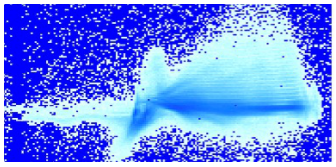

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Self-coherence and the wave/particle duality of electrons

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Apart from being an indispensable tool in material sciences of outstanding spatiotemporal resolution that reaches towards 1 Å at 1 ps [1,2], electron microscopy is uniquely suited to study basic quantum mechanical aspects because the wave/particle duality of electrons can be seen as a window into quantum physics [3]. This contribution experimentally validates a model of electron self-interferences. They originate from coherent-inelastic scattering processes with energy loss $\Delta E = \hbar/2/\Delta t$ at the Heisenberg limit, which marks a boundary between the classical mechanics of particle physics and the quantum mechanics of wave functions. Thereby, wave packages of finite widths are created with 0.5 radian decoherence phase that are characterized by a self-coherence length ls. A method is described that allows measuring ls and thereby self-coherence by the extension of an evanescent field at sample/vacuum interfaces. It is caused by the localization of wave functions upon pulse-like interaction of single electron waves with matter. Further, self-interferences of single matter waves rather than ensemble interferences of many electrons determine the occurrence of lattice fringes in high resolution images if energy losses do not exceed ≈ 100 eV, where the ability is lost to coherently illuminate crystal unit cells. At larger energy losses the wave packages are comparable to the size of atoms and even their constituents and are perceived as particles. The description of electron scattering in a wave picture is mandatory because decoherence determines the measured self-coherence length but does not exist in particle views, which is why a collapse of wave functions upon detection is often postulated.

[1] Kisielowski C, Specht P, Rozeveld SJ, Kang J, Fielitz AJ, D. Barton, Salazar AC, Oscar D. Dubon OD, Van Dyck, D & Yancey DF (2021). Microanalysis 27, 1420-1430.
[2] Chen FR, Van Dyck D, Kisielowski C, Hansen LP, Barton B & Helveg S (2021). Nature communications 12, 5007.
[3] Kisielowski C, Specht P, Helveg S, Chen FR, Freitag B, Jinschek JR & Van Dyck, D (2023). Nanomaterials 13, 971.

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