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Conjugated Phonon and Hot Carrier Transport in 2D Materials

Xinwei Wang
Department of Mechanical Engineering, Iowa State University,
Ames, Iowa 50011, United States

Abstract

Two dimensional (2D) materials have been topics of extensive recent research. Transition metal dichalcogenides (TMDs) 2D materials have attracted great interests due to their distinctive electrical and thermal properties, such as tunable bandgap, strong photoluminescence, and large exciton binding energy. These unique properties are leading to potential applications like solar cells, photodetectors, and field-effect transistors. Knowledge of thermal conductivity, diffusivity, and interface thermal conductance of 2D materials and structural effects are critical for scientific understanding and control of energy transport. Raman spectroscopy-based techniques are the most used one for probing the above physical processes. Under intense photon excitation, hot carriers will be excited and conjugate with phonon transport, making the phenomenon very complicated. This talk will cover how these two physical processes are distinguished using our Energy Transport state-resolved Raman (ET-Raman), a technique developed in our lab that is capable of characterizing transient thermal response down to picoseconds. Our systematic work points out that under tightly focused laser heating (~micron scale), hot carrier transport plays a critical role in heat conduction in addition to phonon transport. For monolayer 2D materials, the radiative electron-hole recombination renders normal laser absorption treatment physically invalid. This problem has been solved successfully using our ET-Raman and the electron-hole radiative recombination efficiency has been determined with high confidence. These very pioneering works open a new direction for characterizing energy transport processes in 2D materials for next generation scientific understanding and design.