MA 58: Spintronics II (jointly with TT, HL)

Time: Thursday 17:15–19:15 Location: HSZ 401

MA 58.1 Thu 17:15 HSZ 401

Spin pumping by short-wavelength exchange-dominated magnons excited by parametric pumping — •Andrii V. Chumak[1], Christian W. Sandweg[1], Yosuke Kajiwara[2], Vitaliy V. Vasyuchka[1], Alexander A. Serga[1], M. Benjamin Jungfleisch[1], Eiji Saitoh[2], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan

Spin pumping from a ferromagnet to a nonmagnetic metal detected by the Spin Hall effect (SHE) has great potential in the context of the development of spintronic devices. In addition, it offers exciting possibilities for the use of spin waves (or their quanta, magnons) for carrying and processing spin-information [Y. Kajiwara, et al., Nature 464, 262 (2010)]. Until now, all experimental investigations into spin pumping have been realized using dipolar-dominated magnons with long wavelengths (limited by the size of the exciting antenna).

Here, we present studies of spin pumping in an exchange-dominated magnon system. Magnons were excited in a ferrite Yttrium Iron Garnet (YIG) film by frequency doubled parametric pumping. The spin pumping was detected via the SHE in a Pt layer deposited directly onto the YIG. Contributions to the spin pumping from different magnon groups, including magnons from the lowest energy state were studied. We show that spin pumping is possible even for magnons without an associated dipolar field. However, the magnon localization, which is in general inversely proportional to wavelength, is of high importance.

MA 58.2 Thu 17:30 HSZ 401

Spin-quadrupole Currents in Spin-valves — •Michael Hell[1,2], Sourin Das[4], and Maarten Rolf Wegewijs[1,2,3] — [1]Intitute for Solid State Research Theory 3, Research Center Jülich — [2]JARA - Fundamentals of Future Information Technology — [3]Institute for Theoretical Physics A, RWTH-Aachen — [4]Department of Physics and Astrophysics, University of Delhi

Spin-quadrupole moments (SQM) quantify the magnetic anisotropy of a nanostructure, in addition to its spin-polarization. We illustrate the possibility of quantum transport of SQM for a simple tunnel junction between two spin-polarized leads. Inspired by this, we present a more general spintronic transport theory for high-spin quantum dots coupled to ferromagnets. We show that SQM has to be treated as an independent degree of freedom, on the same footing as charge and spin polarization. Since SQM and its current are two-particle quantities, they have direct and exchange contributions as well as both local and non-local SQM sources. Moreover, the SQM current operator is derived which is shown to obey a continuity equation. We predict the electric control of the transfer of spin-anisotropy in elementary nanostructures.

MA 58.3 Thu 17:45 HSZ 401

Temporal evolution of spin pumping from a magnetic insulator detected via the inverse spin Hall effect — •Matthias Benjamin Jungfleisch[1], Andrii V. Chumak[1], Vitaliy I. Vasyuchka[1], Alexander A. Serga[1], Peter A. Beck[1], Eiji Saitoh[2], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan

The spin pumping effect, which is the conversion of a magnetization precession into a pure spin current, and the inverse spin Hall effect (iSHE), which is the conversion of a spin current into a charge current, have recently been observed in a Platinum (Pt) / Yttrium Iron Garnet (YIG) structure [Y. Kajiwara, et al., Nature **464**, 262 (2010)]. Up to now the temporal properties of this combined effect is not known. We used the spin pumping effect to inject a spin current pulse from the magnetic insulator YIG into a thin non-magnetic Pt layer and investigated simultaneously the temporal evolution of both, the iSHE voltage using a wide-band oscilloscope and the intensity of the spin waves by means of time resolved Brillouin light scattering spectroscopy. It is revealed that the iSHE voltage evolves slowler in time than the causing spin-wave mode. This is due to the fact, that secondary spin waves created by two-magnon scattering of the externally excited spin-wave mode make a strong contribution to the iSHE signal. The contributions of the externally excited coherent precession and the non-coherent spin waves have been clearly distinguished in our experiment.

MA 58.4 Thu 18:00 HSZ 401

Anisotropic polar magneto-optical Kerr effect (MOKE) of thin epitaxial Fe films on GaAs in ab initio theory and experiment — •Sebastian Putz, Martin Gmitra, Georg Woltersdorf, Jaroslav Fabian, and Christian Back — Universität Regensburg, Universitätsstraße 31, 93053 Regensburg

We investigate the anisotropy of the polar magneto-optical Kerr effect (MOKE) of thin epitaxial Fe films on GaAs both in ab initio theory and experiment. The maximum Kerr rotation at almost normal incidence on Fe/GaAs is obtained from the height of the out-of-plane hard-axis magnetization curves of a perpendicularly magnetized Fe/GaAs sample. It is proportional to the off-diagonal terms of the optical conductivity tensor σ of the Fe/GaAs interface. The C_{2v} symmetric anisotropy of the spin-orbit coupling fields at this interface causes an analogous anisotropy of σ. This, in turn, is measured by our polar MOKE setup at almost normal incidence when the direction of polarization of the incoming linearly polarized light is varied, i.e. the direction of polarization is turned around the surface normal of the out-of-plane magnetized sample. Additionally, we use the linearized augmented plane-wave (LAPW) method, as implemented in WIEN2k, to calculate the optical conductivity tensor σ and obtain the anisotropic polar magneto-optical Kerr angle for experimentally relevant Fe/GaAs slabs.

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MA 58.5 Thu 18:15 HSZ 401

Unveiling the valence band nature of GaMnAs anisotropic carriers by inter-band tunneling spectroscopy — •Romain Giraud, Mara Granada, Edgar Briones, Ulf Gennser, Aristide Lemaitre, and Giancarlo Faini — CNRS/LPN, Route de Nozay, 91460 Marcoussis, France

The discovery of highly anisotropic properties of magnetic tunnel junctions based on GaMnAs [1] has led to new concepts for spintronics devices, such as magnetic memories based on anisotropy relaxation in nanostructures [2], or magnetic switches relying on electrical control of the magnetic anisotropy [3]. However, despite the success of mean-field theories of hole-induced ferromagnetism, a direct evidence of the existence of Bloch states is still missing, and the nature of carriers remains controversial (impurity-band vs. valence-band models).

Here, based on inter-band tunneling spectroscopy of p-GaMnAs/n-GaAs Zener-Esaki diodes [4], we directly evidence the valence band nature of GaMnAs carriers and, importantly, reveal the spin-split valence bands dependence of their cubic and uniaxial anisotropies (which can be tuned under applied bias or magnetic field). In particular, the Fermi energy is found well below the top of the valence band, and the energy dependence of Bloch states anisotropies shows some specific features predicted by a k.p modelling of the spin-split valence bands.

[1] C. Gould et al., Phys. Rev. Lett. 93, 117203 (2004) [2] K. Pappert et al., Nat Phys. 3, 573 (2007) [3] C. Bihler et al., Phys. Rev. B 78, 045203 (2008) [4] R. Giraud et al., Appl. Phys. Lett. 87, 242505 (2005)

MA 58.6 Thu 18:30 HSZ 401

Ferromagnetically contacted carbon nanotubes for spin injection — •Caitlin Morgan[1,2], Klaus Schmalbuch[2,3], Carola Meyer[1,2], and Claus Michael Schneider[1,2] — [1]Forschungszentrum Jülich, Peter Grünberg Institute 7, 52425 Jülich, Germany — [2]JARA Jülich Aachen Research Alliance, 52425 Jülich, Germany — [3]Physikalisches Institut, RWTH Aachen University, Otto-Blumenthal-Straße, 52074 Aachen, Germany

In addition to exhibiting ballistic transport, carbon nanotubes (CNTs) have small spin-orbit interactions and relatively few spin nuclei (13C). These properties suggest a long spin relaxation length in CNTs, giving them a potential application in the field of spintronics.

We study spin injection in CNT-based devices. Samples are fabricated via chemical vapor deposition growth of CNTs onto lithographically prepatterned substrates. The CNTs are then contacted by fer-

romagnetic leads to form 2 and 4 terminal devices for spin injection. Special attention has been given to choosing a ferromagnetic material and shape for contacts. Permalloy and Co-based alloys have been studied in order to find a material with good magnetic properties that also forms a stable electronic interface with CNTs. SQUID and X-ray measurements of thin films were used to select good material systems. The shape and size of the contacts have been optimized to have only one in-plane magnetic domain. SQUID and atomic/magnetic force microscopy were used to study the magnetic properties of nanocontacts. Magnetoresistance measurements of contacted CNT samples are shown and discussed.

MA 58.7 Thu 18:45 HSZ 401

Local formation of a Heusler type structure in a CoFe-Al CPP-GMR spin valve — •Sabine Wurmehl[1], Patrick J. Jacobs[2], Jürgen T. Kohlhepp[2], Henk J.M. Swagten[2], Bert Koopmans[2], Stefan Maat[3], Matthew J. Carey[3], and Jeff R. Childress[3] — [1]Institute for Solid State Research, IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany — [2]Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands — [3]San Jose Research Center, Hitachi GST, 3403 Yerba Buena Road, San Jose, California 95135, USA

The magnetotransport properties of current-perpendicular-to-the-plane giant magnetoresistance devices consisting of ferromagnetic Co-Fe alloys have recently been shown to be significantly improved by addition of up to 28% Al. Nuclear magnetic resonance (NMR) is able to reveal the next neighboring shells of the ^{59}Co nuclei in the Co-Fe-Al magnetic films. This sensitivity to small changes in the local (magnetic and electronic) environment makes NMR an ideal method to determine the local modifications upon addition of Al to the Co-Fe alloy. In our present NMR study, we demonstrate the local formation of a Heusler-like structure by addition of Al to the Co-Fe alloy in CPP-GMR multilayers. The observed local formation of a highly spin-polarized Heusler compound may be correlated to the observed enhancement of the GMR effect [1].

[1] Wurmehl *et al.* Appl. Phys. Lett. accepted (2010).

MA 58.8 Thu 19:00 HSZ 401

Spin relaxation by impurity scattering in metallic systems — Swantje Heers, •Phivos Mavropoulos, Rudolf Zeller, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich

We present calculated results on spin relaxation in Cu, Ag and Au due to scattering at non-magnetic impurities of the 4th, 5th and 6th row of the periodic table ($3d$ up to $6sp$ elements). We consider the processes of spin-flip scattering by spin-orbit coupling (SOC) at the impurity as well as SOC at the host atoms (Elliott-Yafet mechanism). Our results show that the SOC in the host is not so important in Cu, especially for heavy impurities with strong SOC, while it is essential in Au. In our approach we employ the full-potential Korringa-Kohn-Rostoker Green-function method (KKR) for the calculation of the electronic structure and the spin-flip transition probability $P^{ss'}_{\mathbf{kk}'}$, with s being the spin-index. A Fermi-surface integral of P over $\mathbf{k}$ and $\mathbf{k}'$ yields then the spin-relaxation rate $1/\tau_{ss'}$.

In order to go beyond the approximation of independent scattering events, implied by this approach, we calculate the scattering by impurity dimers at increasing distance from nearest to third-nearest neighbours. In this way we simulate possible effects of impurity clustering in the sample, caused *e.g.* by impurity attraction or increasing concentration. We find that the presence of nearest-neighbour dimers has a considerable effect on $\tau_{ss'}$, while the results for dimers with distance beyond second-nearest neighbours are practically the same as in the independent scattering approximation.