Novel Instrumentation for 2D Characterization: Combined Magneto-Optical Magneto-Transport

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Abstract Body: Raman spectroscopy is a powerful, non-destructive optical technique for probing quasiparticles and fundamental physics in two-dimensional (2D) materials. Raman is sensitive to a remarkable number of physical parameters, including layer thickness, defects and disorder, edges and grain boundaries, doping, strain, magnetic ordering, and distinctive excitations such as magnons and charge density waves. Particularly notable for quantum materials, Raman spectroscopy probes the evolution of the electronic structure and the electron-phonon, spin-phonon, and magnon-phonon interactions as a function of temperature, laser energy, and polarization. In this talk, we highlight the unique spectroscopic capabilities available at NIST enabling spatially resolved Raman measurements while simultaneously varying the temperature (1.6 K to 400 K), laser wavelength (tunability from visible to near-infrared), magnetic field (up to 9 T), and electrical bias. We first present a methodology for accurate angle-resolved Raman spectroscopy, which is critical for describing the physical properties of materials with anisotropic Raman response. Subsequently, we discuss helicity-resolved Raman spectroscopy, demonstrating its capability for the selective detection and characterization of chiral phonons. The discussion then shifts to magneto-Raman spectroscopy, where we provide examples of probing magnons and other complex quasiparticle interactions in a series of 2D magnetic material systems. Finally, we present the integration of Raman spectroscopy with simultaneous electrical transport measurements in an hBN/graphene/hBN Hall bar device. We demonstrate spatially resolved and reversible doping of the hBN/graphene/hBN heterostructure achieved by optically activating defects within the stack using both Raman excitation laser and white light illumination. These comprehensive results underscore the versatility and powerful capabilities of Raman-based techniques in unraveling the intricate physics of 2D quantum materials.