Instrumental developments in ultrafast transmission electron microscopy

Alexander Schröder[1,2], Christopher Rathje[2], Niklas Müller[1,2], Jonathan Weber[1,2], Sascha Schäfer[1,2,3]

[1] Institute of Physics, University of Oldenburg, Oldenburg, Germany
[2] Department of Physics, University of Regensburg, Regensburg, Germany
[3] Regensburg Center for Ultrafast Nanoscopy, University of Regensburg, Regensburg, Germany

Time-resolved variants of transmission electron microscopy have started to provide an unparalleled view into the fast and ultrafast dynamics of solid-state nanostructures (see for example [1-4]). A crucial instrumental pre-requisite for constructing the next generation of time-resolved electron microscopes is the development of novel pulsed electron sources, fast detectors and versatile sample excitation schemes. In this talk, I will summarize our recent developments and characterization of a laser-driven cold-field emitter source (in collaboration with JEOL Ltd.), including the achieved electron pulse duration, spectral width, and electron beam brightness. A first application of these high-brightness electron pulses for the imaging of wavelength-dependent optical near-fields in transition metal dichalcogenides will be presented.

In the second part, I will focus on the application of event-based TimePix3 electron detectors in fast electron imaging. Using a neural network approach trained by experimental data with synchronized femtosecond electron pulses, we can improve the time-resolution of the TimePix3 detector utilizing the intrinsic correlations within event clusters [5]. Finally, as two applications for event-based electron imaging, I will discuss the excitation and phase-resolved mapping of nonlinear Duffing modes in a silicon membrane, demonstrating quality factors exceeding 10^5, and the time-resolved Lorentz imaging of photoinduced charging in metal nanoparticles [6].

References

[1] A. Feist, K. E. Echternkamp, J. Schauss, S. V. Yalunin, S. Schäfer, C. Ropers, Nature 521, 200–203 (2015).
[2] A. Feist, N. Bach, N. Rubiano da Silva, Th. Danz, M. Möller, K. E. Priebe, T. Domröse, J. G. Gatzmann, S. Rost, J. Schauss, S. Strauch, R. Bormann, M. Sivis, S. Schäfer, C. Ropers, Ultramicroscopy 176, 63–73 (2017).
[3] A. Feist, N. Rubiano da Silva, W. Liang, C. Ropers, S. Schäfer, Structural Dynamics 5, 014302 (2018).
[4] N. Rubiano da Silva, M. Möller, A. Feist, H. Ulrichs, C. Ropers, S. Schäfer, Phys. Rev. X 8, 031052 (2018).
[5] A. Schröder, Chr. Rathje, L. van Velzen, M. Kelder, S. Schäfer, Ultramicroscopy 256, 113881 (2024).
[6] J. Weber, S. Schäfer, arXiv:2308.10272 (2023).