Electron-enabled Nanoparticle Diffraction

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Modern matter-wave experiments cover a broad mass range from single electrons to molecules and nanoclusters consisting of hundreds or even thousands of atoms. Levitated optomechanics promises to become a platform for matter waves of nanoparticles weighing a billion atomic mass units. I present a scheme for diffracting a massive nanoparticle at its own crystal lattice with help of electrons: when a single electron undergoes Bragg diffraction at a free-falling nanoparticle, momentum conservation implies that the superposition of Bragg momenta is imprinted onto the relative coordinate between electron and nanoparticle, which entangles their wave functions. By imaging the electron interferogram, one maps the nanoparticle state onto a superposition of Bragg momenta, as if it was diffracted by its own lattice. This results in a coherent momentum splitting 1000 times greater than what is achievable with conventional standing-wave gratings, opening new possibilities for experimental tests of fundamental physics at the quantum-classical boundary.