Kolloquium Energie- und Halbleiterforschung

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Dienstag, 14.11.2017, 16.15 Uhr in W0 0-001

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Ultrafast Nanoscale Dynamics

Ultrafast nanoscale dynamics probed by time-resolved transmission electron microscopy

Ultrafast transmission electron microscopy (UTEM) is a promising technique which provides a unique experimental access to ultrafast dynamics on nanometer length scales [1]. In UTEM, a pulsed electron beam with sub-picosecond bunch duration is utilized to stroboscopically probe optically triggered processes. Dynamics in structural, electronic and spin degrees of freedom are generally accessible in UTEM by utilizing the versatile imaging and diffraction capabilities of state-of-the-art electron microscopes. However, up to now, the broad applicability of UTEM was limited by the coherence properties of available pulsed electron sources.
In recent years, we developed nanoscale laser-driven photocathodes, which allow for the generation of electron pulses with largely improved coherence properties. With this approach, we achieve, at the sample position, electron focal spot sizes down to below one nanometer and pulse durations of about 200 fs [2].
High-coherence ultrafast electron probes now enable the investigation of fast processes in nanostructured systems and at interfaces. I will present first applications, including the coherent phase modulation of freeelectron states in optical near-fields [3], which provides a novel approach for plasmon imaging, electron-light interferometry [4], and the optically- induced structuring of electron pulses into attosecond electron pulse trains [5]. An overview on our current developments will be given, with a focus on ultrafast nanoscale mapping of strain tensor fields [6] and nanoscale magnetic processes [7,8]. Finally, I will present some of the next development steps envisioned in the Oldenburg UTEM lab and summarize our future research directions.

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[8] N. Rubiano da Silva, M. Möller, A. Feist, H. Ulrichs, C. Ropers, S. Schäfer, Nanoscale mapping of ultrafast magnetization dynamics with femtosecond Lorentz microscopy, submitted, arXiv:1710.03307.