MeV Ultrafast Electron Scattering at SLAC: Status and Opportunities

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Electron scattering, including diffraction, imaging and spectroscopy, techniques are indispensable research tools for new discoveries in material science, chemistry, biology, as well as for new technology breakthroughs for industrial applications. A new development in the electron scattering family is the use of femtosecond MeV electrons for studying photoinduced non-equilibrium processes. In the last decade, there has been significant worldwide R&D efforts on femtosecond time-resolved MeV electron scattering aiming at reaching ever better temporal, spatial and energy resolutions. SLAC National Accelerator Laboratory is enthusiastically pursuing this research direction.

A MeV ultrafast electron diffraction (UED) system has been built at SLAC, which is now supporting a very active science program, and at the same time serving as a testbed for instrumentation development. In this talk, we will briefly review the design and performance of the machine. A wide range of samples and dynamics, including thin nano-films, hetero-structures, 2D materials, nanoparticles, warm-dense matter, and gas-phase molecules, have been studied. Meanwhile, we are developing new machine capabilities to enable new science opportunities. For example, by generating ultra-low emittance beams and applying strong magnetic focusing, we demonstrated micro-diffraction for measuring μm-size samples or domains while maintaining ultrahigh temporal resolution. We recently added THz pumping capability and we will present results on THz time-stamping of electron beams to enable femtosecond temporal resolution and beyond.

Future developments for UED include better temporal resolution to 10-fs-level and enhanced sample handling capabilities such as heating/cooling, precise rotation control, etc. We are developing key technologies for future UEM with unprecedented combined spatial-temporal resolution based on a superconducting radio-frequency source. We will also discuss a new concept for realizing electron energy-loss spectroscopy using RF gun generated MeV electron beams to study electronic dynamics with sub-eV and 10-fs resolutions.