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Free-Electron Quantum State Reconstruction by SQUIRRELS

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Programmable phase-shaping of free-electron wavefunctions is expected to significantly enhance the capabilities of electron microscopy. In particular, temporal shaping by optical fields promises time-resolved electron diffraction and imaging with attosecond precision.

Here, we demonstrate the generation, coherent control and characterization of free-electron momentum superposition states by optical phase-modulation using multiple near-fields [1-3]. Our recently developed "SQUIRRELS"algorithm (Spectral QUantum Interference for the Regularized Reconstruction of free-ELectron States) reconstructs the free-electron Wigner function from experimental spectrograms, which are obtained by recording electron energy spectra for a range of relative phase delays between two optical near-fields, either at different frequencies or at spatially separated regions along the electron beam path.

Free-space propagation over a few millimetre distance leads to the formation of an attosecond electron pulse train by dispersive reshaping of the electron density [1]. The temporal shape of the electron quantum state is contained in the Wigner function, and we successfully applied SQUIRRELS to experimentally demonstrate the generation of electron density spikes of only 655 attosecond duration (full-width at half-maximum) [3].

[1] A. Feist et al., Nature 521, 200-203 (2015)
[2] K. Echternkamp et al., Nature Physics 12, 1000-1004 (2016)
[3] K. Priebe et al., Nature Photonics 11, 793-797 (2017)

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