

MeV Ultrafast Electron Scattering: Catching electron and phonon in action

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Ultrafast electron scattering instrumentation is one of the most powerful tools for understanding the molecular energy conversion process and direct imaging of phonon transport at the nanoscale. SLAC launched the Ultrafast Electron Diffraction and Imaging (UED&UEM) initiative with the objective of developing the world leading ultrafast electron scattering instrumentation, complementary to the X-ray Free Electron Laser - Linac Coherent Light Source (LCLS). The objective of the SLAC initiative is to develop a UED&UEM facility will possess unique capabilities that enable Grand Challenge science in chemistry, material science, physics and biology. In addition, the ability to couple the UED&UEM measurements with linac-based intense THz and X-ray FEL pump pulses will open new scientific opportunities.

The SLAC UED&UEM facility will take advantage of the recent developments in high-brightness ultrafast electron sources, high-field magnets and electron detection. It will provide direct access to atomic coordinates with temporal resolution down to 100 fs and even below in the diffraction (UED) mode. The ultrafast imaging capabilities of the SLAC UEM will represent a paradigm shift compared to present day facilities, and it can achieve 10-nanometer and 10-picosecond resolution in single-shot mode. To realize high temporal resolution required for the SLAC UED&UEM facility, a MeV high-brightness electron beam generated by a photocathode RF gun will be employed. This allows more electrons to be packed into each bunch, offering single-shot capabilities similar to those of x-rays from LCLS. A further important advantage of relativistic beams is that they eliminate the velocity mismatch between the electromagnetic pump pulses and the electron probe beam. This mismatch limits the time resolution of ultrafast dynamics for dilute samples, such as gas and liquid samples. In addition to the higher temporal resolution, MeV electrons can penetrate thicker samples. Finally, the higher electron beam energy leads to a larger elastic scattering cross section and a decrease in the inelastic scattering cross sections, increasing the diffraction signal and reducing inelastic scattering.

As the first part of this initiative, SLAC developed a MeV Ultrafast Electron Diffraction (UED) setup at the Accelerator Structure Test Area (ASTA) with the goal of providing MeV-, 100-femtosecond-scale electron pulses to support an ultrafast science program – ultrafast material science and gas phase small molecule structure dynamics. The ASTA UED performance and latest ultrafast science experimental results will be discussed.