MA 32: Focus Session: Spin Current Devices

Organizers: S.O. Demokritov (Westfälische Wilhelms-Universität Münster), S.T.B. Goennenwein (Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching), B. Hillebrands (Technische Universität Kaiserslautern)

Spin currents are the spin angular momentum analogue of conventional charge currents. They thus represent a fundamental building block for spintronic devices in the proper sense of the word, in which only spin information is transported, manipulated and stored, while no charge motion is required. In this session, different spin current device concepts will be described, in conjunction with an overview over fundamental spin current physics.

Time: Thursday 9:30–12:00 Location: H10

Topical Talk MA 32.1 Thu 9:30 H10
Spin Hall and spin Nernst effect from first principles — •Ingrid Mertig — Martin Luther University Halle-Wittenberg, 06099 Halle, Germany

Spintronics without magnetic materials is an interesting alternative to the existing spintronics applications. The spin Hall effect creates spin currents in nonmagnetic materials and avoids the problem of spin injection. Future applications of the spin Hall effect require two properties of the materials, a large spin Hall angle and a long spin diffusion length. Ab intio calculations based on density functional theory are a powerful tool to design the desired materials and to get insight into the underlying microscopic processes. We investigated the spin Hall effect in dilute alloys, in particular the intrinsic effect based on the Berry curvature as well as the side-jump and skew-scattering contributions. The results demonstrate that a large extrinsic spin Hall effect is determined by the differences between host and impurity concerning the spin-orbit interaction. An alternative way is to deposit impurities in the adatom position of thin films. Furthermore, we predict a spin current perpendicular to a temperature gradient. The phenomenon is called spin Nernst effect.

Topical Talk MA 32.2 Thu 10:00 H10
Spin currents in ferromagnetic insulator/normal metal hybrids — •Matthias Althammer — Walther-Meißner-Institut, BAdW, Germany — University of Alabama, MINT Center, Tuscaloosa, USA

The controlled generation, manipulation, and detection of spin currents (i.e., of flows of spin angular momentum without an accompanying net flow of charge) - is the key to novel spin transport schemes and novel spintronic devices. We have experimentally investigated pure spin currents in ferromagnetic insulator/normal metal hybrid structures, using yttrium iron garnet, nickel ferrite, or magnetite for the magnetic insulator, and Pt, as well as Cu or Au, for the normal metal layer. On the one hand, we use spin pumping measurements to quantify the spin mixing conductance in our hybrid structures. On the other hand, we observe a novel magnetoresistive effect upon driving a conventional charge current through the Pt. This so-called spin Hall magnetoresistance (SMR) arises from the combined action of spin Hall and inverse spin Hall effect in Pt [1]. The SMR characteristically depends on the magnetization orientation in the magnetic insulator, although no electrical current flows through the latter. The SMR is qualitatively different from the anisotropic magnetoresistance effect arising in ferromagnetic metals, and in particular persists also when a thin Cu or Au layer is inserted between the magnetic insulator and the Pt layer. Taken together, the SMR thus represents a simple and powerful tool for the study of spin current transport in magnetic hybrid structures.

[1] H. Nakayama et al., arXiv 1211.0098.

Topical Talk MA 32.3 Thu 10:30 H10
From magnon flow to spin current and back — •Andrii Chumak — Fachbereich Physik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Magnons have great potential for applications in the transfer and processing of spin information in spintronics. However, this potential can only be fulfilled if an effective means to convert magnon flows into electron-carried spin and charge currents and back is found. The first part of my talk will concentrate on magnon to charge current converters exploiting a combination of two separate physical phenomena: spin pumping, and the inverse spin Hall effect (SHE). In these systems, a precessing magnetization in a magnetic film results in the injection of a spin current into a normal metal layer on its surface through spin pumping and this spin current is then converted into a charge current via the inverse SHE. I shall present a set of experimental results on yttrium iron garnet (YIG) - Pt bi-layers demonstrating that magnons having wavelengths spanning a wide range (from centimeters down to a hundred nanometers) efficiently contribute to spin pumping. I shall also discuss a way of improving of the YIG-Pt interface capable of increasing the spin pumping efficiency. Next I shall discuss charge current to magnon conversion via the direct SHE and spin transfer torque (STT) in similar structures. Our experiments show that passing a DC current through a surface Pt layer results in a variation of spin-wave damping of up to twenty percent in a two-micron thick YIG film. We acknowledge financial support by the DFG (project CH 1037/1-1).

Topical Talk MA 32.4 Thu 11:00 H10
Interaction between spin waves and magnetic domain walls in insulating ferromagnets — •Peng Yan — Kavli Institute of NanoScience, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands

The interplay between spin waves (SWs) and magnetic domain walls (DWs) leads to very rich physics. On one hand, the injection of SWs through a DW tends to drive the DW moving against the SW propagation direction. The mechanism is identified as a magnonic spin transfer torque which is the counterpart of its electronic version [1]. On the other hand, the DW under a static magnetic field can propagate along a dissipationless nanowire through SW emission (or pumping), since SWs carry away both energy and angular momentum [2]. The opposite effect, viz. the modulation of the magnon-mediated heat current by a domain wall is also investigated [3]. In the regime of validity of continuum micromagnetism, a DW is found to have no effect on the heat conductance. However, SWs are found to be reflected by DWs with widths of a few lattice spacings, which is associated with emergence of an additional spin wave bound state. The resulting DW heat conductance should be significant for thin films of yttrium iron garnet with sharply defined magnetic domains.

[1] P. Yan *et al.*, PRL **107**, 177207 (2011).
[2] X.S. Wang, P. Yan *et al.*, PRL **109**, 167209 (2012).
[3] P. Yan and G.E.W. Bauer, PRL **109**, 087202 (2012).

Topical Talk MA 32.5 Thu 11:30 H10
Current driven domain wall dynamics controlled by proximity induced interface magnetization — •Stuart Parkin — IBM Almaden Research Center, San Jose, California, USA

Ultra-thin perpendicularly magnetized nanowires are the ideal medium for high-density memory and logic devices based on magnetic domain walls. Recently it has been reported that domain walls can be driven by current at very high speed in such nanowires. The high velocity and the direction of motion of the domain walls are inconsistent with conventional theories based on transfer of spin angular momentum from the current. Here we show in nanowires formed from atomically thin Co and Ni layers that interfaces with specific metal layers control both the speed and direction of the domain walls. These layers are formed from non-magnetic metals, namely Pt, Pd and Ir, which become magnetic in proximity to strong ferromagnets. When the induced moment is suppressed by the insertion of atomically thin Au layers the domain walls are considerably slowed. We show that the mechanism driving the domain walls derives from the intertwined phenomena of spin Hall currents in the non-magnetic layers and a Dzialoshinskii-Moriya interaction at the cobalt- non-magnetic interface that fixes the chirality of the domain walls.