Multi-purpose Ultrafast Microscopy with a Compact High-Harmonic Source

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We report the design of a flexible beamline for Ultrafast Ptychography capable of full-field, quantitative microscopy with a compact EUV High-order Harmonic Generation (HHG) source, supporting wavelength-scale spatial resolutions.

Recent advances in Coherent X-ray Microscopy opened new exciting avenues for 2D and 3D imaging, allowing to visualize deformations in batteries and solar cells during charge migration, magnetic topologies, catalysts pollution, transistors fabrication defects, neuron activity. These emerging applications open new routes towards the understanding of light-activated nanoscale function in matter, complementing the possibilities offered by optical and electron-based microscopy methods. However, the expansion of this technology is hindered by its limited accessibility.

We developed an innovative EUV ultrafast compact microscope with 13nm and 30nm HHG beams, characterized by high spatial resolution and high throughput, while retaining flexibility and facility-scale beam diagnostics.

Ultrafast microscopy is carried out with a technique for diffractive imaging called Ptychography [1], where multiple diffraction patterns from overlapping fields of view are processed by iterative algorithms [2, 3] to reconstruct the real-space image of the sample.

The ultrafast multipurpose microscope design was carried out by in depth analysis of EUV source size, divergence, and high-order aberrations effects through ray tracing simulations, using the open-source ShadowOui through the OrAnge SYnchrotron Suite (OASYS). It is characterized by a simple and robust off axis *z*-fold XUV focusing scheme, to filter the probe EUV beam to a narrow bandwidth and to focus it onto the sample, providing a geometry demagnification of 10. Accounting for a $1/e^2$ diameter between 30-50μm and a divergence in the range 0.7-2mrad at the EUV beam generation point, we obtain a variable 4 - 10μm beam diameter at the image plane.

The microscope has full in-vacuum automation capabilities, flexibility in experimental geometry (transmission or reflection). The automated motion of the detector allows for the flexible selection of Numerical Apertures (NA) from 0.04-0.6, supporting wavelength-scale spatial resolutions, with ≈40fs time resolution. The ultrafast microscope is equipped with an in-line intensity monitor and a spectrometer capable of recording I_0 beam data and monitoring the spectral quality of the probe beam every 100 pulses at 5kHz (KMLabs, 35fs, 785nm, 3mJ).

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