, V. Kruglyak, S. Neusser, J. Podbielski, D. Schmidt-Landsiedel, S. Tacchi, and J. Topp. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n°228673, from SFB 668 and the German Excellence Cluster 'Nanosystems Initiative Munich'. [1] S. Neusser and D. Grundler, Advanced Materials 21, 2927 (2009); and references therein.

**Invited Talk** MA 26.2 Thu 14:30 H10

**Spin dynamics of complex metallic magnets** — •Paweł Buczek, Arthur Ernst, and Leonid Sandratskii — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

Magnons, often termed as spin-waves, are elementary collective excitations of magnets. Every magnon lowers the magnetization of the system by $2\mu_\mathrm{B}$, carries energy and crystal momentum. Their signature is found in the inelastic neutron scattering, spin polarized electron energy loss spectroscopy, inelastic scanning tunneling microscopy and spin-resolved two-photon photoemission experiments. Magnons and other magnetic excitation can be one of the coupling mechanisms in high temperature superconductivity. They control the thermodynamics of magnets. Spintronics approaches limits where the magnetic excitations start to interfere with operation of the devices.

In this theoretical talk we will outline an *ab-initio* method of studying magnetic excitations based on time dependent density functional theory. The method allows to access both the energies and life times of magnons. We will discuss the applications of the method to half-metallic Heusler compounds. In these materials certain decay channels become inoperative for low-energy spin-waves. Next, we will focus on magnons in thin metallic films, where their properties are strongly influenced by the structure of the films and the presence of substrate. Finally, some attention will be paid to the theoretical interpretation of certain novel experiments capable of probing magnons in nanostructures.

MA 26.3 Thu 15:00 H10

**Time-resolved and wave-vector sensitive observation of a pump-free BEC** — •Christian W. Sandweg[1], Alexander A. Serga[1], Vitaliy I. Vasyuchka[1], Andrii V. Chumak[1], Timo Neumann[1], Björn Obry[1], Helmut Schultheiss[1], Gennadii A. Melkov[2], Andrei N. Slavin[3], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Radiophysics, National Taras Shevchenko University of Kiev, Ukraine — [3]Department of Physics, Oakland University, Rochester, MI, USA

We report on the temporal and wave-vector sensitive investigation of a pump-free Bose-Einstein-Condensate (BEC) of magnons at room temperature. To create the condensate the technique of parametric microwave pumping is used. A microwave photon splits into two magnons with half of the pumping frequency and opposite k-vector. In a competing process only the group of magnons at half of the pumping frequency having the lowest damping survives. The magnons of this dominant group (DG) thermalize to the lowest energy state and a BEC of magnons is formed. The DG not only plays the role of an energy source for the BEC but is in the same time the most important disruptive factor for it. When the pumping is switched off the BEC of magnons can freely evolve which result in a strong increase of intensity of the condensate on the same time scale as the dominant group decays. To separate the BEC dynamics from the evolution of the other components of the magnon gas near the lowest energy state, time-resolved measurements were performed in combination with wave-vector sensitivity.

MA 26.4 Thu 15:15 H10

**Parametric resonance and the kinetics of magnons in Yttrium Iron Garnet** — •Thomas Kloss, Andreas Kreisel, and Peter Kopietz — Goethe-Universität, Frankfurt, Deutschland

The time evolution of magnon gases subject to an external time-dependent microwave field is usually described within the so-called "S-theory", which amounts to deriving self-consistent kinetic equations for the distribution function within the time-dependent Hartree-Fock approximation. For the theoretical description of the recently observed "Bose-Einstein condensation of magnons" under external microwave pumping the "S-theory" should be generalized to include the Gross-Pitaevskii equation for the time-dependent expectation value of the magnon creation and annihilation operator. We explicitly solve the resulting coupled equations within a simple approximation where only the condensed mode and its fluctuations are retained. We also re-examine the usual derivation of time-dependent effective boson models from a realistic spin model for Yttrium-Iron-Garnet films and argue that for strictly parallel pumping (where the time-dependent part of the magnetic field is parallel to its static component) the magnons should condense.

MA 26.5 Thu 15:30 H10

**Reversible folding of acoustic spin waves in an one-dimensional magnonic crystal** — •Jesco Topp[1], Mikhail Kostylev[3], Detlef Heitmann[1], and Dirk Grundler[2] — [1]Institut für Angewandte Physik, Universität Hamburg, 20355 Hamburg, Germany — [2]Physik-Department E10, Technische Universität München, 85747 Garching, Germany — [3]School of Physics, M013, University of Western Australia, 35 Stirling Hwy, 6009 Crawley, WA, Australia

Spin waves can be tailored by geometric confinement, through inhomogenuous internal fields or bandstructure engineering in magnonic crystals, i.e. periodic arrays of magnetic structures that support spin-wave propagation from structure to structure. We have investigated spin waves in a one-dimensional magnonic crystal fabricated out of from 300 nm wide and 20 nm thick nanowires and investigated the magnetic-field dispersion near the Brillouin-zone center by means of broadband microwave spectroscopy. The spin-wave spectrum of this crystal can be controlled by (reversibly) modifying the bandstructure of the crystal during the experiment. We find that two different kinds of spectra can be chosen, depending on the unit cell of the crystal. A simple cell (a single wire) or a complex one (two wires with antiparallel magnetization) can be selected using a careful magnetic-field history. Modes of the complex unit cell can be understood by a folding of the (simple cell's) wavevector dispersion into the new Brillouin zone. The lowest-order acoustic spin wave and its folded counterpart exhibit a peculiar magnetic-field dispersion. Funding via "SFB 668" and the "Nanosystems Initiative Munich" (NIM) is acknowledged.

MA 26.6 Thu 15:45 H10

**Sub-wavelength non-diffractive spin-wave beams** — Thomas Schneider[1], •Alexander A. Serga[1], Andrii V. Chumak[1], Christian W. Sandweg[1], Simon Trudel[1], Sandra Wolff[2], Mikhail P. Kostylev[3], Vasil S. Tiberkevich[4], Andrei N. Slavin[4], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Nano + Bio Center, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [3]School of Physics, M013, University of Western Australia, Crawley, WA 6009, Australia — [4]Department of Physics, Oakland University, Rochester, Michigan 48309, USA

We report on the investigation of linear sub-wavelength non-diffractive spin-wave beams in a 2D magnetic medium. These beams, are formed due to the anisotropy which is induced in the magnetic media by the bias magnetic field. Due to this anisotropy, it is possible, that spin waves have different oriented wave vectors but an identical direction of group velocity. A newly developed waveguide antenna allows the excitation of spin waves with the necessary wide angular wavevector spectrum. We investigated the dependence of the behaviour of the non-diffractive beams on the magnetic field and the antenna spectrum using space-, time- and phase-resolved Brillouin light scattering spectroscopy. It is shown that the sub-wavelength spin-wave beams propagate without noticeable broadening for more than 10 mm. The measurements demonstrate that the beam width is of the same order of magnitude as the wavelength. Results on the reflection and scattering of the beams are reported.

MA 26.7 Thu 16:00 H10

**Splitting of the homogeneous mode in high power ferromagnetic resonance experiment** — •Peter Majchrak[1], Georg Woltersdorf[1], Thorsten Kachel[2], Christian Stamm[2], Hermann Dürr[2], and Christian Back[1] — [1]Institut für Exp. und Angewandte Physik, Uni Regensburg, 93040 Regensburg — [2]BESSY II, Albert-Einstein-Straße 15, 12489 Berlin, Germany

Utilizing X-ray magnetic circular dichroism (XMCD) we measured the transversal components of the precessing magnetization in a thin film under cw microwave excitation (phase locked to the X-ray pulses) in a coplanar waveguide structure. From the signal calibrated by XMCD hysteresis loops we directly evaluated the absolute values of precessing magnetization. At large microwave fields the susceptibility becomes nonlinear due to the decrease of the effective magnetization and the excitation of parametric spin waves (Suhl instability). The measured amplitude of the excursion saturates above the critical field and at the same time the resonance line of the uniform mode is splitting. The split of the line increases with growth of the pumping field and that results in an effective linewidth broadening. The measurement of both components of the complex susceptibility allows for evaluation of the phase of the two modes with respect to the exciting field and then to reconstruct their lineshapes. This way we distinguished two separate uniform precession modes, which appeared in nonlinear regime and characterized their phase and the resonance field for various microwave excitation amplitudes. Support by the BMBF (05 ES3XBA/5) is gratefully acknowledged.

MA 26.8 Thu 16:15 H10

**All-optical detection of phase fronts of propagating spin waves in a $Ni_{81}Fe_{19}$ microstripe** — •Katrin Vogt, Helmut Schultheiss, Sebastian J. Hermsdoerfer, Philipp Pirro, Alexander A. Serga, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

We present the determination of the wavelength and phase of propagating spin waves in magnetic microstructures made of $Ni_{81}Fe_{19}$ using the shorted end of a coplanar waveguide for local excitation. The spin wave characteristics have been measured by phase resolved Brillouin light scattering microscopy. This recently developed technique allows for the experimental visualization of the phase structure of propagating spin waves and is employed here to magnetic microstructures. The results show an excellent agreement with the calculated dispersion relations for the spin-wave waveguide modes.

Financial support by the DFG Priority Program SPP 1133 is gratefully acknowledged as well as the Nano+Bio Center of the Technische Universität Kaiserslautern for their assistance in sample preparation.

MA 26.9 Thu 16:30 H10

**ESR in CuCrO2** — •Mamoun Hemmida[1], Hans-Albrecht Krug von Nidda[1], Nikola Pascher[1], Alois Loidl[1], and Christine Martin[2] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, 86135 Augsburg, Germany — [2]Laboratoire CRISMAT, UMR 6508 CNRS-ENSICAEN, and IRMA FR3095, 6 Boulevard Maréchal Juin, Caen Cedex 4, France

Electron Spin Resonance (ESR) measurements were performed at X band (9.4 GHz) frequency on a delafossite compound CuCrO2, both on single crystal and polycrystalline samples, which represents a model system of the two-dimensional triangular lattice Heisenberg antiferromag- net. The spin-spin relaxation behavior, which appears in the temperature dependence of the linewidth is similar to that previously observed in some iso-structural rock salt Cr- compounds like HCrO2, LiCrO2, and NaCrO2. In those oxides, the linewidth is well described in terms of a Berezinskii-Kosterlitz-Thouless (BKT) like scenario [1, 2, 3]. The deviation from the ideal BKT scenario was attributed to the effect of geometrical frustration [4]. References [1] V. L. Berezinskii, Sov. Phys. JETP 32, 493 (1971). [2] J. M. Kosterlitz and D. J. Thouless, J. Phys. C 6, 1181 (1973). [3] J. M. Kosterlitz, J. Phys. C 7, 1046 (1974). [4] Hemmida, M., Krug von Nidda, H.-A., Buettgen, N., Loidl, A. , Alexander, L. K., Nath, R., Mahajan, A. V., Berger, R. F., Cava, R. J., Singh, Yogesh, and Johnston, D. C., Phys. Rev. B 80, 054406 (2009). 1

MA 26.10 Thu 16:45 H10

**Spin dynamics in a ferromagnetic spin-orbital chain beyond mean-field decoupling** — •Alexander Herzog[1], Andrzej Oleś[1,2], Peter Horsch[1], and Jesko Sirker[1,3] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]Marian Smoluchowski Institute of Physics, Jagellonian University, Kraków, Poland — [3]Technische Universität Kaiserslautern, Fachbereich Physik, Kaiserslautern, Germany

We study the spin dynamics and thermodynamics of a one-dimensional spin-orbital model relevant for transition metal oxides. In mean-field decoupling this model shows a dimerized phase at intermediate temperatures while the spins order ferromagnetically in the ground state. Using a modified spin-wave theory we calculate the dynamical spin structure factor in the uniform and dimerized phase. We then address the question how the spin dynamics is affected if the spin-orbital coupling is taken into account beyond mean-field. Finally we also study corrections to thermodynamic quantities beyond the mean-field decoupling and compare with a numerical solution of the model obtained by the density-matrix renormalization group.