Ultrafast transmission electron microscopy with nanoscale photocathodes

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Ultrafast transmission electron microscopy (UTEM) is a laser pump/electron probe technique which enables the investigation of ultrafast processes on nanometer length scales. In UTEM, a pulsed electron beam with sub-picosecond pulse duration is employed to stroboscopically probe ultrafast laser-driven dynamics with the imaging and diffraction capabilities of electron microscopy. The potential of this approach crucially depends on the implementation of bright laser-driven electron source within the constraints of a functional electron microscope.
Here, we present the development of an advanced UTEM source based on photoemission from a sharp needle-shaped cathode, which is adapted to a commercial transmission electron microscope. Within this setup, we experimentally determined the achievable spatial resolution, the electron beam spot size and the intrinsic beam emittance. The temporal structure of the probing electron bunch is characterized by inelastic electron scattering from laser-driven optical near-fields. Based on these electron bunch properties, we demonstrate the broad usability of the Göttingen UTEM instrument for time-resolved electron imaging, diffraction and spectroscopy, and we discuss future research directions.