Ultrafast Spectroscopy of 2D Materials, Semiconductor Defects, and Devices

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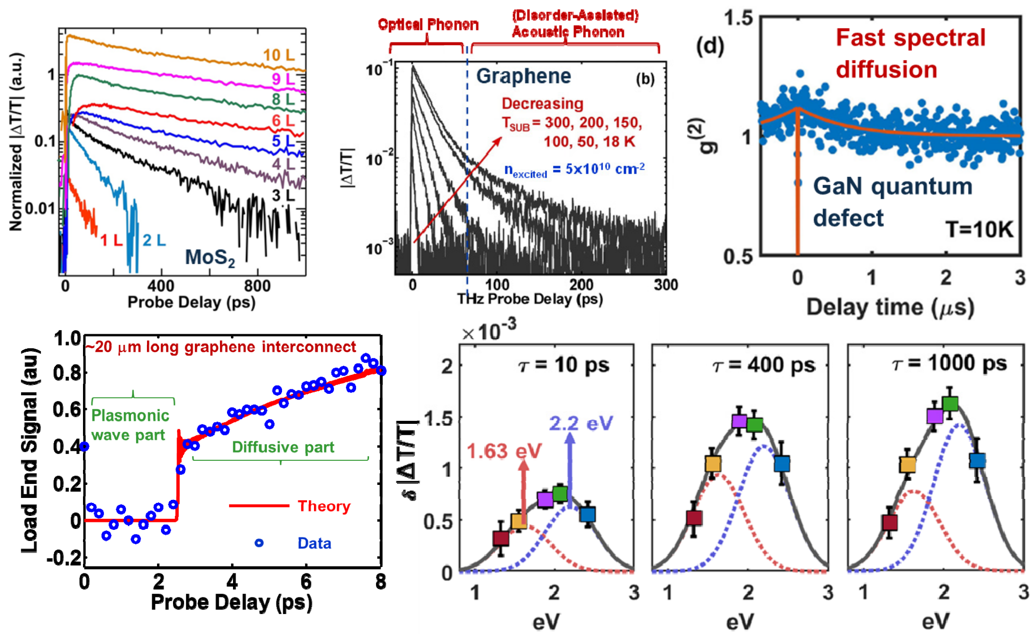
Ultrafast spectroscopy has become a valuable tool to study the dynamics of single-particle as well as of collective excitations associated with carriers, phonons, spins, magnons, plasmons, etc, in semiconductor materials, nanostructures, and in devices. In this talk, we will present our ultrafast spectroscopy results from work done in the last several years on novel semiconductors, including 2D materials, on defects in wide bandgap semiconductors, and on devices.



Top row, left to right: i) Ultrafast optical pump-probe results for 2D MoS2 with different layer number ii) Ultrafast optical/THz pump-probe results for graphene iii) Fast spectral diffusion in GaN quantum defects measured using photon correlation spectroscopy.

Bottom row, left to right: i) Ultrafast signal transmission in a graphene plasmonic interconnect ii) Time-dependent absorption spectra of defects in optically excited Ga2O3 measured with ps time resolution.

Our work on 2D graphene has shown that many body effects, including Auger scattering and plasmon emission, are responsible for ultrafast carrier recombination on sub-ps time-scales and optical phonons and acoustic phonons are responsible for carrier cooling on hundreds of ps time scales. Our work on 2D TMDs has shown that defect-assisted recombination due to Auger scattering is responsible for fast exciton and carrier recombination on sub-100 ps time scales. Defects pose the biggest challenge for the utilization of 2D materials in practical and useful electronic and optical devices. Our ultrafast spectroscopy work on graphene plasmons has shown that micron scale plasmon guides can beat copper electrical interconnects in signal propagation delays. By using supercontinuum ultrafast spectroscopy, we have shown that time-dependent absorption spectra of defects in semcionductors can be obtained with ps time resolution and enable one to determine the nature of the defects. Finally, we show that ultrafast techniques can be used to characterize fast dynamics associated with single quantum defects in semiconductors. This talk will discuss the techniques used as well as the physics explored using these techniques.