Super-oscillating Electron Wave Functions with Sub-diffraction Spots

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Almost one and a half centuries ago, Ernst Abbe and shortly after Lord Rayleigh derived the minimum, diffraction-limited spot radius of an optical lens to be $1.22\lambda/(2\sin\alpha)$, where λ is the wavelength and α is the semi-angle of the beam's convergence cone. In this work [1], we show how to overcome this limit and realize the first super-oscillating massive-particle wave function, which has an arbitrarily small central spot that is much smaller than the Abbe-Rayleigh limit and theoretically even smaller than the de Broglie wavelength. We experimentally demonstrate an electron central spot of radius 106 pm, which is more than two times smaller than the diffraction limit of the experimental setup used. Such an electronic wave function can serve as a probe in scanning transmission electron microscopy, providing improved imaging of objects at the sub-Ångström scale.

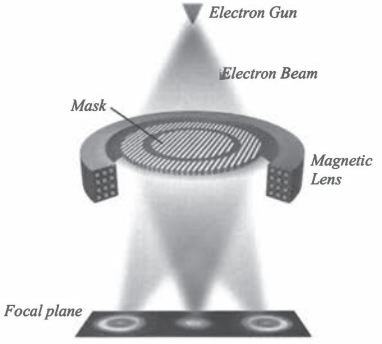

Figure 1. Schematic description of super-oscillating electron wave function generation. The desired wave function is created in the +1 and -1 diffraction orders.

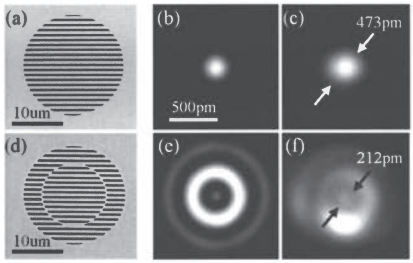

Figure 2. SEM images of binary amplitude masks (a,d), shown alongside simulations (b,e) and experimental results (c,f) for a circular aperture and super-oscillation masks of diameter 20 μm and α=5.2 mrad. The measurements of super-oscillating electron beam (f) exhibit central hot-spots of radius and 106 pm, compared to diffraction limit Airy disk radii of 235 pm.

References

[1] Roei Remez, Yuval Tsur, Peng-Han Lu, Amir H. Tavabi, Rafal E. Dunin-Borkowski and Ady Arie, "Super-oscillating Electron Wave Functions with Sub-diffraction Spots", arXiv, 1604.05929 (2016).