Transverse Shaping of Electron Beams Using Light

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Light–matter coupling at the quantum level offers a direct handle to tailor free-electron wavefunctions, and electron beam shaping with structured light has been demonstrated as a proof of concept in [1]. In this contribution, we develop a light-based framework for aberration correction in ultrafast electron optics using pulsed ponderomotive lenses. We present two theoretical routes: (i) spherical aberration correction by imprinting a tailored transverse phase through interaction with a modified Laguerre–Gaussian (LG) laser beam [2], and (ii) chromatic aberration correction in which a time-dependent optical potential, synchronized to a chirped electron pulse, compensates the energy-dependent focal shift [3]. We conclude with our experimental demonstration of a light-based electron aberration corrector [4], establishing optically programmable correction as a practical route toward higher resolution and simpler ultrafast electron microscopes.

References

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[2] Chirita Mihaila, M. C., & Kozák, M., *Optics Express*, 33(1) (2025) 758–775.

[3] Chirita Mihaila, M. C., Laštovičková Streshkova, N., & Kozák, M., *Physical Review Letters*, 134(20) (2025) 203802.

[4] Chirita Mihaila, M. C., Koutenský, P., Moriová, K., & Kozák, M., *Nature Photonics*, 19(12) (2025) 1309–1314.

Figures

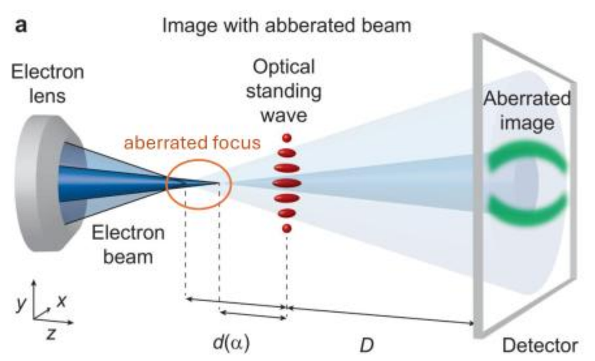

Figure 1: In the presence of spherical aberration, the focal position depends on the rays' convergence angle, so different angular components of the beam focus at different distances (aberrated focus). This angle-dependent focusing distorts a point-projection image of an optical standing wave: fringes that are uniformly spaced in the field appear curved at the detector because the magnification varies with the convergence semi-angle α (image adapted from [4]).

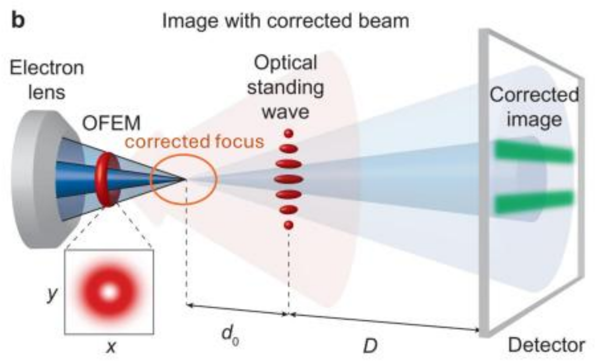

Figure 2: A LG beam of charge 1 (see inset) applied upstream of the electron focus implements an optical field element that compensates spherical aberration. When the corrector is applied, electrons are refocused to a common focal plane, restoring the point-projection fringes to straight, uniformly spaced lines. As a result, the separation between the geometric focus and the standing-wave interaction region becomes independent of the electron semi-angle (image adapted from [4]).