The miniaturization of electronic components such as transistors to nanoscale dimensions is nearing the fundamental limit where the discrete atomic nature of the dopants in semiconductor materials becomes important. In addition to scaling of conventional technologies, electro/optic control over single dopants is a basis for next-generation quantum-based information processing in the solid state. This motivates an emerging field of ‘solotronics’, whereby individual impurity atoms in semiconductors are used as either classical or quantum bits for computing. In recent years, the scanning tunneling microscope (STM) has proved to be a useful tool for directly measuring the properties of individual impurities in semiconductors, and probing how these properties depend on reduced symmetries due to proximity to interfaces, native defects or other impurities. Though STM imaging can often provide more direct insight into the atomic configurations of defects, and STM spectroscopy can elucidate impurity levels, the ability to resolve dopant dynamics is limited by a slow instrumental response time.

We have developed an ultrafast scanning tunneling microscopy (UF-STM) technique to study how reduced symmetries influence the dynamics of individual dopants in semiconductors. To overcome the inherently slow instrumental response time, we have designed and built a portable ultrafast oscillator (PUPIL) operating in the near IR (wavelength = 1.55 microns = 200 THz). PUPIL can resonantly excite band-to-dopant transitions and is suitable for pump-probe dynamics studies. We will discuss initial studies on PUPIL-induced changes in STM spectroscopy on individual dopants and adatoms on GaAs and InSb surfaces. With laser illumination, we observe shifts in dopant states within the bandgap, and a pronounced screening of the tip-induced electric field. We will also discuss prospects for continuing and expanding this work to more broadly probe laser/matter dynamics.