MA 26: Spin dynamics and transport

Time: Wednesday 9:30–13:00 Location: H37

MA 26.1 Wed 9:30 H37

Electric-field control of interfacial spin-orbit fields — •Lin Chen[1], Martin Gmitra[2], Michael Vogel[1], Robert Islinger[1], Matthias Kronseder[1], Dieter Schuh[1], Dominique Bougeard[1], Jaroslav Fabian[2], Dieter Weiss[1], and Christian Back[3] — [1]Institute of Experimental and Applied Physics, University of Regensburg, Germany — [2]Institute of Theoretical Physics, University of Regensburg, Germany — [3]Department of Physics, Technical University Munich, Germany

Electric-field control of current-induced spin-orbit magnetic fields provides a route towards the low-power spin-orbit torque devices. Here, we show that the current-induced spin-orbit magnetic fields at the Fe/GaAs (001) interface [1] can be controlled with an electric field. In particular, by applying a gate-voltage across the Fe/GaAs interface, the interfacial spin-orbit field-vector acting on Fe can be robustly modulated via the change of the magnitude of the interfacial spin-orbit interaction [2]. Our results illustrate that the electric-field in a Schottky barrier is capable of modifying spin-orbit magnetic fields, an effect that could be used to develop spin-orbit torque devices with low-power consumption. [1] L. Chen et al., Nature Commu. 7, 13802 (2016). [2] L. Chen et al., Nature Elect. 1, 350-355 (2018).

MA 26.2 Wed 9:45 H37

Analysis of the spin transfer torques as a function of domain wall length — •Hamidreza Kazemi[1], Bertrand Dupé[2], Nicholas Sedlmayr[3], Imke Schneider[1], Jairo Sinova[2], and Sebastian Eggert[1] — [1]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany — [3]Department of Physics and Medical Engineering, Rzeszów University of Technology, Rzeszów, Poland

Use of a spin polarized current for the manipulation of magnetic domain walls in ferromagnetic nanowires has been the subject of intensive research for many years. Recently, due to technological advancements creating nano-contact with special characteristics are becoming more and more prevalent. Our goal is to delve into the full quantum investigation of the behavior of the spin transfer torques in a nano-contact of $Ni_{80}Fe_{20}$. According to our DFT calculations the physical behavior of low energies can be described by the s-d model which couples the domain wall and the itinerant electrons. To investigate spin transfer torques, we solve the scattering problem of a noninteracting tight-binding Hamiltonian including an s-d term. Moreover, the resulting magnetoresistance is calculated and compared with experiments.

MA 26.3 Wed 10:00 H37

Hybrid simulation of nonequilibrium spin dynamics — •Johan Briones, Sebastian Weber, Christopher Seibel, Sanjay Ashok, and Baerbel Rethfeld — Department of Physics and Optimas Rearch Center, TU Kaiserslautern, Germany

The complex phenomenon arising after a magnetic film has been excited by a femtosecond laser pulse is studied using a hybrid model (similar to [1]). It consists of a combination of two methods: A Monte Carlo model and the muT model [2]. The former will trace individual high energy nonequilibrium electrons [3], including spin-dependent scattering processes and spin-flip probabilities. The latter, will treat the low energy electrons as an ensemble, tracing their temperature and chemical potential. The magnetization dynamics will be investigated by using a two-band dynamic model which will be first applied to the case of Nickel.

The long-term perspective of this project is to develop a model that can describe the non-equilibrium transport and its effect on magnetization dynamics.

[1]N. Medvedev et al., New J. Phys, 15, 015016 (2013).
[2]B. Y. Mueller and B. Rethfeld, Phys. Rev. B, 90, 144420 (2014).
[3]K. Huthmacher et al., Physica A, 429, 241-251 (2015).

MA 26.4 Wed 10:15 H37

Electric-field control of spin-orbit torques CoFeB thin films — •Mariia Filianina[1,2], Jan-Philipp Hanke[1,3], Kyujoon Lee[1], Dong-Soo Han[1], Yuriy Mokrousov[1,3], and Mathias Kläui[1,2] — [1]Institute of Physics, Johannes Gutenberg University, Mainz, Germany — [2]Graduate School of Excellence Material Science in Mainz, Mainz, Germany — [3]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Jülich, Germany

Energy-efficient control of magnetization via electric fields has attracted significant interest. These so-called magneto-electric effects have been studied in various systems with the focus put on the manipulations of magnetic anisotropies [1]. However, electric field effects to tune current-induced spin-orbit torques (SOTs) for magnetization switching, which is crucial for spintronics applications, has been little investigated [2].

Here we report on strain-controlled SOTs in perpendicularly magnetized W/CoFeB/MgO multilayers grown on a piezoelectric substrate. The SOTs are evaluated by magnetotransport and second-harmonic methods [3] under different in-plane strains. We find that the strain leads to a non-trivial change in field-like and damping-like torques. We compare our experimental results with theoretical ab initio calculations and uncover the microscopic origin of the observed strain effects on the magneto-electric coupling.

1. S. Finizio et al., Phys. Rev. Appl., Vol. 1, p. 021001 (2014). 2. K. Cai et al., Nat. Mater., Vol. 16, p. 712 (2017). 3. T. Schulz et al., Phys. Rev. B, Vol. 95, p. 224409 (2017).

MA 26.5 Wed 10:30 H37

Scattering of spinon excitations in the 1D Heisenberg model by potentials — •Xenophon Zotos[1,2] and Alexandros Pavlis[1] — [1]Department of Physics, University of Crete,Greece — [2]Leibnitz Institute/IFW Dresden, Germany

By a semi-analytical Bethe ansatz method we study the scattering of a spinon, the elementary quantum many-body topological excitation in the 1D Heisenberg model, by a local and a phonon potential. In particular, we contrast the scattering of a spinon to that of a free spinless fermion in the XY model. This study provides insights in the spin transport by one dimensional quantum magnets with embedded interfaces modeled here as prototype local potentials.

MA 26.6 Wed 10:45 H37

Quantum fluctuations of magnetization via spin shot noise — •Alireza Qaiumzadeh and Arne Brataas — Center for Quantum Spintronics, NTNU, Norway

Recent experiment in current-driven spin valves demonstrate magnetization fluctuations that deviate from semiclassical predictions [1]. We posit that the origin of this deviation is the spin shot noise. On this basis, our theory predicts that the magnetization fluctuations asymmetrically increase in biased junctions irrespective of the current direction. At low temperatures, the fluctuations are proportional to the bias, but at different rates for opposite current directions. Quantum effects control fluctuations even at higher temperatures [2]. Our theory shows the important contribution of so far overlooked spin shot noise on spin transfer torque phenomena.

[1] A. Zholud, R. Freeman, R. Cao, A. Srivastava, S. Urazhdin, Phys. Rev. Lett. 119, 257201 (2017). [2] A. Qaiumzadeh and A. Brataas, arXiv:1808.02907 (2018).

MA 26.7 Wed 11:00 H37

Tracking the order parameter motion during a coherent antiferromagnetic spin precession — •Christian Tzschaschel[1], Takuya Satoh[2], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zurich, Switzerland — [2]Department of Physics, Kyushu University, Japan

Recently, antiferromagnets attract increasing attention for spintronics applications. The high frequency of antiferromagnetic (AFM) resonances suggests the possibility to coherently control AFM order on picosecond time scales. AFM spin dynamics, however, are often obscured by the relative inaccessibility of the AFM order parameter. Here, we directly reveal the dynamics of the AFM order using time-resolved optical second-harmonic generation (SHG). Exploiting the inverse Faraday effect, we optically excite a specific magnon mode in hexagonal $YMnO_3$ and track the ensuing order-parameter dynamics. The coherent Z-mode precession results in a symmetry reduction of the AFM order from $\underline{6}m\underline{m}$ to 3. SHG as a symmetry sensitive technique allows us to separate electron from spin dynamics, which enables a time-resolved quantitative tracking of the AFM order parameter. Specifically, we can estimate the optically induced spin canting angle to be approximately 0.5°. In combination with the simultaneously measured Faraday rotation, we obtain access to both the compensated and uncompensated components of the order parameter, which allows us to track its motion during the AFM spin precession. Probing dynamic symmetry reductions constitutes a general approach, which allows tracking AFM spin dynamics also in anharmonic situations, such as spin reorientations.

15 min. break

MA 26.8 Wed 11:30 H37

Magnetic and transport properties of the transition metal dichalcogenides intercalated by 3d-elements — •S. Polesya[1], S. Mankovsky[1], S. Mangelsen[2], W. Bensch[2], S. Medvedev[3], and Hubert Ebert[1] — [1]Dept. Chemistry, LMU Munich, D-81377 Munich, Germany — [2]Institute of Inorganic Chemistry, 24118 Kiel, Germany — [3]Max Planck Inst. for Chem. Physics of Solids, 01187 Dresden, Germany

The magnetic and transport properties of the $2H{-}NbS_2$ and $2H{-}TaS_2$ compounds intercalated by $3d$-elements have been investigated by first-principles calculations of the electronic structure using the Korringa-Kohn-Rostoker (KKR) method. We focus on the systems with 33% and 25% of intercalation which allow the formation of ordered phases characterized by $\sqrt{3}\times\sqrt{3}$ and 2×2 in-plane arrangements of the magnetic atoms, respectively. The calculations have been performed both for stoichiometric composition as well as taking into account small deviation from stoichiometry to investigate its impact on the magnetic and transport properties. The ground state magnetic structure as well as finite temperature magnetic properties have been studied via Monte Carlo simulations using the exchange coupling parameters calculated from first principles. The Kubo-Greenwood linear response formalism was used to calculate the temperature dependent electrical resistivities of the systems, both for ambient pressure as well as function of the increasing pressure. The calculated results are in rather good agreement with the available experimental data.

MA 26.9 Wed 11:45 H37

Spin-orbit torque in the surface of the topological insulator Bi_2Te_3 doped with magnetic defects — •Adamantia Kosma[1], Philipp Rüssmann[2], Stefan Blügel[2], and Phivos Mavropoulos[1] — [1]Department of Physics, National and Kapodistrian University of Athens, Panepistimioupolis 15784 Athens, Greece — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

We present an *ab initio* investigation of the spin-orbit torque [1,2], exerted on the moments of transition metal impurities at the surface of the topological insulator Bi_2Te_3. We employ the multiple scattering approach as implemented in the full-potential relativistic Korringa-Kohn-Rostoker (KKR) Green function method, combined with the Boltzmann transport equation [3]. We analyze the spin accumulation and the spin flux contribution to the spin-orbit torque on the magnetic defects in response to the electric field, and we discuss the correlation of the spin-orbit torque to the spin current on the Fermi surface. We interpret the results based on the localization and the spin-polarization of the surface states. In addition, we investigate the effect of the concentration of impurities on these quantities by considering multiple random distributions of defects. This work was supported by computational time granted from the Greek Research Technology Network (GRNET) in the National HPC facility–ARIS–under project ID pr00504-TopMag. [1] A. Manchon and S. Zhang, Phys. Rev. B **79**, 094422 (2009). [2] F. Freimuth *et al.*, Phys. Rev. B **92**, 064415 (2015). [3] G. Géranton *et al.*, Phys. Rev. B **93**, 224420 (2016).

MA 26.10 Wed 12:00 H37

Frequency and angular dependencies of spin-orbit-induced magnetic fields and torques — •Filipe Souza Mendes Guimarães, Manuel dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Magnetization dynamics can be driven by ac electric currents through effective magnetic fields induced by the spin-orbit interaction [1]. In metallic multilayers, the precessing magnetic moment pumps spin currents to the normal metal, which is then converted back to charge currents. We have previously shown how these dynamical processes contribute to the different magnetoresistances and Hall currents of Fe/W(110) and Co/Pt(001) bilayers [2]. In this contribution, we analyze how the effective magnetic fields and the different torques acting on the magnetic moment of these bilayers depend on their rotation angle and on the frequency of the electric field. Even though the effective field acting on the magnetic layer has an ordinary non-resonant behavior, the resulting spin-orbit and external torques present complex responses in all directions. These dynamical results may help to understand switching processes and give guidance for the design of efficient heterostructures.

[1] D. Fang *et al.*, Nat. Nanotechnol. 6, 413 (2011)
[2] F. S. M. Guimarães *et al.*, Sci. Rep. **7**, 3686 (2017)
– Funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator grant 681405 – DYNASORE).

MA 26.11 Wed 12:15 H37

Long-ranged spin transport in magnetism: the role of topology and frustration — •Ricardo Zarzuela[1], Héctor Ochoa[2], Yaroslav Tserkovnyak[3], and Jairo Sinova[1] — [1]Institute of Physics, Johannes Gutenberg-Universität, 55128 Mainz, Germany — [2]Physics Department, Columbia University, New York, NY 10027, USA — [3]Department of Physics and Astronomy, University of California, Los Angeles, California 90095, USA

Spintronics offers new routes towards the design of energy-efficient architectures for the next generation of high-speed electronic devices. However, it also faces the problem of fast degradation of spin signals resulting from decoherence processes. Topological protection of spin textures, rooted in the existence of energy barriers due to topological constraints, seems to play a fundamental role in overcoming this issue and leads to long relaxation lengths (algebraic vs. exponential decay). This robustness usually relies on the existence of an underlying rotational symmetry in spin space (e.g, the U(1) symmetry associated with conventional effective spin superfluids), which breaks down in the presence of parasitic (relativistic) interactions arising during the fabrication process of spintronic devices. In magnetic systems with frustrated interactions dominated by exchange, these symmetry-breaking interactions become "averaged-out" at the macroscopic level and the topological robustness is effectively restored. In this talk I will discuss recent theoretical advances in the long-ranged transport of spin in materials with frustrated (magnetic) interactions, with special attention to that mediated by the spin-superfluid state and skyrmions.

MA 26.12 Wed 12:30 H37

High field magnetoresistivity and spin fluctuation theory in thin film MnSi — •Nico Steinki[1], David Schroeter[1], Niels Wächter[1], Dirk Menzel[1], Hans Werner Schumacher[2], Ilya Sheikin[3], and Stefan Süllow[1] — [1]IPKM, TU Braunschweig, Germany — [2]Physikalisch Technische Bundesanstalt, Braunschweig, Germany — [3]Laboratoire National des Champs Magnétiques Intenses, CNRS, UGA, Grenoble, France

Spin fluctuations in the itinerant helical magnet MnSi have been discussed in terms of the self-consistent renormalization (SCR) theory [1]. Correspondingly, previous high field studies on bulk MnSi have been taken as proof of basic SCR predictions [2]. Here, we present a study of the magnetoresistivity of thin film MnSi in high magnetic fields. We establish that the magnetoresistivity of thin film MnSi can essentially be understood in terms of spin fluctuation theory, allowing us to compare our data to studies of bulk material. However, despite a close qualitative resemblance of bulk and thin film data, there are clear quantitative differences. We propose that these reflect modifications to the spin fluctuation spectra in thin film MnSi, as compared to bulk material.

[1] T. Moriya, Spin Fluctuations in Itinerant Electron Magnetism, (Solid-State Sciences) (Berlin: Springer) (1985).

[2] T. Sakakibara, H. Morimoto, and M. Date: J. Phys. Soc. Jpn. **51**, 2439 (1982).

MA 26.13 Wed 12:45 H37

Boolean and quantum nanologic from first principles — •Wolfgang Hübner, Dibyajyoti Dutta, Stefan Sold, and Georgios Lefkidis — Technische Universität Kaiserslautern and Research Center OPTIMAS, Kaiserslautern, Germany

After having established Ni_4 as a paradigm for the theoretical treatment of ultrafast spin dynamics on highly correlated magnetic nanostructures [1], we apply the state-of-the-art equation-of-motion coupled-cluster with single and double excitations (EOM-CCSD) method for the quantum chemical calculations of both Ni_4 and the synthesized Co_3Ni-EtOH [2]. Thus we can enrich our zoo of laser-triggered magnetic logic functionalities, for which we exploit the spin degree of freedom as the sole information carrier. This zoo includes the ERASE functionality (also necessitating breaking of the time reversal symmetry), as well as the Boolean OR, AND, and the universal CNOT gates.

Due to the high precision of EOM-CCSD, we can go beyond classical logic and consider not only the direction and localization of the spin but also its quantum nature. Thus we additionally find the *which path* interference effect, in which the phase of the spin reveals information about the exact path traveled in a laser-induced spin transfer process [3], and construct the universal $\sqrt{\mathrm{NOT}}$ quantum logic gate (analogue to the Hadamard gate). Last but not least we show that laser-induced spin transfer can also reach the actual CMOS length scale.

[1] W. Hübner *et al.*, Phys. Rev. B **96**, 184432 (2017)
[2] D. Dutta *et al.*, Phys. Rev. B **97**, 224404 (2018)
[3] D. Chaudhuri *et al.*, Phys. Rev. B **96**, 184413 (2017)