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Phase shaping of the free-electrons wavefunction with fs-laser pulses in an RF-cavity-based UTEM

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Interest is growing around developing techniques to shape the wavefunction of electrons.
We propose to use the time-dependent electromagnetic fields of ultrashort laser pulses to control the quantum-mechanical phase of electron pulses. We present a theoretical model showing that the ponderomotive interaction between electrons and a high-intensity strongly-focused laser beam can be used to develop a non-material phase-shaper. This contribution also a model of the interaction, in which we derive a quantal phase from the classical action integral along the relativistic classical path. Results extend to realistic configurations of the electromagnetic fields. Our model proves that a phase-shift of $\pi/2$ can be achieved by focusing the laser pulses produced by a fs-oscillator to a waist size of 2⊠. Any phase shift can be induced by suitably varying the laser power and spot size.
An application of the method is the development of light-based phase-plates for phase contrast imaging of weakly scattering specimens. A light-based phase-plate ensures a stable, tunable phase shift, helping overcome material device limitations.
We provide details on the experimental realization of the device in an RF-cavity-based ultrafast transmission electron microscope that has a 75 MHz fs-oscillator integrated into its setup.

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