High-quality, high-repetition rate, ultrashort electron bunches generated with an RF-cavity

HIGH-QUALITY, HIGH-REPETITION RATE, ULTRASHORT ELECTRON BUNCHES GENERATED WITH AN RF-CAVITY

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In collaboration with FEI Company, we are studying the possibility of using microwave TM110 streak cavities in combination with a slit, to chop a continuous electron beam into 100 fs electron bunches. We have shown that this can be done with minimal increase in transverse emittance and longitudinal energy spread. Furthermore, these bunches are created at a repetition rate of 3 GHz. Accurately synchronized to a mode-locked laser system, this allows for high-frequency pump-probe experiments with the beam quality of high-end electron microscopes.

At Eindhoven University of Technology, we will soon implement such a cavity in a 200 keV Tecnai, which should result in high-frequency ultrafast (S)TEM with sub-ps time-resolution while maintaining the atomic spatial resolution of the TEM.

HOLOGRAPHIC IMAGING AND OPTICAL SECTIONING IN THE ABERRATION-CORRECTED STEM

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The correction of spherical aberration enables efficient holographic imaging in the scanning transmission electron microscope (STEM) if the energy width of the incident electron beam is sufficiently reduced. Holographic imaging implies that the Fourier transform of the image is linearly related with the elastic scattering amplitude of the object. Effective optical sectioning can be realized in the aberration-corrected STEM by employing “holographic” phase-contrast imaging. This imaging mode requires a segmented bright-field detector and a Fresnel phase plate which can be formed with a sufficient degree of accuracy by adjusting appropriately the third-order spherical aberration and the defocus of the corrected objective lens. By subtracting the signals of the annular detector segments covering the region of destructive interference of the scattered wave with the non-scattered wave from that recorded by the annular segments covering the regions of constructive interference, we obtain a pure phase contrast image which may be conceived as a holographic image because the terms of the intensity which depend quadratic on the scattering amplitude cancel out. Theoretical results will be presented which demonstrate the feasibility of the proposed method. In particular, the method enables the transfer of spatial frequencies over a large range which exceeds significantly that of conventional phase contrast imaging.

HIGH-BRIGHTNESS BEAMS FOR ULTRAFAST MICRODIFFRACTION AND IMAGING

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Currently the ultrafast electron diffraction (UED) with 10^3-10^5 electrons per pulse has achieved sub-picosecond temporal resolution and atomic resolution. However, direct ultrafast imaging of a nanometer scale specimen through coherent single-particle diffraction has not been achieved largely due to insufficient intensity when tuned to a coherence length that matches the size of the specimen under the projected phase space density. A source-limited performance can be delivered by proper and flexible electron optical designs to rotate the phase space so as to optimize the performance limited only to the Liouvilles theorem constraint, which is ultimately subject to the brightness of the electron sources preserved during the production of the electron beam. Utilizing a recently implemented high-brightness electron source under a DC-gun linear acceleration field, we test the performance of such a beamline for ultrafast electron microdiffraction and coherence imaging. We demonstrate the feasibilities of single-shot mirodiffraction on a single micrometer-sized domain in Highly Ordered Pyrolytic Graphite (HOPG) and coherent diffractive imaging of 10 nm scale charge-ordered domain structures in single-crystal complex materials, as qualified by the measured brightness at the sample plane. These initial results show that source-limited performance even from a sub-relativistic electron beamline can drastically improve the current performance of ultrafast electron imaging and diffraction.
