Title: Ultrafast Spectroscopy to Elucidate Electron and Lattice Dynamics

Abstract:
The ability to observe the movement of electrons in complex materials has been challenging due to the lack of suitable spectroscopic techniques for measuring the motion of electrons with state-specific resolution. To address this challenge, I designed and constructed a tabletop ultrafast pump-probe X-ray absorption spectrometer based on high-harmonic generation (HHG), which enables state-specific probing of electrons with femtosecond time resolutions. In my talk, I will describe this new frontier of ultrafast science and technology and highlight the recent applications of this method to study charge transfer excitons, electron trapping, exciton dissociation, and interfacial charge transfer dynamics in light-harvesting metal oxide semiconductors. However, a detailed understanding of these ultrafast processes also requires probing the phonon motions coupled to the electrons. The second part of my talk will focus on the use of time-domain Raman spectroscopy to probe molecular-like phonon wave packets, lattice structural dynamics, and exciton-phonon coupling in two-dimensional perovskites. Therefore, my research on time-resolved X-ray and Raman spectroscopy provides a detailed nanoscale understanding of electron and phonon motions that govern charge separation, trapping, transport, and recombination processes in materials. These examples illustrate the abilities and future promises of these ultrafast spectroscopic techniques to provide rational design principles of functional materials with numerous technologically relevant applications spanning photocatalysis, photovoltaics, and information storage and processing.