Coherent Phase Control of Ultrashort Electron Pulses by Traveling Optical Waves

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In recent years, several studies explored the optical manipulation of free-electron beams, including the imaging of complex plasmonic fields [1-3], efficient free-space acceleration [4] and attosecond bunching of electrons [5-7]. Addressing the transverse beam direction, a Zernicke phase plate was demonstrated [8] and elastic electron diffraction at standing light waves was observed in the Kapitza-Dirac effect [9]. However, precise optical phase control of free-electron wave packets in space and time remains challenging.

Here, we demonstrate the quantized transfer of optical energy and transverse momentum to a high-coherence electron beam. In an ultrafast transmission electron microscope (UTEM) [10], photoemitted low-emittance ultrashort electron pulses are collimated to a micrometre- scale transverse coherence length and transmitted through a laser-illuminated graphite thin film (Fig. 1a). The imprinted three-dimensional sinusoidal phase modulation yields a coherent superposition of correlated energy-momentum ladder states [11], which is mapped by its far- field scattering distribution (Fig. 1b).Hereby, we demonstrate the coherent control of free- electron beams by spatially structured optical phase modulation. Notably, this constitutes a coherent inelastic beam splitter for free-electron beams.

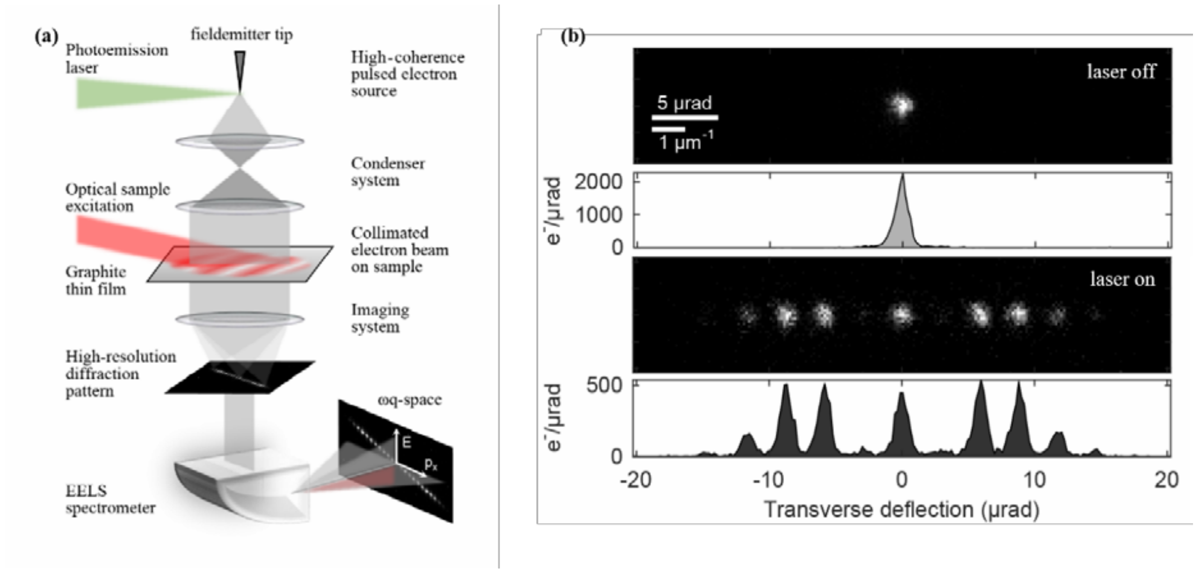

Figure 1: (a) High-coherence ultrashort electron pulses are diffracted from a traveling wave optical phase grating and their scattering distributions is analyzed in reciprocal (transverse) and in energy (longitudinal) space. (b) High-dispersion diffraction images acquired by counted electron imaging using a direct electron detection camera (Direct Electron DE-16).

References:

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