MA 35: Spintronics (other effects) (joint session MA/TT)

Time: Wednesday 15:00–18:00 Location: POT/0112

Invited Talk MA 35.1 Wed 15:00 POT/0112

Magneto-optic Kerr effects of higher order in magnetization in thin films of different crystal orientations — •Timo Kuschel — Johannes Gutenberg University Mainz, Germany

The magneto-optic Kerr effect (MOKE) is an important tool to study magnetic properties of thin films. While the MOKE contribution linear in magnetization (LinMOKE) is mainly used for Kerr imaging, Kerr spectroscopy, time-resolved MOKE, and vectorial magnetometry of ferromagnetic thin films [1], the MOKE contributions quadratic in magnetization (QMOKE) [2] have been used for investigations of antiferromagnetic materials, spin-orbit torques, and structural order of Heusler compounds [3]. Recently, we have identified MOKE contributions of third order in magnetization (cubic MOKE, CMOKE) [4] and studied its dependence on the structural domain twinning of Ni(111) thin films.

In this talk, I will introduce these MOKE effects of higher order and describe their angular dependencies with respect to the crystal orientations of the thin films. While it is quite simple to find CMOKE in (111)-oriented films, it is not straightforward to identify it in (001)-oriented samples. I will discuss the reasons. Furthermore, I will report on the material systems that have shown CMOKE so far and mention potential applications.

[1] T. Kuschel et al., J. Phys. D: Appl. Phys. 44, 265003 (2011)
[2] R. Silber, TK et al., Phys. Rev. B 100, 064403 (2019)
[3] R. Silber, TK et al., Appl. Phys. Lett. 116, 262401 (2020)
[4] M. Gaerner, TK et al., Phys. Rev. Applied 22, 024066 (2024)

MA 35.2 Wed 15:30 POT/0112

Ignition of spin-triplet supercurrent in a ballistic S/F/S Josephson junction with precessing magnetization — •Elizaveta Andriyakhina, Miad Mansouri, Maxim Breitkreiz, and Piet Brouwer — Freie Universität Berlin, Germany

We develop a theory for a ballistic Josephson junction with a ferromagnetic (including half-metallic) interlayer whose uniformly precessing magnetization generates a controllable equal-spin (triplet) supercurrent. In a co-rotating frame, the driven junction maps to an effective static problem that can be treated with a scattering-matrix approach to obtain Andreev bound states and the dc Josephson current.

A key result is that steady precession produces a spin-dependent non-equilibrium occupation in the rotating frame, yielding a finite dc supercurrent. In the half-metal limit the junction is “off” without precession, but becomes “on” when a finite precession angle induces phase-sensitive Andreev levels and a triplet current.

For small precession angles, the induced current is approximately sinusoidal in phase and the critical current scales quadratically with the precession angle (and with drive parameters), enabling microwave-controlled switching via ferromagnetic resonance.

MA 35.3 Wed 15:45 POT/0112

Magnetic Domain Wall Motion under Microwave Excitation — •Lukas Fischer[1], Rouven Dreyer[2], Jae-Chun Jeon[1], Georg Woltersdorf[2], and Stuart Parkin[1] — [1]Max-Planck Institute of Microstructure Physics, Halle (Saale), Germany — [2]Martin-Luther-University Halle-Wittenberg, Halle (Saale), Germany

Chiral domain walls (DWs) and their synchronous motion via current pulses in magnetic conduits (so-called magnetic racetracks) are of enormous interest due to their fast speed, non-volatility, and capability of creating high bit-density for advanced memory and logic technologies. Most experimental and numerical studies have focused on the motion of the DWs by spin-orbit torque using nanosecond-long current pulses which are not efficient in coupling to magnetization precessions of the magnetic material, typically occurring in the GHz regime.

Here we present that the microwave excitation of chiral Néel DWs in a magnetic microwire with perpendicular magnetic anisotropy significantly impacts the DW motion. We use either magnetic fields or electrical currents at RF-frequencies to explore the pronounced impact on the DW motion. Firstly, we directly visualize the high-frequency response of the DW by using the Super-Nyquist sampling magneto-optical Kerr effect. We then determine the effect of this excitation on the DW motion. When the DW is excited in the presence of a static, transverse magnetic field, it exhibits unidirectional self-propulsion. Moreover, the resonant excitation in a static, longitudinal field leads to a current-triggered, sustained DW motion over micrometer distances, which dramatically increases the effective DW displacement.

MA 35.4 Wed 16:00 POT/0112

Assembly of Magnetic Heterostructures with Chiral Nanographenes — •Chi Fang, Wenhui Niu, Jitul Deka, and Stuart Parkin — Max Planck Institute of Microstructure Physics, Halle(Saale) 06120, Germany

Chirality-induced spin selectivity (CISS) is an emergent phenomenon whereby chiral molecules act as efficient spin filters, selectively transmitting electrons of a particular spin orientation. A central challenge in advancing CISS-based spintronics lies in experimentally verifying spin filtering in structurally defined, laterally extended molecular systems, using standard solid-state device techniques that yield reproducible and robust spin-dependent transport signals. Here, we present direct experimental evidence of the CISS effect in helical nanographenes (NGs), using magnetoresistance (MR) measurements in magnetic heterostructures. The device architecture included a bottom electrode ferromagnetic contact, orthogonally patterned and electrically isolated by an AlOx layer to confine current to the junctions. NG, a synthetically tailored chiral molecule, was spin-coated to form a thin, uniform layer serving as a spin-filter interface. Different from previous works, the ferromagnet layer grown directly on the substrate offers a better performance of the magnetic properties. Both enantiomeric devices showed MR values around 1 % at room temperature, with minimal variation over the 10*400 K temperature range, indicating robust and reproducible spin selectivity. [1] B. Bloom et al. Chem. Rev. 124(4), 2014;[2] S. Ham et al. Micromachines 15(4), 528, 2024;[3] S. Yang et al., Nat. Rev. Phys. 3, 328, 2021.

MA 35.5 Wed 16:15 POT/0112

Alloying-Driven Modifications of the Magnetic Properties in Transition-Metal Iodides — •Paulina Jureczko[1,2] and Martin Gmitra[1,3] — [1]Institute of Experimental Physics, Slovak Academy of Sciences, 04001 Košice, Slovakia — [2]Institute of Physics, University of Silesia in Katowice, 41-500 Chorzów, Poland — [3]Institute of Physics, Pavol Jozef Šafárik University in Košice, 04001 Košice, Slovakia

Single-layer transition-metal dihalides have recently emerged as a platform for exploring two-dimensional magnetism and topology. Using density-functional theory, we investigate the electronic and magnetic properties of MI_2 monolayers and alloyed $M_{1-x}N_xI_2$ systems, where M and N represent Mn, Fe, Co, Ni. We analyze how chemical substitution modifies exchange interactions and spin-orbit-driven topological features by computing the Berry curvature and Chern numbers. The results reveal that alloying provides an efficient route for tuning magnetic anisotropy and topological phases in transition-metal iodides, underscoring their potential relevance for 2D spintronics.

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15 min break

MA 35.6 Wed 16:45 POT/0112

Spintronic THz Frequency Conversion Mediated by Ferromagnetic/Oxide Interfaces — •Kang Jin[1], Ruslan Salikhov[1], Stefan Kober[2], Igor Ilyakov[1], Jan-Christoph Deinert[1], Aleksandra Lindner[1], Jürgen Fassbender[1,3], Sebastian F. Maehrlein[1,3], Zhe Wang[2], and Jürgen Lindner[1] — [1]HZDR — [2]TU Dortmund — [3]TU Dresden

Frequency conversion is a key nonlinear phenomenon for communication and data processing technologies. Exploring this phenomenon at terahertz (THz) frequencies is of particular interest, as the high carrier frequency enables faster data transfer and higher operational speeds. Previous experiments have revealed that THz frequency conversion could serve as a distinctive probe for THz-light-induced ultrafast spin-transfer currents (STCs) at Ferromagnetic (FM)/Non-Magnetic (NM) interfaces. Building on these findings, we report THz frequency conversion using cost-effective NM materials (such as SiO2 and Al2O3 films) and demonstrate their origin from the interfacial inverse Rashba-Edelstein effect. We compare conversion efficiencies and characteristics of different samples, revealing that FM interfaces, featuring offstoichiometric SixOy and AlxOy, achieve conversion efficiencies comparable to heavy metal capping layers (i.e. Ta). The deposition sequence and the oxidation level of the samples were found to critically influence the sign of the spin-charge conversion. The observed THz second harmonic generation represents a spintronic foundation for developing THz frequency mixers and rectifying components.

MA 35.7 Wed 17:00 POT/0112

Magnetic hyperfine fields in solids without inversion symmetry induced by an external electric field — •Alberto Marmodoro[1,2,3,4], Hubert Ebert[1], Sergiy Mankovsky[1], and Jan Minar[3] — [1]LMU Munich, Munich, DE — [2]Inst. of Physics of the Czech Acad. of Sci., Prague, CZ — [3]University of West Bohemia, Pilsen, CZ — [4]Czech Technical University., Prague, CZ

An electric field induces in a solid without inversion symmetry spin and orbital magnetization - a phenomenon called Edelstein effect. This induced magnetization has to have its counterpart in an induced magnetic hyperfine field seen by nuclear magnetic moments. Corresponding NMR experiments have been performed recently on Te with success [1]. Using Kubo's linear response formalism implemented on the basis of the relativistic Korringa-Kohn-Rostoker Green function technique a description for the field induced hyperfine field (EFI-HFF) has been developed in analogy to that for the spin and orbital Edelstein effect [2]. The EFI-HFF drastically differs from that induced by an external magnetic field as the later one does not need missing inversion symmetry. Making use of a Gordon decomposition of the electronic current a splitting of the EFI-HFF into its spin and orbital parts is achieved [3]. This allows to discuss them in relation to their counterparts concerning the magnetization as well as the role of the spin-orbit coupling for them. Corresponding numerical results are presented for Te.

[1] T. Furukawa et al., Phys. Rev. Res., **3**, 023111 (2021). [2] S. Wimmer et al. Phys. Rev B, **103**, 024437 (2021). [3] M. Battocletti and H. Ebert, Phys. Rev. B, **64**, 094417 (2001).

MA 35.8 Wed 17:15 POT/0112

Theoretical description of the optical activity and directional dichroism of chiral solids — •Hubert Ebert and Sergiy Mankovsky — Ludwig Maximilian University of Munich, Munich, DE

A scheme to deal with the optical activity and directional dichroism of solids on the basis of Kubo's linear response formalism is presented. Accounting for the $\vec{q}$-dependence of the radiation field implies that the corresponding optical transitions described in $\vec{k}$-space are no more vertical. More important, one is led to corrections to the electric dipole matrix element due to the electric quadrupole and magnetic dipole interaction. The scheme is implemented making use of the relativistic Korringa-Kohn-Rostoker Green function (KKR-GF) formalism. Corresponding applications to chiral Te that has time reversal ($\mathcal{T}$) but no inversion ($\mathcal{I}$) symmetry led to a $\vec{q}$-dependent optical conductivity tensor with off-diagonal elements caused by the interference of the electric dipole and its correction terms giving rise to optical activity. In the case of anti-ferromagnetic Cr_2O_3 without $\mathcal{T}$-symmetry the correction terms lead to directional dichroism that strongly depends on whether a magnetic configuration with or without $\mathcal{I}$- but with combined $\mathcal{IT}$-symmtetry is considered.

MA 35.9 Wed 17:30 POT/0112

Intrinsic and Proximity-Enhanced Spin-Orbit Torques in Fe_3(Ge,Ga)Te_2 and WTe_2 Heterostructures — •Gusthavo Brizolla[1], Stepan Tsirkin[2], Yaroslav Zhumagulov[2], and Jaroslav Fabian[1] — [1]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [2]EPFL, Lausanne, Switzerland

Spin-orbit torques (SOTs) in 2D magnets and their heterostructures offer a route to ultra-thin, energy-efficient memories where currents can switch magnetization without external magnetic fields. Materials such as Fe_3GeTe_2 (FGT) and Fe_3GaTe_2 (FGaT), and their interfaces with low-symmetry WTe_2, are especially promising, but the angular dependence and microscopic origin of their SOTs are still not fully understood. Here we compute SOTs in FGT, FGaT and WTe_2-proximitized heterostructures using first-principles (DFT) calculations and compare two protocols for mapping the angular dependence: self-consistent magnetization rotation and rigid rotation of a fixed exchange field. They agree when spin-orbit mixing is weak, but differ strongly near in-plane alignment, where interband hot spots and evolving spin-orbit hybridization amplify the torkances. In WTe_2 heterostructures, broken symmetry and Te-Te interfacial hybridization further boost torques with out-of-plane spin polarization. These results provide design rules for field-free current control in 2D magnets and show that the angle dependence of spin-orbit coupling must be treated explicitly to obtain reliable SOT angular maps.

MA 35.10 Wed 17:45 POT/0112

Spin vacuum switching — •Eddie Harris-Lee[1,2], John Kay Dewhurst[2], Samuel Shallcross[1], and Sangeeta Sharma[1,3] — [1]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Berlin, Germany. — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany. — [3]Institut für Theoretische Physik, Freie Universität Berlin, Berlin, Germany.

While physical mechanisms underpinning spin switching are established for nano- to pico-second time scales, here we present a physical route to magnetization toggle control at < 100 femtoseconds. A minority spin current injected into a ferromagnet is shown to create a minority "spin vacuum" that then drives rapid charge redistribution from the majority channel and spin switching. We demonstrate this mechanism reproduces many of the features of recent sub-picosecond switching of ferromagnetic Co/Pt multilayers, and provide simple practical rules for the design of materials to optimize "spin vacuum" control over magnetic order.

Harris-Lee *et al.*, Sci. Adv. **10**, eado6390 (2024). DOI:10.1126/sciadv.ado6390