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Correction of the “Deterministic” Part of Space-Charge Interaction in Momentum Microscopy of Charged Particles

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Ultrahigh-brightness sources like (X-ray) free electron lasers (XFELs), but also table-top higher harmonics sources with their inherent time structure in the range of few femtoseconds offer fascinating experimental possibilities for spectromicroscopy. Unfortunately, electron imaging methods like *Photoemission Electron Microscopy* (PEEM) or *Photoelectron Momentum Microscopy* [1] at such sources are facing a dramatic loss in performance due to the space-charge problem. Coulomb interaction in the beam can induce prohibitively large energy broadenings ΔE of hundreds to thousands of eV. In this contribution we present a theoretical study of the space charge effect in a special type of electron microscopy and propose a way to eliminate part of the effect by exploiting its “deterministic” nature. The Coulomb interaction in the beam can be separated into two parts. The first, integral part reflects the charge distribution and its temporal evolution; this part leads to a rotation of the distribution in six-dimensional phase-space. This is referred to as *deterministic* part of the space charge interaction. The second part describes the individual electron-electron scattering processes that are *stochastic* and lead to irreversible heating of the electron beam. We have considered the space-charge effect for the case of a momentum microscope in the hard X-ray range, based on simulations with the General Particle Tracer (GPT) code [2]. We find that momentum microscopy offers a pathway for a correction of the deterministic part of the Coulomb interaction, since the instrument detects the k||- distribution in an imaging microscope column. For XFEL applications in the hard X-ray range (i.e. photon energies in the range of 5-10 keV) a strong immersion field of 5 MV/m accelerates and widens the electron beam very rapidly, in order to reduce Coulomb repulsion. The correction makes use of the fact that the best-fit line of the electron distribution in an energy-vs-radius plot for the electron beam is strongly tilted. This line can thus be used for a re-normalization of the measured kinetic energies. A calculation for a model distribution assuming a 5 keV core-level signal in the presence of a 10 times more intense low-energy signal from the secondary electron cascade predicts a gain in energy-resolution by almost an order of magnitude. In practice, energy discrimination can exploit concepts of time-of-flight electron microscopy [3] using a delayline image detector. Furthermore, the method allows implementing an imaging spin filter into the microscope column [4, 5]. The results are important for other spectroscopic methods dealing with charged particles at high-brightness femtosecond-sources

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