MA 30: Focus Session "Spin Currents in Magnetic Nanostructures", Organization: Mathias Kläui (Univ. Mainz)

Time: Wednesday 15:00–18:45 Location: EB 301

Invited Talk MA 30.1 Wed 15:00 EB 301

Spin transfer in conducting and insulating magnetic systems — •Yaroslav Tserkovnyak — University of California, Los Angeles

I will review recent developments in the theory of current-induced magnetization dynamics and reciprocal pumping phenomena. Following early realization of the importance of these effects in layered magnetic structures, much attention has been recently paid to continuous ferromagnetic systems with strong magnetic textures (such as domain walls, vortices, skyrmion lattices etc.) as well as magnetic phases with antiferromagnetic or other magnetic order. Magneto-thermoelectric phenomena have furthermore generated a flurry of experimental and theoretical activities, and the field has branched out to encompass new materials, both conducting and (trivially or topologically) insulating. Despite the apparent diversity of underlying magnetic orderings, materials, phases, and nanoscale configurations, it turns out there are very simple guiding principles that allow one to streamline phenomenological and microscopic understanding, put forward insightful experimental predictions, and propose applications, as will be discussed in this talk.

Topical Talk MA 30.2 Wed 15:30 EB 301

Spin pumping with photons and phonons — •Mathias Weiler[1], Franz D. Czeschka[1], Hans Huebl[1], Frederik S. Goerg[1], Matthias Althammer[1], Lukas Dreher[2], Martin S. Brandt[2], Rudolf Gross[1], and Sebastian T. B. Goennenwein[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Walter Schottky Institut, Technische Universität München, Garching, Germany

Spin pumping and the inverse spin Hall effect are key phenomena to generate and detect pure spin currents. In a systematic study of the photon-driven spin pumping effect in a series of ferromagnet/normal metal hybrids, we found that the inverse spin Hall voltage V_{DC} scales with the magnetization precession cone angle, irrespective of the particular properties of the ferromagnet [1]. In a complimentary approach, we show that spin pumping can also be driven by exploiting the purely virtual magnetic driving field caused by coherent phonons in magnetoelastic media [2]. To this end, we excite a Co/Pt thin film bilayer by radio frequency surface acoustic wave pulses and measure V_{DC}. In our time-resolved experiments, we can disentangle photon- and phonon-driven contributions to V_{DC} and find evidence for resonant spin current generation in the exclusive presence of an elastic excitation.

This demonstrates that spin pumping in ferromagnet/normal metal hybrids is a generic phenomenon that can be consistently modeled irrespective of magnetic material and excitation mechanism.

[1] F. D. Czeschka *et al.* Phys. Rev Lett. **107**, 046601 (2011)
[2] M. Weiler *et al.* (2011) arXiv:1110.1187

Invited Talk MA 30.3 Wed 16:00 EB 301

Generation of superdiffusive spin-currents through femtosecond laser excitation of ferromagnetic/non-magnetic hybrid structures — •Peter M. Oppeneer[1], Marco Battiato[1], Karel Carva[1,2], and Pablo Maldonado[1] — [1]Uppsala University, S-751 21 Uppsala, Sweden — [2]Charles University, 12116 Prague, Czech Republic

The process of femtosecond laser excitation in a metallic ferromagnet is analyzed theoretically. Laser excitation creates spin-polarized hot electrons with fast transport characteristics. We develop a semi-classical model for transport of such excited electrons, treating the multiple electronic collisions exactly /1/. The derived transport equation is solved numerically and it is shown that the spin-transport is neither diffusive nor ballistic, it is superdiffusive. Due to distinct lifetimes of majority and minority electrons effectively a spin-polarized current is created. Considering ferromagnetic/non-magnetic layer structures where the ferromagnetic layer is laser excited, and solving the resulting spin-dynamics numerically in the time-domain, we show that injection of a superdiffusive spin-current in the non-magnetic layer is achieved. The injected spin-current consists of hot, mobile majority spin electrons and is nearly 100% spin-polarized. It could be used as a means to accomplish domain wall movement or in spin-based electronics.

/1/ M. Battiato, K. Carva, P.M. Oppeneer, Phys. Rev. Lett. **105**, 027203 (2010).

MA 30.4 Wed 16:30 EB 301

Spin filtering in spinel ferrite $CoFe_2O_4$ — •Michael Foerster, Diego F. Gutierrez, and Josep Fontcuberta — Institut de Ciència de Materials de Barcelona ICMAB-CSIC, Campus de la UAB, 08193 Bellaterra, Catalonia, Spain

Spin filtering promises an effective approach to generate highly spin polarized currents, e.g. for spin injection. Spin filters are realized by tunneling barriers from magnetic insulators, where the exchange split band gap results in spin dependent transmission probabilities. Moodera et al. validated this concept using Europium chalcogenides [1].

However, these compounds have low Curie temperatures and only few magnetic insulators with transitions clearly above room temperature exist. Spinel ferrites, e.g. $CoFe_2O_4$ (T_C = 790 K), are considered most promising candidates. Using point contact spetroscopy, the spin filtering efficiency of $CoFe_2O_4$ thin films on $SrRuO_3$ bottom electrodes has been evaluated [2], but is found to be much below expectations based on calculated band structures. The possible reasons for this low filtering efficiency, which is common for reports on spinel ferrites, are addressed by probing two key properties of ultrathin films: transport, using conducting AFM [3], and magnetic properties when grown on different substrates [4], revealing the points that have to be considered for further optimization.

[1] J.S. Moodera et al., J. Phys.: Condens. Matter 19, 165202 (2007).
[2] F. Rigato et al., Phys. Rev. B 81, 174415 (2010).
[3] M. Foerster et al., Appl. Phys. Lett. 97, 242508 (2010).
[4] M. Foerster et al., Phys Rev. B, published online.

MA 30.5 Wed 16:50 EB 301

Lateral Spin Valves: Transport Measurements and Magnetization Dynamics — •Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

We study spin-dependent transport in lateral spin-valve devices with tunnel barriers at the interfaces between normal and ferromagnetic metals. Different total conductivities per cross-sectional area are achieved by variation of the oxygen pressure, the oxidation time, and the thickness of the oxidized interface metal layer. We find that with decreasing tunnel conductance the amplitude of the nonlocal spin-valve effect increases by two orders of magnitude up to saturation [1]. Currently the combination of magnetization dynamics and spin transport often addressed as spin-pumping is of great interest [2]. First experimental results including the detection of pure spin currents have been presented [3]. Here we aim at an all-metal lateral spin valve, where the spins are injected into an adjacent normal metal via a ferromagnet with precessing magnetization at resonance. We present a study of the magnetization dynamics of ferromagnetic electrodes. The cone angles of the precessional motion of the magnetization at resonance are determined by measurements of the anisotropic resistance of a single electrode. Large cone angles of up to 13.7 degree are observed [4].

[1] A. Vogel et al., APL 94, 122510 (2009); [2] Y. Tserkovnyak et al., PRL 88, 117601 (2002); [3] M.V. Costache et al., PRB 78, 064423 (2008); [4] N. Kuhlmann et al., PRB submitted (2011).

20 min. break

MA 30.6 Wed 17:30 EB 301

All-electrical spin injection and detection in lateral $Co_2FeSi/GaAs$ devices — •Pawel Bruski, Rouin Farshchi, Oliver Brandt, Jens Herfort, Abbes Tahraoui, and Manfred Ramsteiner — Paul-Drude-Institut Berlin, Hausvogteiplatz 5-7, 10117 Berlin, Germany

The ferromagnetic Heusler alloy Co_2FeSi is closely lattice matched to GaAs and is predicted to be half-metallic, meaning that electrons at the Fermi level are 100% spin-polarized. We demonstrate the successful all-electrical injection and detection of spins in the $Co_2FeSi/GaAs$ hybrid system using a lateral device structure.

The electrical spin detection is achieved through a nonlocal spin-sensitive measurement, which separates the charge and current paths to exclude parasitic effects such as local Hall effects. Evidence for electrical spin injection and detection has been obtained by spinvalve and Hanle measurements, where the latter presents the most robust proof for all-electrical spin injection and detection by revealing the spin precession in an external magnetic field.

A fit based on a one-dimensional spin drift-diffusion model, which takes into account spin relaxation and precession, is in excellent agreement with our experimental Hanle data. A spin lifetime in GaAs of several ns and a spin injection efficiency of 16% are obtained from the fit, with the latter value being close to results acquired from optoelectronic devices consisting of the $Co_2FeSi/(Al,Ga)As$ hybrid system.

MA 30.7 Wed 17:45 EB 301

Optimization of spin injection and detection in lateral nanostructures by geometrical means — •Ondřej Stejskal, Jaroslav Hamrle, and Jaromír Pištora — Department of Physics and Nanotechnology Centre, VSB - Technical University of Ostrava, Czech Republic

Lateral nanostructures are important branch of spintronic devices as they extend possibilities of simpler perpendicular devices. For efficient operation of lateral devices, it is important to maximize spin injection and spin detection efficiency. Several approaches were proposed, such as design of new injector/detector materials (e.g. half metals), or using spin-barried between spin injector/detector and spin conductor (such as MgO barrier).

Here, we suggest alternative optimization of spin injection and detection, by engineering the dimensions of the lateral device. For example, we show that spin injector efficiency can be increased by reduction of cross-sectional area of junction between injector and spin conductor or by increasing the cross-section of the spin-conductor. Furthermore, in lateral spin-valve structures, the detection is provided by second FM element (detector). Depending on purpose of the device, different quantities may need to be optimized, such as spin voltage on detector (in case the purpose is reading of the magnetic state of the detector) or spin current flowing into the detector (in case the spin-manipulation of the detector is important). We discuss how those quantities may be optimized by variation of the cross-sectional area, resistivity and polarization of the junction between detector and spin conductor.

MA 30.8 Wed 18:00 EB 301

Wave-diffusion theory of spin transport in metals after ultrashort-pulse excitation — •Steffen Kaltenborn[1], Yao-Hui Zhu[2], and Hans Christian Schneider[1] — [1]University of Kaiserslautern, Kaiserslautern, Germany — [2]Beijing Technology and Business University, Beijing, China

We present theoretical results for spin and charge-current dynamics after ultrafast spin-polarized excitation in a normal metal. It is first shown analytically how the macroscopic wave-diffusion equations [1] provide a unified description of ballistic and diffusive properties of spin and charge transport including the "intermediate" regime in which transport is characterized by both ballistic and diffusive features. These equations are then applied to a simplified model of ultrafast excitation of spin polarized carriers in gold films of thickness up to several hundred nanometers. If one assumes spin-dependent momentum relaxation times, the computed dynamics of the spin and charge density at the surface of the films of varying thickness qualitatively reproduce recent measurements [2], which were interpreted as arising from the transition from ballistic to diffusive transport. Our calculations support this interpretation, and indicate that the signatures observed in the experiment are quite generic for ultrashort timescales and thin films because they can be traced back to a combination of ballistic and diffusive properties of spin and charge transport.

[1] Y.-H. Zhu, B. Hillebrands, and H. C. Schneider, Phys. Rev. B 78, 054429 (2008)

[2] A. Melnikov et al., Phys. Rev. Lett. 107, 076601 (2011)

MA 30.9 Wed 18:15 EB 301

Direct detection of magnon spin transport by the inverse spin Hall effect — •Andrii Chumak, Benjamin Jungfleisch, Alexander Serga, Roland Neb, and Burkard Hillebrands — Fachbereich Physik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany

The combination of the spin pumping effect with the inverse spin Hall effect (ISHE) allows the use of spin waves (or magnons) for the carrying of signals in spintronic devices. In spite of sufficient progress in these studies, no magnon-carried spin transfer has yet been shown directly. We use a spatially separated inductive spin-wave source and an ISHE detector to demonstrate the signal transport by travelling magnons in a time resolved experiment. The setup comprises a 2.1 μm thick YIG waveguide with a 10 nm thick (200 μm x 3 mm) Pt strip deposited on the top. The YIG waveguide is magnetized along its long axis by applying an external bias magnetic field of 1754 Oe. In order to excite short spin-waves packets the 50 μm wide Cu microstrip antenna is placed at a distance of 3 mm from the Pt strip. While propagating under the Pt layer, the spin-wave packet generates a spin current in it due to spin pumping, and the delayed ISHE DC pulse is detected. The delay appears due to the finite spin-wave group velocity and proves the magnon nature of the spin transport. The experiment suggests to utiliza spin waves for the transfer of spin information over macroscopic distances in spintronic devices and circuits. Besides, the contribution of secondary excited magnons to the ISHE voltage is refered in our studies.

MA 30.10 Wed 18:30 EB 301

Light-induced spin pumping in two-dimensional electron systems with random Rashba spin-orbit interaction — •Vitalii Dugaev[1,2], Michal Inglot[2], Evgeny Sherman[3], Jamal Berakdar[1], and Jozef Barnas[4] — [1]Martin-Luther-Universität Halle-Wittenberg, Halle, Deutschland — [2]Rzeszow University of Technology, Rzeszow, Poland — [3]Universidad del Pais Vasco, Bilbao, Spain — [4]Adam Mickiewicz University, Poznan, Poland

Rashba spin-orbit interaction plays an important role in two-dimensional electron systems leading to numerous spin-dependent effects like spin relaxation or anomalous and spin Hall effects. In some cases, the Rashba interaction can be strongly fluctuating in space with zero average value. The most important examples are some symmetric sandwiched structures with semiconductor quantum wells. We consider several different two-dimensional systems with random Rashba interaction. Besides the simple model with a parabolic energy spectrum we also analyze the Dirac model of electrons in graphene. We show that in the case of free-standing graphene the main source of spin-orbit interaction is related to corrugated and rippled surface. Our calculations demonstrate that in all cases the electromagnetic radiation can be used to effectively generate charge and spin densities. The mechanism of spin polarization under electromagnetic radiation is related to fluctuations of Rashba spin-orbit interaction strongly coupled to the electromagnetic field. We believe that this effect of spin pumping can be used in spintronics applications for optically-controlled generation and manipulation of the spin currents.