PHYSIKALISCHES KOLLOQUIUM

EINLADUNG

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speaks

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about

Time-resolved transmission electron microscopy: Probing ultrafast processes on nanometer length scales

Ultrafast transmission electron microscopy (UTEM) is a promising technique for the investigation of ultrafast dynamics with nanoscale spatial resolution [1]. In UTEM, a pulsed electron beam with sub-picosecond bunch duration is utilized to stroboscopically probe laser-induced processes, using the imaging and diffraction capabilities of electron microscopy. While this approach was already pioneered in the 1980s [2], and greatly improved in the last decade [3], its potential crucially depends on the spatial beam properties achievable for ultrashort electron pulses.

Based on the recent progress in the construction of coherent pulsed electron sources, we present the first implementation of a 3rd-generation UTEM instrument. Utilizing localized photoemission from a nanoscale needle photocathode, we obtain highly coherent electron pulses with electron focal spot sizes on the sample of a few nanometers and electron pulse durations of about 300 fs.

In this colloquium, we will present several applications enabled by the advantageous beam properties in the Göttingen UTEM instrument: (1) Using collimated femtosecond electron pulses, we demonstrate real-space Lorentz imaging of magnetic vortex structures in a nano-patterned permalloy film, opening up the investigation of ultrafast magnetism in UTEM. (2) With electron pulses focused to a few nanometers, we locally probe laser-induced acoustic phonons, originating from the edge of a single-crystalline graphite flake. (3) We demonstrate optical phase modulation of free electron beams in laser-driven near-fields, yielding coherent superpositions of electron momentum states [4]. Spatially and temporally tailored, localized light fields allow for a coherent optical control of the three-dimensional phase structure of free electron wavepackets, with applications in metrology and attosecond spectroscopy.

Finally, I will discuss future research directions of 3rd-generation UTEM instruments, using their broad capabilities for time-resolved electron imaging, diffraction and spectroscopy.

[1] A. H. Zewail, A. H. Four-dimensional electron microscopy. *Science* **328,** 187–93 (2010).
[2] O. Bostanjoglo, *Adv. Imaging Electron Phys.* **121**,1 (2002).
[3] D. J. Flannigan, A. H. Zewail. 4D Electron Microscopy: Principles and Applications. *Acc. Chem. Res.* **45**, 1828−1839 (2012).
[4] A. Feist, K. E. Echternkamp, J. Schauss, S. V. Yalunin, S. Schäfer, C. Ropers. Quantum coherent optical phase modulation in an ultrafast transmission electron microscope. *Nature* **521,** 200–203 (2015).

All interested persons are cordially invited.
Gez. Prof. Dr. Christoph Lienau, Prof. Dr. Niklas Nilius, Prof. Dr. Martin Holthaus