THz-based attosecond metrology for ultrafast electron diffraction

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In recent ultrafast THz pump – electron probe experiments at SLAC ASTA UED, laser-generated strong THz radiation is used to selectively excite samples. Femtosecond electron beams with MeV kinetic energies are used to capture the structural response of the dynamic process, providing valuable information that is complementary to those obtained with X-ray and optical probes. Electrons are ideal for probing thin samples (of monolayer to sub-micrometer thickness) with much reduced radiation damage compared to X-rays, and capable of accessing multiple orders in a single diffraction pattern thanks to their extremely short (picometer and shorter) wavelengths. Being charged particles, the probing electrons interact with the electromagnetic fields of the THz pump pulse itself as well as with those excited around the sample substrates and mounts. These fields generate considerable temporal and spatial-dependent distortions of the observed diffraction patterns, introducing challenges in extracting the response of the sample itself. On the other hand, since the temporal shape of the THz field is known, the precise time delay between THz pump and electron probe pulses can be extracted. Each single-shot diffraction pattern has a time stamp with femtosecond precision built-in, stemming from the THz-induced transverse momentum kick. Here we report on experimental results of the interactions between strong THz and femtosecond electron beams mediated by diffraction samples and specific resonant structures. The results demonstrate the feasibility of characterizing the bunch length and timing jitter of electron beams, and eventually building a timing-tool for ultrafast electron scattering with attosecond accuracy.