MA 29: Spin Transport and Orbitronics, Spin-Hall Effects I (joint session MA/TT)

Time: Wednesday 9:30–12:45 Location: POT/0112

Invited Talk MA 29.1 Wed 9:30 POT/0112

Exploring the interplay between spin and chirality — •Angela Wittmann — Johannes Gutenberg University Mainz, Germany

Chirality is omnipresent in nature, bridging magnetic and molecular spin phenomena. At the core of this connection lies the chiral-induced spin selectivity (CISS) effect, describing the highly efficient generation of spin polarized currents in chiral molecules. Despite extensive experimental evidence, the underlying mechanisms of CISS remain debated. Here, we explore how chirality is directly linked to the intrinsic magnetic moments in molecules and how molecular design can be harnessed to control spin phenomena at hybrid chiral molecule magnetic interfaces [1]. Our findings pave a pathway towards functional "chiralitronic" devices - turning a fundamental puzzle into a technological opportunity.

[1] A. Moharana, AW et al., Sci. Adv.11, eado4285 (2025)

MA 29.2 Wed 10:00 POT/0112

Chiral Molecule-Induced Magnetic Anisotropies — •Simon Sochiera[1], Ashish Moharana[1], Yael Kapon[2], Fabian Kammerbauer[1], Shira Yochelis[2], Mathias Kläui[1], Yossi Paltiel[2], and Angela Wittmann[1] — [1]Johannes Gutenberg University, Mainz, Germany — [2]Hebrew University of Jerusalem, Jerusalem, Israel

The chiral-induced spin selectivity effect promises novel spintronic devices. Despite numerous interdisciplinary experiments revealing its implications and trends, this phenomenon challenges our theoretical understanding of the interplay between spin and chirality, particularly regarding apparent time-reversal symmetry breaking. This symmetry breaking can be observed by measuring a magnetic thin film's anisotropy upon chiral-molecule adsorption. We quantify this phenomenon by measuring the magnetic anisotropy through electrical magnetotransport measurements. Upon chiral-molecule adsorption, we observe a 35% change in out-of-plane hard-axis anisotropy. This approach enables sensitive probing of magnetic property changes induced by different chiral molecular systems on various conductive or insulating magnetic thin films. Correlating molecular properties, such as spin-orbit coupling, with their impact on magnetic anisotropy will be crucial for understanding the fundamental mechanisms of chiral-induced spin selectivity and for facilitating the design of spintronic devices that require a precisely tuned anisotropy.

MA 29.3 Wed 10:15 POT/0112

Generation, Transmission, and Conversion of Orbital Torque by an Antiferromagnetic Insulator — •Shilei Ding[1,2], Paul Noël[2], Gunasheel Kauwtilyaa Krishnaswamy[2], Niccolò Davitti[2], Giacomo Sala[2], Marzia Fantauzzi[3], Antonella Rossi[2,3], and Pietro Gambardella[2] — [1]School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore 637371, Singapore — [2]Department of Materials, ETH Zürich, 8093 Zürich, Switzerland — [3]Dipartimento di Scienze Chimiche e Geologiche, Università degli Studi di Cagliari, Campus di Monserrato S.S. 554, Italy

Orbital currents and orbital torques have recently emerged as powerful tools for controlling magnetization, yet their transport has been studied almost exclusively in metals. We report the first demonstration of orbital generation, transport, and conversion through an insulating antiferromagnet CoO. By inserting CoO between Cu* and Co, we show that orbital transport is preserved and the orbital-torque efficiency is strongly enhanced. Temperature-dependent measurements indicate that orbital transport above the Néel temperature is mediated by thermal fluctuations, while antiferromagnetic order and exchange bias provide additional transport channels at low temperature. These results identify insulating antiferromagnets as effective mediators of orbital angular momentum and highlight transition-metal oxides with unquenched orbital moments as promising materials for efficient spin-orbitronic technologies.

MA 29.4 Wed 10:30 POT/0112

Modern theory of the Orbital Hall effect from Wannier Representation — •Mirco Sastges[1,2], Insu Baek[3], Hojun Lee[3], Hyun-Woo Lee[3], Yuriy Mokrousov[1,2], and Dongwook Go[4] — [1]Peter Grüunberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [3]Department of Physics, Pohang University of Science and Technology, Pohang, Kyungbuk 37673, South Korea — [4]Department of Physics, Korea University, Seoul 02841, South Korea

In the field of orbital dynamics and orbital transport a particularly important quantity is the so-called orbital Hall conductivity (OHC), which is expressed in terms of operators of velocity and orbital angular momentum (OAM). To overcome the difficulties in treating the unbounded position operator, very often the so-called atom-centered approximation (ACA) is used. However, while being very practical, this approach captures only some local contributions to the OAM operator. Here, we will report on developing a new approach to quantify the OAM operator in the basis of Wannier functions, which is based on the modern theory of orbital magnetization. This method allows us to capture both local and itinerant contributions to the OHC. By performing first principles calculations for selected transition metals we show that a significant correction to the OHC due to non-local contributions arises, while the local effects are captured in accordance to the ACA. Our approach is very promising since it improves our understanding of OAM and allows for a precise estimation of the OHC.

MA 29.5 Wed 10:45 POT/0112

Chirality-induced orbital Edelstein effect in an analytically solvable model — •Lennart Schimpf, Börge Göbel, and Ingrid Mertig — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg

Chirality-induced spin selectivity (CISS), a phenomenon wherein chiral structures selectively determine the spin polarization of electron currents flowing through the material, has garnered significant attention due to its potential applications in areas such as spintronics, enantioseparation, and catalysis. The underlying physical effect is the Edelstein effect that converts charge to angular momentum. Besides a spin contribution, there exists a contribution based on the orbital angular momentum but the precise mechanism for its generation remains yet to be understood. Here, we introduce the minimal model for explaining the phenomenon based on the orbital Edelstein effect [1]. We consider nonlocal intersite contributions to the current-induced orbital angular momentum and reveal the underlying mechanism by analytically calculating the Edelstein susceptibilities in a tight-binding and Boltzmann approach. While the orbital angular momentum is directly generated by the chirality of the crystal, the spin contribution of each spin-split band pair relies on spin-orbit coupling. Using tellurium as an example, we show that the orbital contribution surpasses the spin contribution by orders of magnitude.

[1] B.Göbel, L. Schimpf, I. Mertig, Phys. Rev. Res. 7, 033180 (2025)

15 min break

MA 29.6 Wed 11:15 POT/0112

Spin-charge and Orbital-charge Interconversion on SrTiO3-based Two-dimensional Electron Gases: A Semiclassical Approach — •Le Viet Duc Pham and Annika Johansson — Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle (Saale), Germany

Two-dimensional electron gases (2DEGs) at SrTiO3-based oxide interfaces display large, gate-tunable Rashba-like spin-orbit coupling (SOC) that enables spin-charge interconversion via the spin Edelstein effect [1, 2]. It has also been demonstrated that the orbital Edelstein effect, i.e, current-induced orbital magnetization, is larger than the spin Edelstein effect by more than one order of magnitude [3]. Yet, most transport studies assume a constant relaxation time [1, 3], potentially underestimating the role of anisotropic relaxation times and scattering-in contributions. Here, we systematically study charge-spin and charge-orbital conversion in SrTiO3-based 2DEGs, combining the Boltzmann semiclassical transport theory and various ansatzes for the scattering terms, such as constant relaxation time, momentum relaxation time, as well as scattering on various impurity potentials. Comparing different scattering approaches, we gain insights into the influence of impurity scattering on charge-spin and charge-orbital interconversion phenomena.

[1] Vaz, Diogo C., et al. Nature Materials 18.11 (2019): 1187-1193.

[2] Caviglia, A. D., et al. Physical Review Letters 104.12 (2010): 126803. [3] Johansson, Annika, et al. Physical Review Research 3.1 (2021): 013275.

MA 29.7 Wed 11:30 POT/0112

Quantum geometry for orbital magnetization and spintronics from parallel transport of Bloch states — •Johannes Mitscherling, Jan Priessnitz, and Libor Šmejkal — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany

Quantum geometry emerges as a unifying, quantitative guiding principle for the linear and nonlinear response functions of quantum matter. Going beyond current-current responses [1,2], we identify the generator of parallel transport of Bloch states, given by the commutator of the band projector and its momentum derivative, as a further essential building block of quantum geometry [3]. I will show that orbital magnetism arises from the non-commutativity of adiabatic transport in orthogonal directions. We will see that the spin Berry curvature and the spin quantum metric, which control the linear spin conductivity, are not fundamentally geometric but yield three geometric contributions of distinct physical origin. Our theory enables efficient numerical and analytical evaluations for general Bloch Hamiltonians with an arbitrary number of potentially degenerate bands. I will exemplify the results in application to altermagnets [4] and p-wave magnets [5].

[1] Avdoshkin*, Mitscherling*, and Moore, PRL 135, 066901 (2025). [2] Mitscherling*, Avdoshkin*, and Moore, PRB 112, 085104 (2025). [3] Mitscherling and Šmejkal, to be submitted. [4] Šmejkal, Sinova, and T. Jungwirth, PRX 12, 031042 (2022). [5] Birk Hellenes, Jungwirth, Jaeschke-Ubiergo, Chakraborty, Sinova, and Šmejkal, arXiv:2309.01607v3.

MA 29.8 Wed 11:45 POT/0112

Signatures of magnon dispersion in spin transport — •Sebastian Sailler, Denise Reustlen, Michaela Lammel, Sebastian T. B. Goennenwein, and Richard Schlitz — Department of Physics, University of Konstanz, 78457 Konstanz, Germany

The spin Hall magnetoresistance (SMR) provides electrical access to the magnetization of a magnetically ordered material. It recently became clear that changes in the net magnetization due to magnon creation and annihilation can be observed in the SMR. However, the number of magnons - and thus the magnetization - can also be modified by changing the energy of the system. In this work, we experimentally demonstrate that the changes of magnon occupation due to magnetic fields and crystal orientation sensitively modify the SMR response. Higher magnetic fields reduce the magnon population by pushing the magnon manifold to higher energies, leading to an increase of magnetization and thus the SMR. In turn, the influence of the anisotropic magnon gap in yttrium iron garnet films leads to a crystal orientation dependence of the SMR. The magnetic field and orientation dependence can be rationalized in terms of the changing magnon occupation. Our results showcase that magnetoresistive effects not only probe the properties of the static magnetization, but also reveal information about the dynamics, i.e., the magnons.

MA 29.9 Wed 12:00 POT/0112

Non-reciprocal spin-orbital-charge interconversion via magnon transport in nonlocal devices — •Jose Omar Ledesma-Martin[1], Sachin Krishnia[1], Edgar Galindez-Ruales[1], Duc Tran[1], Marcel Gasser[1], Dongwook Go[1,2], Gerhard Jakob[1], Yuriy Mokrousov[1,2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Mainz, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Jülich, Germany

In magnetic systems, angular momentum is carried by electrons' spin and orbital angular momentum. We use devices based on Pt nanowires on insulating magnets to study angular-momentum transport mediated by magnons, enabling angular-momentum information to propagate without charge flow. In these systems, magnons are generated by spin accumulation from the Spin Hall Effect (SHE) and detected via the inverse Spin Hall Effect (iSHE). In conventional Pt-YIG nonlocal geometries, this spin-charge interconversion is fully reciprocal: interchanging the injector and detector yields equal efficiencies. We further confirm that this power-to-power efficiency remains reciprocal when the thickness of one Pt wire is varied. However, when Ru is used as a source and detector of orbital currents via the orbital Hall effect (OHE) and inverse OHE, the reciprocity is broken. In our devices, the combined SHE + OHE-driven magnon generation, followed by detection through the iSHE, becomes ~35% more efficient than the reverse process, demonstrating nonreciprocity in the system. (1)

(1) J.O. Ledesma-Martin, Nano Lett. 2025, 25, 8, 3247-3252

MA 29.10 Wed 12:15 POT/0112

Giant orbital magnetoresistance in orbital magnets — •Sachin Krishnia[1], Christin Schmitt[1], Edgar Galindez Ruales[1], Takashi Kikkawa[2], Timo Kuschel[1], Eiji Saitoh[2], Olena Gomonay[1], Yuriy Mokrousov[1], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Mainz, Germany — [2]Department of Applied Physics, The University of Tokyo, Tokyo, Japan

Generation and transport of large orbital angular momentum (OAM) currents have recently emerged as a key research area in the field of orbitronics. In contrast to spin currents, whose generation depends on weak spin-orbit coupling, OAM currents arise directly from the coupling between crystal momentum and electronic OAM even in light and environmentally friendly materials (Cu, Al, Cr)[1]. A major challenge has been to exploit these giant orbital currents in magnetic systems, where static magnetization is dominated by spin. We show that this limitation can be overcome by employing magnetic materials in which OAM contributes significantly to the static magnetization. Using these orbital magnets, we demonstrate two orders of enhancement of orbital Hall magnetoresistance, compared to the spin counterpart. This enhancement originates from the interaction of the dynamic OAM generated in light metals with the static orbital moments of the orbital magnet. Our results establish a pathway to harness giant OAM currents for device functionalities that cannot be achieved with conventional spin-dominated magnets[2]. [1] S. Ding et al, PRL 125, 177201 (2020). [2] C. Schmitt, S. Krishnia et al. (under review).

MA 29.11 Wed 12:30 POT/0112

Spin-Current Sensitivity in $CuSeO_3$ Across the Antiferromagnetic Transition — •Ankita Nayak[1], Mathew James[1], Maxim Mostovoy[2], and Aisha Aqeel[1] — [1]University of Augsburg, 86135Augsburg, Germany — [2]Zernike Institute for Advanced Materials, University of Groningen, Nijenborgh 4, 9747 AG Groningen, The Netherlands

Antiferromagnets are promising materials for next-generation spintronics due to their robustness against magnetic fields and ultrafast dynamics. Spin Hall magnetoresistance (SMR) provides a sensitive method to probe spin transport at normal-metal–antiferromagnetic-insulator interfaces. In antiferromagnets, SMR can detect Néel-vector reorientation, spin-flop behaviour, and short-range correlations above the ordering temperature, as shown in systems such as NiO and α-Fe_2O_3.

Here, we use SMR in a Pt/$CuSeO_3$ bilayer to investigate spin transport in the unconventional antiferromagnet $CuSeO_3$. An AC current in the Pt Hall bar generates a transverse spin accumulation, whose interface reflection modulates the Pt resistance and enables electrical detection of the magnetic state.

$CuSeO_3$ consists of Cu(1) spin dimers and Cu(2) spins that order antiferromagnetically below 8 K. SMR measurements between 5 and 100 K with magnetic-field rotation in three planes reveal clear SMR signals, including a finite response above the Néel temperature, indicating persistent spin correlations. The plane-dependent SMR amplitude also reflects the intrinsic magnetic anisotropy of $CuSeO_3$.