Energy and Charge Carrier Dynamics in Nanoscale Thermal Characterization

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In 2D materials thermophysical properties characterization, photon irradiation is widely used to induce localized temperature gradient and energy transport. The laser absorption process involves excitation of electrons to conduction band, hot carrier diffusion, cascading energy transport from electrons to optical phonons, then to acoustic phonons, and final heat conduction by acoustic phonons. In-depth physics understanding of this nonequilibrium and the energy exchange among energy carriers is critical to high-level laser-assisted manufacturing, probing, design, control, optimization, and new synthesis discovery. This talk will cover our pioneering and systematic work on investigating the thermal nonequilibirum among energy carriers in 2D materials under intense photon irradiation. To tackle this big challenge, an energy transport state-resolved Raman (ET-Raman) technique was invented in our lab that is capable of thermal probing down to sub-micron scale and picoseconds. For the first time, we distinguished the temperature rises of different modes of optical phonons and acoustic phonons, and reported their energy coupling factor. Both supported and free-standing nm-thick 2D materials have been characterized. This breakthrough leads to the first time measurement of intrinsic thermal conductivity and interface thermal conductance of 2D materials. For monolayer 2D materials, the electron-hole recombination will re-emit photons. This radiative recombination will also be reported based on our ET-Raman characterization, uncovering some very intriguing energy absorption features.