Mapping and controlling of optical near fields in an ultrafast transmission electron microscope

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Electron microscopy allows for the mapping of optical properties of metallic and dielectric nanostructures via cathodoluminescence [1] or electron-energy-loss spectroscopy (EELS) [2]. In recent years, a new method, photon-induced near-field electron microscopy (PINEM) [3], has been established in ultrafast transmission electron microscopes, enabling quantitative measurements of near-field strengths [4]. In this new approach, ultrashort laser pulses (picosecond to femtosecond pulse duration) excite specific spectral modes of a sample, and pulses of high-energy electrons interacting with the associated near-fields experience stimulated energy gain and loss. In contrast to EELS, which probes the intrinsic properties of a nano-optical system with a spectral resolution limited by the electron microscope used (sub-100 meV with a monochromator), PINEM provides an access to the extrinsic optical modes with a spectral resolution limited only by the spectral bandwidth of the laser. This is achieved by electron-energy gain spectroscopy (EEGS), where the near-field strengths are measured for different laser wavelengths [5]. This makes PINEM and EEGS powerful additions to the electron microscopy toolbox.

In this talk I will give an overview of our efforts in the Göttingen UTEM project [6] to exploit these new capabilities of ultrafast transmission electron microscopy for mapping and controlling optical near-fields in metallic and dielectric nano- and microstructures [7,8]. I will present recent studies on mode selective reconstruction of plasmonic near fields [9], measurements of the time evolution of such near-fields with attosecond precision and illustrate how we intend to use these near fields for atomic gas excitation and for probing nonlinear optical excitations.

References

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