Measurement and Control of Electron Dynamics Using THz Pulses

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Phase-locked, few-cycle pulses of THz light are powerful tools for both probing and driving ultrafast charge carrier dynamics.

As an example of THz pulses as a time-resolved probe, I discuss recent multi-THz spectroscopy experiments on the widely researched hybrid organometallic halide perovskites. These solution processable materials have been successfully applied to a variety of optoelectronic devices, most notably high efficiency photovoltaics achieving up to 22% power conversion efficiency in the lab (comparable to silicon). Their long carrier lifetimes and relative insensitivity of their electronic transport properties to the presence of impurities have been puzzling, considering their similarities to other direct band gap semiconductors like GaAs. This led to a proposal that charge carriers exist as large polarons, protected against scattering by their correlation to polar lattice vibrations. In this talk, I show ultrafast THz measurements provide direct evidence for the existence of polarons in these materials, resolving the quantum dynamics of their formation.

In addition, strong field THz pulses can now be used to control the motion of charged particles on sub-cycle time scales. Along these lines, I will discuss our recent work on sub-cycle THz field emission of femtosecond electron wave packets from metal nanotips. We show that through field-assisted tunneling directly from the metal's Fermi level, impressive electron bunch charges up to 10^6/shot are emitted on a sub-cycle time scale. These electrons are subsequently accelerated in the local THz field in the vicinity of the nanotip to keV energies over 100 nm length scales. We discuss possible applications as a source for single shot ultrafast electron diffraction and as a test bed for high field physics.