Terahertz Spatiotemporal Probing of Quasiparticle Dynamics: From the Orbital Hall Effect to Magnon in Strong Spin-Orbit Coupling Systems

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The control of orbital and spin degrees of freedom in two-dimensional (2D) and topological materials is essential for next-generation quantum technologies. Among these, the orbital Hall effect (OHE) in topological semimetals has emerged as an effective mechanism for generating and manipulating orbital currents, yet its high-speed dynamic nature has been challenging to resolve. In this presentation, we demonstrate the spatiotemporally resolved orbital Hall effect in a topological semimetal using advanced terahertz (THz) spectroscopic techniques[1]. By capturing sub-picosecond orbital-to-charge conversion, we provide direct evidence of how topological electronic structures dictate the flow and relaxation of orbital currents in low-dimensional systems.

Building on this experimental framework, we further extend our THz probing to magnons—the quantized collective excitations of spin waves. While OHE focuses on electronic orbital transport, THz-frequency magnons offer a complementary view of spin dynamics, providing detailed access to time-resolved phase, handedness, and coherence in ordered magnetic systems[2,3,4].

By combining the study of orbital Hall transport and magnon-mediated spin information transfer through THz precision, this work highlights an integrated approach to understanding interacting quantum systems. Our findings position THz spectroscopy as a powerful tool for providing fundamental insights into the coherent interplay between orbital and spin degrees of freedom in quantum materials.

References

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