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Nonlinear THz light-matter interactions in transition metal systems

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Nonlinear light-matter interactions provide unique opportunities to manipulate material parameters on ultrafast timescales. Intense research is currently focused on nonlinear THz-field-driven dynamics, addressing fundamental questions related to picosecond coherent processes of charge carriers, spins, and order parameters. Several theoretical approaches have been developed to describe nonlinear electronic THz responses, such as those underlying THz harmonic generation in Dirac materials, doped semiconductors, and superconductors. In contrast, the nonlinear THz response of transition metals remains largely unexplored.

Recently, we have demonstrated nonlinear THz dynamics in metallic heterostructures arising from spin-dependent charge carrier scattering via unidirectional spin Hall magnetoresistance [1], as well as from coupled spin-charge and orbital-charge interactions [2]. Furthermore, we have observed a general nonlinear response in heavy metals with partially filled d-band shells [3], which may originate from strong spin-orbit coupling effects. In this presentation, I will discuss our latest results on nonlinear THz responses in transition metal alloys and partially oxidized metals.

[1] R. Salikhov et al., Ultrafast unidirectional spin Hall magnetoresistance driven by terahertz light field, *Nature Communications* **16**, 2249 (2025).
[2] G.L. Prajapati et al., Terahertz harmonic generation across the Mott insulator-metal transition, *Phys. Rev. B* **113**, 045118 (2026).
[3] R. Salikhov et al., spin-orbit interaction driven terahertz nonlinear dynamics in transition metals, *npj Spintronics* **3**, 3 (2025).