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Electron Beam Aberration Correction Using Optical Fields

Andrea Konecna and F. Javier Garcia de Abajo

ICFO - The Institute of Photonic Sciences, Castelldefels, Catalonia, Spain

Over last decades, electron microscopy has become very powerful and versatile technique for nano- or atomic-scale imaging and spectroscopy [1]. Major advancements and outstanding capabilities have been made possible thanks better spatial and temporal control over the amplitude and phase of the wave function that characterizes the fast electrons used as sample probes. Control over the beam shape is commonly achieved by means of complex arrangements of magneto- and electrostatic electron lenses that enable sub-Ångstrom focusing and beam scanning, as well as correcting aberrations of electron optics. The phase of the electron wave function can be additionally modified by introducing static phase plates.

We envision an alternative to traditional electron-optics elements emerging by using optically-driven phase plates and enabling dynamical shaping of electron-beam wave functions both in space and time. This approach capitalizes recent experimental demonstrations of wave function control through optical near fields [2-4]. The electron-light interaction can in principle allow us to generate arbitrary electron beam shapes; as an application with high potential for improving the resolution of electron microscopes, we employ it here to correct for aberrations of standard electro- or magneto-static lenses used in current setups.

We demonstrate aberration correction via the interaction of the electron wave function with suitably profiled optical fields. We illustrate this concept by focusing on primary spherical aberration, which due to rotational invariance typically requires complex and expensive aberration correctors. Our work suggests that an optical corrector can help to significantly improve the focal spot and beam profile over the aberrated configuration, and that it can be in principle used to eliminate any undesired beam distortions in both standard and ultrafast (scanning) transmission electron microscopy. Optical aberration correctors could offer better versatility and compactness with respect to traditional corrector designs, and we foresee that they could open a new era of electron microscopy both in aberration correction and in the generation of on-demand electron beams [5].

References

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