Bayerische Akademie der Wissenschaften

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Open Master Theses in Spintronics / Magnetic Nano-Hybrids

July 2015

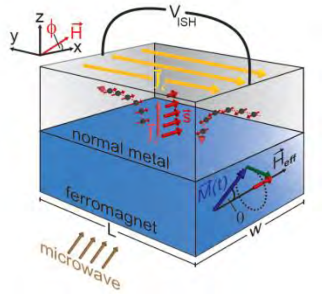
About us:

The scientific activities of the „magnetism group“ at the Walther-Meißner-Institut are focused on current topics in spintronics & magnetic hybrid systems, e.g. *spin currents, spin-dependent thermo-galvanic effects, spin dynamics, spin mechanics, multi-functional magnetic nanostructures, and magnetic oxide thin film heterostructures*. We exploit a variety of experimental techniques, ranging from magnetic thin film and multilayer deposition (laser-MBE, sputtering, electron-beam evaporation) and state-of-the-art nanofabrication techniques (optical and electron-beam lithography, ion beam etching) to the investigation and manipulation of magnetic nanostructures via electrical, thermal, mechanical, optical, magnetic, and microwave-based experimental techniques.

Open master theses:

Pure spin currents in compensated ferrimagnets and in antiferromagnets

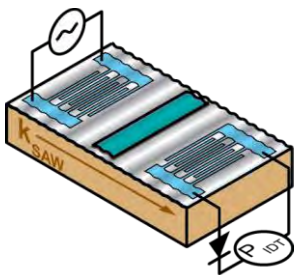
– what is the impact of coupled magnetic sublattices on pure spin transport ?–



A pure spin current is a directed flow of angular momentum, without any (net) corresponding charge current. Pure spin currents have intriguing properties. For example, they can propagate in magnetically ordered but electrically insulating materials, such as yttrium iron garnet ($Y_3Fe_5O_{12}$, YIG). This opens new perspectives for spintronic devices. The generation and detection of spin currents in ferromagnet/normal metal hybrid structures, e.g., via spin pumping or the so-called spin Hall magnetoresistance, is firmly established at WMI. We currently focus on spin transport in electrically insulating materials with coupled magnetic sublattices (compensated ferrimagnets as well as antiferromagnets).

We are looking for a motivated and enthusiastic master student for spin Hall magnetoresistance (SMR) experiments in antiferromagnet/normal metal heterostructures, as well as magnetic insulator/normal metal nanostructures. The thesis work comprises the fabrication and the spectroscopy of corresponding heterostructure devices. An important aspect hereby is the realization of magneto-transport dip-stick for a high-field magnet cryostat, enabling a full 3D rotation of the sample in situ. The impact of coupled magnetic sublattices, of the type of magnetic order, and of dimensionality on pure spin current transport shall then be studied using this setup.

Magnetoelastic surface acoustic wave resonators

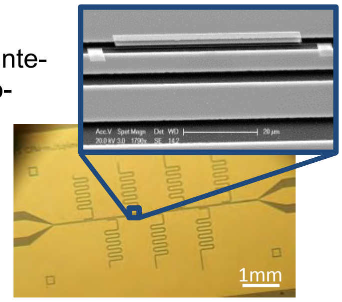


Magnetoelastic coupling enables a control of the magnetization direction in ferromagnetic thin films by means of elastic strain. At WMI, we have established the use of this magnetoelastic interaction in the GHz frequency range for acoustically driven spin wave resonance in an acoustic delay line, providing an alternative to the conventional photon-driven spin wave resonance. However, these photon-driven studies of spin wave resonances are often carried out in microwave photon cavities, which allows to study the coupling of the resonator and the magnetic system. Now, corresponding coupling phenomena between an acoustic resonator and the magnetic system shall be investigated.

We are looking for a highly motivated master student for fabrication and characterization of surface acoustic wave (SAW) resonators on $LiNbO_3$ substrates. To this end, nano-lithography shall be used to define interdigital transducers and grooved resonators on the piezoelectric substrate. An important aspect will be the microwave-frequency characterization and optimization of these resonators to achieve high resonator quality factors at GHz frequencies. Ferromagnetic thin films shall then be deposited within the resonator and the coupling between the resonator and the magnetoelastic thin films shall be investigated experimentally.

Nano-mechanics with a spin

– Nano-beam-based hybrids: from fabrication to Einstein-de Haas experiments –



Nano-mechanical beams are prototype harmonic oscillators, and can be straightforwardly integrated with other nanoscale systems. For example, coupling nano-beams to coplanar microwave cavities yields so-called hybrid electro-mechanical systems with intriguing properties, e.g., electro-mechanically induced transparency. In a similar fashion, ferromagnetic nanostructures can be integrated with nano-beams. This enables the design and the investigation of spin-phonon coupling down to the single excitation level, or nanoscale Einstein-de Haas experiments, in which the angular momentum change arising from magnetization reversal is transferred into a mechanical vibration of the beam.

We are looking for a motivated master student for a magnetic nano-beam oriented master thesis. The goal of your project is to investigate the static and dynamic interplay between the mechanical properties of double layer nano-beams and its magnetic properties. In your thesis project you will fabricate freely suspended nanostructures based on silicon nitride and ferromagnetic double layers using state-of-the-art nano-lithography and metal deposition techniques. Further, you will investigate the nano-structures using optical interferometry as well as DC current transport techniques to investigate the interaction between their mechanical and the magnetic properties from both perspectives.

Fabrication of ferromagnetic insulator/normal metal hybrid structures for pure spin current experiments

– thin film technology, x-ray diffraction, magnetometry, spin current transport –

A fascinating manifestation of spin physics in the solid state are pure spin currents. Experimentally, their generation or detection is often based on the interconversion of spin and charge currents, taking advantage of the spin Hall or inverse spin Hall effect, respectively. This makes ferromagnetic insulator/normal metal hybrid structures such as yttrium iron garnet ($Y_3Fe_5O_{12}$, YIG)/platinum (Pt) hybrids very attractive. However, YIG is only the prototype of a large class of ferromagnetic insulators. Particularly, substituting yttrium by other rare earth ions leads to garnet materials with three different magnetic sub-lattices exhibiting a rich phase diagram with very interesting magnetic properties. The aim of this thesis is the fabrication of such hybrid structures using laser molecular beam epitaxy (laser-MBE) as well as electron beam physical vapor deposition and the investigation of their spin current properties.

We are looking for a motivated and enthusiastic master student for the fabrication of ferromagnetic insulator/normal metal hybrid structures using laser molecular beam epitaxy (laser-MBE) as well as electron beam physical vapor deposition. An important aspect hereby will be the fabrication of high-crystalline garnet thin films, monitored via reflection high energy electron diffraction (RHEED). The thin film samples will then be characterized structurally using high-resolution X-ray diffraction (HRXRD) and atomic force microscopy (AFM) as well as magnetically via superconducting quantum interference device (SQUID) magnetometry. After optimization of the deposition parameters, spin Hall magnetoresistance as well as spin Seebeck experiments will be performed to investigate their spin current properties.

Magnetization Dynamics and Damping at mK Temperatures

In magnetic resonance, a high frequency magnetic drive field is employed to excite the precessional motion of the magnetization of a magnet. The high frequency drive is counteracted by magnetization damping, i.e., the relaxation channels for magnetization excitations. While magnetization damping is rather well understood from room temperature down to temperatures of a few Kelvin, the evolution of different magnetization damping mechanisms in the mK temperature range have not been systematically studied experimentally to date. Detailed knowledge about this temperature regime, however, would be highly desirable for example for magnetization dynamics in the single quantum (single excitation) limit.

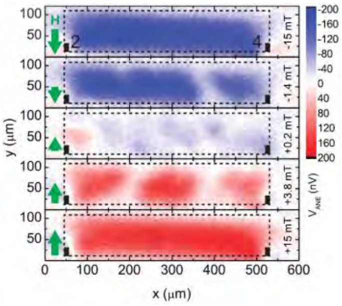
Using an established mK broadband magnetic resonance setup at WMI, the goal of this master thesis is to systematically measure the magnetization dynamics and damping properties of yttrium iron garnet (YIG) as well as doped garnet thin films, and to critically compare the experimental results with the damping mechanisms proposed in the literature.

Engineering Magnetization Dynamics in a Magnetic Insulator

In magnetic resonance, a high frequency magnetic drive field is employed to excite the precessional motion of the magnetization of a magnet. Besides this fundamental excitation, where all spins are precessing in an orchestrated, collective motion, higher order magnetic resonance modes can be excited and investigated using broadband microwave spectroscopy techniques. Furthermore, as these properties rely on the „magnetic“ bandstructure of the material, they can also be tailored using nano-fabrication methods yielding engineered magnetic structures such as waveguides or resonators.

We are looking for a talented master student, who is eager to explore the different possibilities for tailoring the dynamic magnetic properties of yttrium iron garnet (YIG). The goal of your thesis is to design, fabricate and investigate tailored magnetic bandstructures in YIG, in particular also in freely suspended films. The thesis work involves simulation of the (magnetic) structures, advanced nano-patterning, as well as high frequency spectroscopy of the fabricated devices.

Spatially resolved Spin Caloritronic Experiments at Low Temperatures



The electrical resistance of a ferromagnet depends on the orientation of the magnetization vector, giving rise to the so-called anisotropic magnetoresistance (AMR) effect. Instead of applying a charge current and recording the resulting voltage drop, however, one can also apply a thermal gradient (a temperature difference) and detect the resulting electric fields. This so-called thermopower is anisotropic in ferromagnets (anisotropic thermopower, anomalous Nernst effect). Furthermore, charge voltages also can also arise because of thermally driven spin transport in combination with the inverse spin Hall effect (spin Seebeck effect). We currently use a scannable, focused laser beam to locally heat a magnetic sample, while recording the ensuing thermos-galvanic voltages. This room-temperature setup shall now be transferred into a magnet cryostat.

The goal of this master thesis is to record the spatially resolved spin Seebeck (or anomalous Nernst) response of thin film magnetic samples as a function of temperature. This in particular requires setting up and testing a magnet cryostat-compatible scanning laser system.

Contact:

If you are interested in one of the above thesis topics, if you would like to receive more information, or if you want to get a look inside the labs and the WMI magnetism team, please contact Dr. Sebastian Gönnenwein (email: goennenwein@wmi.badw.de, phone: 289 14204, room 104), Dr. Hans Hübl (email: huebl@wmi.badw.de, phone: 289 14311, room 138), Dr. Matthias Opel (email: opel@wmi.badw.de, phone: 289 14237, room 135), Dr. Stephan Geprägs (email: gepraegs@wmi.badw.de, phone: 289 14225, room 135), Dr. Mathias Weiler (email: mathias.weiler@wmi.badw.de, phone: 289 14226, room 138), or Dr. Matthias Althammer (email: matthias.althammer@wmi.badw.de, phone 289 14210, room 111).

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