Self accelerating electron Airy beams

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April 18, 2012

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In the framework of quantum mechanics, Berry and Balazs found a unique solution to the one dimensional Schrödinger equation1 of a massive free particle, shaped in the form of the Airy function, which preserves its shape despite the spectral energy dispersion of the particle wave function. Remarkably, this wave packet evolves in time with a constant acceleration. Nearly 30 years later, this concept was implemented by Siviloglou and co-workers in the optical domain, whereby self-bending and shape preserving optical Airy beams have been realized2. Since then, self accelerating beams have attracted appreciable interest, and new applications have been proposed for these beams, including micro-particle manipulation3, generation of plasma channels in air and water4 and applications in lasers5–6 and in nonlinear optics7. However, all the experimental realizations so far relied on the wave-packet of zero mass photons. Here we report the first generation and observation of the Airy wave packet1 of free electrons, or electron Airy beams, which are neither mediated nor coupled to photons. These wave packets are shape-preserving matter waves, as they exhibit self acceleration without applying any external force. Like its photonic counterpart, the electronic beam found to have the ability to self-heal8 and to return to its original shape after passing an obstacle. The electronic Airy beam is generated by diffraction of electrons through a nano-scale hologram9–10 that adds cubic phase modulation in the transverse plane. The entire measurement is performed inside a transmission electron microscope. This electronic beam shaping technique enables to extend recently found optical schemes to matter waves, so that they can be engineered with various profiles and self-accelerate along any arbitrary curved trajectory11. This also opens up new possibilities for shaping and manipulating Airy beams by magnetic and electric fields12,13.

References


Figure 1 | (color online). (a) A schematic representation of the generation of electron Airy beams. Electrons are emitted from a field emission gun of the TEM. A spatially coherent beam of electrons is transmitted through a nano fabricated hologram, which adds transverse cubic phase modulation to the electronic beam. It is then focused by a magnetic lens. Electron Airy wave packet is formed in the back focal and recorded as it propagates in space. The Airy electron beam is shape preserving, self accelerating (without an external force) matter wave. When electron Airy beam bumped into an obstacle it self-heals and restores to it's original shape. (b, c) TEM image of the nano scale grating fabricated by a focused ion beam imprinting on Silicon-nitride membrane substrate. (b) Hologram that generates 2D Airy grating on a spatial carrier frequency (c) Mask that generates 2D Airy beam without a carrier. (e, f) Experimental transverse profile photographs displaying 2D and 1D electron Airy beam generated at the back focal plane. .