Terahertz Spectroscopy of Quantum Materials

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Traditionally, infrared spectroscopy has played an instrumental role in elucidating the nature of superconductors. Historically. the first observation of the superconducting energy gap of elemental metals by Tinkham et al. guided the formulation of the celebrated Bardeen-Cooper-Schrieffer theory of superconductivity. Here, we show that the advent of terahertz spectroscopy has brought a quiet revolution in the field of superconductivity research. Above all, frequency-dependent conductivity spectra of thin-film superconducting samples can nowadays be precisely determined without resorting to Kramers-Kronig analysis. Further, terahertz spectroscopy can be conducted in the presence of an external magnetic field, revealing exotic gapless superconductivity. Similarly, while microwave spectroscopy has played a major role in elucidating the spin excitations of magnetic materials, with pulsed terahertz light, we can now probe quantum dynamics of magnons in the time domain, excavating key information on magnetic order and magnetic phase transitions. The terahertz technique can be further extended to disordered magnetic systems such as quantum spin liquid phases. Here, we review our recent experimental results based on the terahertz technique on representative ferromagnets, antiferromagnets, and spin liquid candidates.