Physical Chemistry Seminar

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Ultrafast Optical Microscopy of Excitonic Interactions in Two – Dimensional Semiconductors

Strong optical nonlinearities at the single- or few-photon level are a key ingredient for many quantum photonic technologies, including photon switches and deterministic photonic gates. Achieving this regime requires that a single excitation modifies the system strongly enough to suppress additional excitations within a finite spatial interaction region. However, in most semiconductor systems excitons interact only weakly, making it extremely difficult to reach the few-photon nonlinear regime.

In this talk, I will present how ultrafast optical microscopy can be used to directly probe and visualize excitonic interactions in two-dimensional semiconductors, where reduced dielectric screening and strong light–matter coupling enhance many-body effects. Using spectrally and spatially resolved transient reflection microscopy, we measure how photoexcited populations modify the optical response with simultaneous resolution in time, energy, and space .

I will highlight how excitonic states with different internal structure give rise to qualitatively different nonlinear optical responses, revealing the role of spatial extent in shaping these interactions. I will then turn to doped systems, where coupling to a Fermi sea leads to interaction effects that extend over surprisingly long length scales and can suppress additional excitations within a finite region.

Together, these results point toward new routes for realizing strong and spatially extended optical nonlinearities in solid-state systems, and suggest a path toward controlling interactions at the level required for future quantum photonic applications.