Tensorial Spin Hall Magnetoresistance and Unconventional Spin-Orbit Torques

Abstract

As an established paradigm of spin-charge conversion, the spin Hall effect (SHE) and its inverse effect have been widely utilized to generate, detect, and characterize spin-orbit torques. However, recent experiments suggested that the archetypal SHE geometry could be violated in materials with special crystal symmetry, such as semimetal WTe2 and its variances. We propose a phenomenological description for such generalized spin-charge transport, bringing about a new concept dubbed tensorial SHE (t-SHE). In the presence of the spin diffusion process, the t-SHE gives rise to: 1) unconventional spin-orbit torques with unique features, and 2) a new form of magnetoresistance generalizing the known spin-Hall magnetoresistance. By solving the magnetization dynamics driven by a time-harmonic current, we predict a series of harmonic signals arising from the t-SHE and its ensuing magnetoresistance, which enables practical methods to experimentally characterize the unconventional spin-orbit torques originating from the t-SHE.

Presenter

Ran Cheng (Associate Professor, University of California, Riverside)

Bio

Dr. Ran Cheng obtained his Ph.D. in Physics from the University of Texas at Austin in 2014, followed by a postdoc appointment at Carnegie Mellon University. In 2018, he joined the University of California, Riverside, as an Assistant Professor and was promoted to Associate Professor in 2025. He holds joint appointments in the Departments of Electrical and Computer Engineering, Physics and Astronomy, and Materials Science and Engineering. Dr. Cheng leads a research group in theoretical Condensed Matter Physics with a focus on spintronics, magnetism, and topological materials. He explores a broad range of fundamental physical phenomena and their implications in advanced materials, especially in magnetic topological insulators and antiferromagnetic nanostructures. His research is driven by both experimental insights and mathematical intuitions. His research is supported by the DoD MURI Award, the NSF CAREER Award, funding from the W.M. Keck Foundation, and several intramural grants.