MA 37: Focus Session: Insulator Spintronics

New building blocks for magnonics

Time: Wednesday 15:45–19:15 Location: H38

Invited Talk MA 37.1 Wed 15:45 H38
Magnon Transport and Magnonic Topological Insulators — •Daniel Loss — University of Basel, Switzerland

The physics of spin and magnon transport in magnetic insulating systems has attracted a lot of attention in recent years due to fundamental reasons but also due to promising applications such as low-dissipation devices. In my talk I will focus on the magnon counterparts of electron transport such as the Wiedemann-Franz law, the Josephson effect in magnon BECs, persistent magnon currents, magnon quantum Hall conductance, and magnon topological edge states in Skyrmion lattices.

Invited Talk MA 37.2 Wed 16:15 H38
Implementation of the Stimulated-Raman-Adiabatic-Passage mechanism in magnonics — •Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Magnonics is the field of spin waves. Being wave-based, magnonics bears the advantage of the ease of implementation of computation schemes developed in other areas of wave-based phenomena. One example is the concept of "quantum- classical analogy", which was created in the field of waveguide optics. It was shown, that the use of classical light in optical waveguides allows for the physical realization of quantum phenomena in atom physics, such as the population transfer between two states via a third, intermediate, dark state, where direct transitions between the two states are dipole forbidden. This process is referred to as STImulated Raman Adiabatic Passage (STIRAP) and has found various applications in many fields of physics.

We present first results of the magnonic realization of such a STIRAP process (m-STIRAP). Using micromagnetic simulations, we show that the population of magnons can be transferred between two waveguides via an intermediate waveguide. If the "counterintuitive" coupling scheme is used, the intermediate waveguide is not excited during the transfer, thus resembling the quantum-classical analogy of a dark state.

Our results bear high potential for future magnonic device functionalities and designs by bringing together the wealth of quantum-classical analogy phenomena with the wealth of means to control wave propagation in magnonic systems.

MA 37.3 Wed 16:45 H38
Hybridization of Ferro- and Antiferromagnetic Magnon Modes in GdIG — •Lukas Liensberger[1,2], Akashdeep Kamra[3], Hannes Maier-Flaig[1,2], Stephan Geprägs[1,2], Andreas Erb[1], Sebastian T. B. Goennenwein[4], Rudolf Gross[1,2,5], Wolfgang Belzig[6], Hans Huebl[1,2,5], and Mathias Weiler[1,2] — [1]Walther-Meißner-Institut — [2]Physik-Department, Technische Universität München — [3]Center for Quantum Spintronics, Norwegian University of Science and Technology — [4]Institut für Festkörper- und Materialphysik, Technische Universität Dresden — [5]Nanosystems Initiative Munich — [6]Department of Physics, University of Konstanz

The ability to tailor the static and dynamic magnetic properties of rare-earth iron garnets has stimulated a multitude of research studies and resulted in numerous applications. One prime example of this material class is the compensated ferrimagnet gadolinium iron garnet (GdIG). We investigate the magnetization dynamics of a single crystal GdIG disk using broadband magnetic resonance and study in particular the dispersion relation of the ferro- and the antiferromagnetic modes. Close to the magnetization compensation temperature T_c we observe a strong and tunable interaction of these two modes. We explain our observations by employing a two-sublattice model for the ferrimagnet and find good agreement with theory. A weak, anisotropy-induced coupling is exchange enhanced close to T_c and yields strong coupling. The clock- and counterclockwise precessing modes thereby hybridize into linearly oscillating modes.
We acknowledge financial support by the DFG via project WE5386/4.

15 min. break

Invited Talk MA 37.4 Wed 17:15 H38
Spintronics at interfaces of insulators and non-magnetic metals - magnon Bose-Einstein condensation and induced superconductivity — •Niklas Rohling, Eirik Løhaugen Fjaerbu, and Arne Brataas — Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491, Trondheim, Norway

The coupling between a normal metal (NM) on one side and an antiferromagnetic (AFI) or ferromagnetic insulator (FI) on the other side allows for spin transport through the interface via spin pumping and spin transfer torque (STT). We describe this coupling by a Heisenberg exchange Hamiltonian and perfectly matching lattices. The coupling of the electronic and magnonic states then depends crucially on their amplitude at the interface. We discuss briefly the possibility of generating a magnon Bose-Einstein condensate via STT [1,2]. Then we focus on a model describing superconductivity induced by interfacial coupling to magnons in a FI-NM-FI trilayer [3]. The electron-magnon interaction at the interfaces induces electron-electron interactions, which in turn can result in p-wave superconductivity. We solve the gap equation numerically, estimate the interface coupling strength for yttrium iron garnet (YIG)-Au-YIG and EuO-Au-EuO trilayers, and find critical temperatures in an experimentally accessible range.

[1] Bender et al., Phys. Rev. Lett. **108**, 246601 (2012); Phys. Rev. B **90**, 094409 (2014).
[2] Fjærbu, Rohling, Brataas, Phys. Rev. B **95**, 144408 (2017).
[3] Rohling, Fjærbu, Brataas, Phys. Rev. B **97**, 115401 (2018).

Invited Talk MA 37.5 Wed 17:45 H38
Magnon Transport and Dynamics in Magnetic Insulator — •Jing Liu — University of Groningen

I will give an overview of our recent results of the transport of thermal magnons in a magnetic insulator, yttrium iron garnet. We have shown that these can be generated electrically and by Joule heating, and can propagate with a typical relaxation length of 10 micrometers[1]. We have developed a theoretical description, where the magnon transport is driven by (a combination of) a gradient of the temperature (magnon spin Seebeck effect) or by the gradient of the magnon chemical potential[2].

Recently, we demonstrated that the magnon transport can be modulated by the injection of magnons by an intermediate electrode, which acts analogously to a gate electrode in electrical field effect transistor[3]. Besides, we investigated the interaction between (nonlocal) magnon transport of thermal magnons and GHz magnetization dynamics. We observe both enhancement and suppression of the magnon transport, and I will discuss the possible origins[4]. Finally, we discovered a new way to inject and detect magnon by using the anomalous spin Hall effect of permalloy. This also provides a possibility of injecting magnon spins with an out-of-plane component[5,6].

[1] L.C. Cornelissen, J. Liu et al. Nature Phys. 11, 1022 (2015) [2] L.C. Cornelissen et al. Phys. Rev. B94, 014412 (2016) [3] L.C. Cornelissen, J. Liu et al. Phys. Rev. Lett. 120, 097702 (2018) [4] J. Liu et al. Arxiv 1810.11667 (2017) [5] K.S. Das et al. Phys. Rev. B96, 220408(R) (2017) [6] K.S. Das, J. Liu et al. Nano Lett. 18. 5633 (2018)

MA 37.6 Wed 18:15 H38
Enhanced magnon spin transport in $NiFe_2O_4$ thin films on the lattice-matched substrate $MgGa_2O_4$ — Juan Shan[1], Amit V. Singh[2], Lei Liang[1], Ludo C. Cornelissen[1], Zbigniew Galazka[3], Arunava Gupta[2], Bart J. van Wees[1], and •Timo Kuschel[1,4] — [1]Zernike Institute for Advanced Materials, University of Groningen, The Netherlands — [2]MINT Center, University of Alabama, USA — [3]Leibniz-Institut für Kristallzüchtung, Berlin, Germany — [4]Center for Spinelectronic Materials and Devices, Bielefeld University, Germany

We report on enhanced magnon spin transport properties in epitaxial $NiFe_2O_4$ (NFO) films grown on $MgGa_2O_4$ substrates [1] compared to NFO films deposited on standard $MgAl_2O_4$ [2]. The reduction of the lattice mismatch from 3.2% to 0.8% decreases the number of antiphase boundary defects in the NFO films and, thus, improves structural and magnetic properties. Further, spin transport is strongly improved as we have studied by nonlocal magnon spin transport experiments with Pt injector and detector strips. While the magnon spin diffusion length in the NFO films of around 3 μm is not changed drastically, the nonlocal spin transport signal is enhanced by two orders of magnitude. This increase is detectable for both electrically and thermally excited magnons. In addition, we observe spin transport signals in NFO that point to magnetoelastic coupling identified as magnon polarons [1]. These findings make lattice-matched NFO being an important alternative to $Y_3Fe_5O_{12}$ (YIG) in terms of spin transport properties.

[1] J. Shan et al., Appl. Phys. Lett. 113, 162403 (2018)
[2] J. Shan et al., Appl. Phys. Lett. 110, 132406 (2017)

Invited Talk MA 37.7 Wed 18:30 H38

Tunable long distance spin transport in antiferromagnetic insulators — •Mathias Kläui — Institute of Physics, Johannes Gutenberg-University Mainz

We probe spin transport in insulating antiferromagnets, such as NiO [1,2], CoO [3] and hematite [4]. Spin currents are generated by heating as resulting from the spin Seebeck effect and by spin pumping measurements and we find in vertical transport short (few nm) spin diffusion lengths [2,3].

For hematite, however, we find in a non-local geometry that spin transport of tens of micrometers is possible. We detect a first harmonic signal, related to the spin conductance, that exhibits a maximum at the spin-flop reorientation, while the second harmonic signal, related to the Spin Seebeck conductance, is linear in the amplitude of the applied magnetic field [4]. The first signal is dependent on the direction of the Neel vector of the antiferromagnet and the second one depends on the induced magnetic moment due to the field. From the power and distance dependence, we unambiguously distinguish long-distance transport based on diffusion [4] from predicted spin superfluidity that can potentially be used for logic [5].

References: [1] L. Baldrati et al., PRB 98, 024422 (2018) [2] L. Baldrati et al. PRB 98, 014409 (2018) [3] J. Cramer et al., Nature Comm. 9, 1089 (2018) [4] R. Lebrun et al., Nature 561, 222 (2018). [5] Y. Tserkovnyak et al., PRL 119, 187705 (2017).

MA 37.8 Wed 19:00 H38

All-electrical control of spin transport in a three-terminal yttrium iron garnet/platinum nanostructure — •T. Wimmer[1,2], M. Althammer[1,2], L. Liensberger[1,2], N. Vlietstra[1], S. Geprägs[1], M. Weiler[1,2], R. Gross[1,2,3], and H. Huebl[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Nanosystems Initiative Munich (NIM), München, Germany

The transport of information via spin waves (magnons) in ferromagnetic materials provides novel, intriguing pathways towards information processing and manipulation beyond charge-based semiconductor technology. Here, the investigation of the transport of magnons in transistor like structures is of key importance.

In this study, we investigate the transport and control of magnon spin currents using an all-electrical detection and manipulation scheme. To this end, we utilize three parallelly aligned, electrically isolated platinum (Pt) electrodes deposited on a 13 nm thin yttrium iron garnet (YIG) film. The outer Pt contacts act as spin current injector and detector while the center one realizes the control of the magnon conductance. All electrodes use the (inverse) spin Hall effect to act on the magnon system. We are able to control the magnon spin conductance by up to 60 %/mA. Most interestingly, in addition to the linear control of the magnon transport, we find a highly non-linear regime to the spin conductance modulation.

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