TECHNISCHE UNIVERSITÄT
IN DER KULTURHAUPTSTADT EUROPAS
CHEMNITZ

Institut für Physik
Physikalisches Kolloquium



Donnerstag, 19.11.2026, 15:30 Uhr
Ort: Reichenhainer Str. 90;
Zentrales Hörsaal- und Seminargebäude, Raum C10.013

Dr. Ruslan Salikhov
Helmholtz-Zentrum Dresden-Rossendorf

All-THz probing of ultrafast spin-orbit torques and spin-charge interconversion

Electronic spin and orbital angular momentum are fundamental quantum degrees of freedom underlying a wide range of magnetic phenomena. Nonequilibrium electronic transport can generate spin and orbital angular-momentum currents that transfer angular momentum to magnetic order, thereby exerting torques on the magnetization. Over the past three decades, these effects have enabled the efficient manipulation and switching of magnetization in ferromagnetic (FM) thin films and heterostructures, establishing spintronics and, more recently, orbitronics as promising platforms for controlling magnetic states and developing emerging information technologies. In particular, current-induced spin-orbit torques (SOTs) have enabled magnetization switching in ferromagnet/heavy-metal (FM/HM) heterostructures. Such systems are consequently being explored for advanced magnetic-memory technologies, particularly spin-orbit torque based magnetic random-access memory (SOT-MRAM) [1].

Understanding the mechanisms and efficiencies by which charge currents are converted into spin currents on ultrafast (picosecond) timescales, as well as how these currents generate ultrafast SOTs, is a major frontier of current research. Such understanding is essential for developing next-generation memory, logic, and neuromorphic devices capable of operating at terahertz (THz) frequencies [2].

To address this, I will introduce an **all-THz metrology** for probing ultrafast SOTs and spin-charge interconversion in magnetic heterostructures. Ultrafast SOTs are detected through THz-field-driven picosecond magnetization dynamics and the excitation of nanometre-wavelength perpendicular standing spin waves across the thickness of FM films [3]. Spin-to-charge interconversion are probed through nonlinear THz second-harmonic generation (TSHG): THz-driven ultrafast demagnetization combined with the inverse spin Hall effect provides information about spin-to-charge conversion [4], while unidirectional spin Hall magnetoresistance probes charge-to-spin conversion through interfacial magnetoresistive effects [5]. Together, these techniques establish a unified all-THz approach to ultrafast spin and orbital transport, which I will demonstrate through the example of SOT self-generation in a single ferromagnetic layer. These THz-based characterization techniques offer a promising route towards designing THz-frequency memory elements without costly and environmentally burdensome heavy metals [6].

[1] V. D. Nguyen, et al. Recent progress in spin-orbit torque magnetic random-access memory. npj Spintronics **2**, 48 (2024).

[2] A. El-Ghazaly, et al. Progress towards ultrafast spintronics applications. J. Magn. Magn. Mater. **502**, 166478 (2020).

[3] R. Salikhov, et al., Coupling of terahertz light with nanometre-wavelength magnon modes via spin-orbit torque. Nat. Phys. **19**, 529–535 (2023).

[4] I. Ilyakov, et al. Efficient ultrafast field-driven spin current generation for spintronic terahertz frequency conversion. Nat. Com. **14**, 7010 (2023).

[5] R. Salikhov, et al. Ultrafast unidirectional spin Hall magnetoresistance driven by terahertz light field. Nat. Com. **16**, 2249 (2025).

[6] K. Jin, S. Kober, et al. Ultrafast spin-orbit torques and spin-charge interconversion at oxidation-tailored NiFe/oxide interfaces. https://doi.org/10.21203/rs.3.rs-9886807/v1