# TT 9: Transport: Spintronics and Magnetotransport (jointly with HL, MA)

Time: Monday 9:30–12:00 Location: A 053

TT 9.1 Mon 9:30 A 053

**Low Temperature THz Spectroscopy and Transport in Nanostructures** — •Julian Braun, Sergej Andreev, Elke Scheer, and Torsten Pietsch — Universität Konstanz, Konstanz, Germany

Theoretical predictions [1] suggest a new source for THz radiation, based on a spin relaxation in metallic heterocontacts. In a dilute ferromagnet a spin imbalance can be created by a spin polarized current originating in a ferromagnet of opposite magnetization. Relaxation in the energetically more favorable spin distribution should occur by emission of a photon with an energy in the THz range.

We constructed a compact cw-THz spectrometer working at temperatures down to 4 K and a frequency range from 0.1 GHz to 2000 GHz. Installed in a vector magnet we can thereby correlate magnetotransport measurements with the spectroscopic analysis to investigate the spin imbalance in metallic heterocontacts. Additionally characterization measurement on different metallic and superconducting samples will be presented.

[1] A.M. Kadigrobov et al., Europhys. Lett. 67, 948-954 (2004).

TT 9.2 Mon 9:45 A 053

**Room-Temperature Spin Thermoelectrics in Metallic Films** — •Sebastian Tölle[1], Cosimo Gorini[2], and Ulrich Eckern[1] — [1]Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — [2]Faculty of Physics, University of Regensburg, 93040 Regensburg, Germany

Efficient heat-to-spin conversion is the central goal of spin caloritronics. When considering metallic systems, two interesting phenomena stand out in this field: the spin Nernst effect and thermally-induced spin polarizations. They consist in the generation of, respectively, a spin current or a spin polarization transverse to an applied temperature gradient, i.e., they are the thermal counterparts of the well known spin Hall effect and current-induced spin polarization (Edelstein effect). We study these phenomena considering dynamical spin-orbit coupling, namely the spin-orbit coupling with phonons and vibrating impurities, which give rise to a dynamical side-jump mechanism and dynamical Elliott-Yafet spin relaxation. Such processes, which have not been considered before in this context, dominate at temperatures $T > T_D$, with $T_D$ the Debye temperature. This condition is met in typical spin injection/extraction experiments performed at room temperature in transition metals such as Pt, Au, and Ta. Our results show a nonlinear $T$-dependence of the spin Nernst and spin Hall conductivities due to an interplay between intrinsic (Bychkov-Rashba type) and extrinsic (dynamical) spin-orbit coupling [1].

[1] S. Tölle, C. Gorini, and U. Eckern, arXiv:1409.1809 (2014) (accepted for publication in Phys. Rev. B).

TT 9.3 Mon 10:00 A 053

**Phonon Skew Scattering** — •Cosimo Gorini[1], Ulrich Eckern[2], and Roberto Raimondi[3] — [1]Institut für Theoretische Physik, Universität Regensburg — [2]Institut für Physik, Universität Augsburg — [3]Dipartimento di Fisica, Università Roma Tre

In spin injection/extraction experiments in metallic systems, the observed temperature behaviour of the (inverse) spin Hall effect is used to determine the dominant spin-orbit mechanism in the sample. This is a fundamental issue of high practical importance.

The current understanding of the high-$T$ behaviour is based on a phenomenological extrapolation from the low-$T$ theory. The latter predicts that (i) a $T$-independent (inverse) spin hall signal is a signature of dominant side-jump, and (ii) its scaling as the mobility indicates dominant skew scattering.

Our quantum field theoretical (Keldysh) calculation shows, however, that at typical experimental temperatures phonon-induced skew scattering also leads to a $T$-independent signal – just as side-jump does. Thus, discerning between the two appears a more complicated issue than until now expected.

TT 9.4 Mon 10:15 A 053

**Single atom memory described by the quantum master equation: Ho on Pt(111)** — •Christian Karlewski[1,2], Michael Marthaler[1], Wulf Wulfhekel[3], and Gerd Schön[1,2] — [1]TFP, Karlsruher Institut für Technologie — [2]INT, Karlsruher Institut für Technologie — [3]PHI, Karlsruher Institut für Technologie

Miniaturizing current memory bits to optimize the storage density is an important task of information technology research. The ultimate goal are single atoms as one bit. Single magnetic holmium atoms on a platinum (111) surface have been investigated in Nature 503, 242 (2013) and have highly stable magnetic moments, in or out of the plane. Stability can be maintained for several minutes, making holmium a great candidate as single atomic storage. The theoretical description of this system is based on the quantum master equation of open quantum systems. We will show that even if the system in total behaves as a classical bit with two states, a full quantum mechanical description is needed to catch the dynamics properly. The dependence of the lifetime of this system on different parameters is investigated and we will show that it might be possible to improve the properties of our system even further by understanding the mechanisms which at present limit the lifetimes.

TT 9.5 Mon 10:30 A 053

**Observation of spatial fluctuations of the Rashba parameter by scanning tunneling spectroscopy** — •Jan Raphael Bindel[1], Marcus Liebmann[1], Jascha Ulrich[2], Eugene Sherman[3], and Markus Morgenstern[1] — [1]II. Institute of Physics B, RWTH Aachen University, Aachen, Germany — [2]Institute for Quantum Information, RWTH Aachen University, Aachen, Germany — [3]Basque Foundation for Science, Ikerbasque, Bilbao, Spain

We investigate a 2DES induced by Cs surface doping of p-type InSb(110) and evaluate the Rashba parameter on the local scale. The Rashba effect is one of the possibilities to manipulate spins by external gate voltages which led to the proposal of the spin transistor. As a local property, however, the Rashba effect is prone to disorder as ubiquitous in semiconductors, which, in turn, induces spatial fluctuations of the strength of the Rashba effect, and, thus, spin dephasing [1]. Recently, we have shown that the Rashba effect can be probed by STS in magnetic fields as an additional contribution to the spin splitting [2]. Here, we investigate the correlations between the electrostatic potential and the Rashba effect on the local scale. A detailed magnetic field dependence analysis of the spin splitting is required in order to disentangle the Rashba parameter from the Zeeman effect and the spatially fluctuating exchange enhancement. Moreover the nodal structure of the wave functions has to be considered in higher Landau levels, where it leads to multiple peak structures [3].

[1] Glazov et al., Physica E 42, 2157 (2010).
[2] Becker et al., PRB 81, 155308 (2010).
[3] Hernangómez-Pérez et al., PRB 88, 245433 (2013).

**15 min. break.**

TT 9.6 Mon 11:00 A 053

**Magnetoresistance in Weyl semimetals** — •Janina Klier[1,2], Igor Gornyi[1,3], and Alexander Mirlin[1,2,4] — [1]Institute for Nanotechnology, Karlsruher Institute for Technology, Karlsruhe, Germany — [2]Institute for Theoretical Condensed Matter physics, Karlsruher Institute for Technology, Karlsruhe, Geermany — [3]A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia — [4]Petersburg Nuclear Physics Institute, St. Petersburg, Russia

We theoretically study the magnetoresistvity of a Weyl semimetal within two disorder models: pointlike impurities and charged impurities. Impurity scattering is treated using a self-consistent Born approximation. We find an unusual broadening of Landau levels which leads to a rich structure of various regimes in temperature-magnetic field plane. In particular, the magnetoresitance shows non-monotonous behavior. In the limits of strongest magnetic fields for pointlike impurities, this leads to a vanishing magnetoresistance. For charged impurities, broadening of Landau levels is less important in high magnetic fields. This leads to a positive linear magnetoresistance in strongest magnetic fields.

TT 9.7 Mon 11:15 A 053

**Spin-orbit induced longitudinal spin transport in non-magnetic solids** — •Sebastian Wimmer, Marten Seemann, Kristina Chadova, Diemo Ködderitzsch, and Hubert Ebert — Ludwig-Maximilians-Universität München, München, Deutschland

A group-theoretical scheme is presented that allows investigating the symmetry properties of response tensors relevant to the field of spintronics. For the spin conductivity tensor it is shown that only the magnetic Laue group has to be considered in this context. In this case non-vanishing transverse elements, found without making reference to the two-current model, give rise to the spin Hall and Edelstein effects in non-magnetic as well as magnetic solids. In the latter case non-vanishing longitudinal elements cause among others the spin-dependent Seebeck effect. For non-magnetic solids having low symmetry non-vanishing longitudinal elements are shown to exist as well. These give rise to spin-orbit induced *longitudinal* spin transport that has not been considered before. Numerical studies confirm these findings and demonstrate that the longitudinal spin conductivity may be in the same order of magnitude as the conventional transverse one.

TT 9.8 Mon 11:30 A 053

**Topological transitions in the geometric phase in spin interferometers** — •Henri Saarikoski[1], Enrique Vazquez[2], Jose Pablo Baltanás[2], Diego Frustaglia[2], Fumiya Nagasawa[3], and Junsaku Nitta[3] — [1]RIKEN Center for Emergent Matter Science (CEMS), Saitama 351-0198, Japan — [2]Departamento de Física Aplicada II, Universidad de Sevilla, E-41012 Sevilla, Spain — [3]Department of Materials Science, Tohoku University, Sendai 980-8579, Japan

An electronic spin transported around a circuit acquires a phase factor that depends on the geometry of the path in the parameter space. In the adiabatic limit this is the Berry phase and it has been argued that it can undergo an abrupt transition via manipulation of the topology of the path [1]. However, spin transport in mesoscopic structures is usually nonadiabatic, which is associated with the Aharonov-Anandan geometric phase. Here we identify the characteristic signatures of topological transitions in nonadiabatic spin transport by 1D and 2D calculations of mesoscopic loops. We find that the topological transition is characterized by an *effective* Berry phase due to correlations between dynamic and geometric phases close to the region where the transition occurs. This effective Berry phase is related to the topology of the field texture rather than the spin-state structure. The transition manifests as a distinct dislocation of the interference pattern in the quantum conductance. The phenomenon is robust, and can be observed in mesoscopic arrays of loops where phase coherence is significant.

[1] Y. Lyanda-Geller, Phys. Rev. Lett. 71, 657 (1993).

TT 9.9 Mon 11:45 A 053

**Use of resonant tunneling in spin transfer torque magnetic tunnel junctions** — •Bhaskaran Muralidharan[1], Niladri Chatterji[2], and Ashwin Tulapurkar[1] — [1]Department of Electrical Engineering, IIT Bombay, Powai, Mumbai-400076, India — [2]Department of Physics, IIT Bombay, Powai, Mumbai- 400076, India

We propose a novel device that uses resonant tunneling to enhance the spin-transfer torque switching characteristics of magnetic tunnel junctions. The proposed device structure is a resonant tunneling magnetic tunnel junction based on a MgO-semiconductor heterostructure sandwiched between a fixed magnet and a free magnet [1]. We employ the non-equilibrium Green's function formalism coupled self consistently with the Landau-Lifshitz-Gilbert-Slonczewski equation to demonstrate that the physics of resonant tunneling leads to improved tunnel magneto-resistance characteristics as well as lower switching voltages in comparison with traditional trilayer devices. Using this framework, we also demonstrate a novel spin torque oscillator design at zero applied magnetic field, by simply engineering parallel and perpendicular spin torques.

[1] N. Chatterji, A. A. Tulapurkar and B. Muralidharan, ArXiv: 1411.6454, (2014).