Multi-modal tomography with a hard X-ray nanoprobe

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Designed for quantitative three dimensional characterization of the morphology and the elemental composition of specimens at the nanoscale, the ID16A-NI beamline of the ESRF produces currently the world's brightest nanofocus. With the endstation located at 185 m from the source, the beamline is optimized for coherent hard X-ray imaging and X-ray fluorescence microscopy. It offers extreme focusing down to 13 nm with a very high photon flux (up to 10^{12} photons/s at ΔE/E$\sim$1%) [1]. The selected energies, 17 keV and 33.6 keV, are well suited for applications in biomedicine, materials science and nanotechnology. The two coherent imaging techniques, X-ray holographic [2] and ptychographic [3] tomography, provide the distribution of the electron density at length scales ranging from $\sim$130 nm down to $\sim$10 nm, while keeping a relatively large field of view. Complementary, X-ray fluorescence microscopy delivers label-free trace element quantification with detection limit down to subppm level [4].

The instrument attains its unique properties by combining highly performing nanofocusing optics (fixed curvature multilayer coated KB optics) with a carefully designed mechanical device for stable sample positioning and accurate scanning. Apart from a high efficiency and large numerical aperture, the optics is compatible with a large energy bandwidth and creates a relatively large cone beam without central beam stop and order selecting aperture. This combination is critical for efficient holographic tomography and X-ray fluorescence analysis. On the downside, despite the use of state-of-the-art substrates, the optics introduces strong wavefront inhomogeneities. A specific holographic acquisition scheme allows remedying this limitation. Alternatively, the inhomogeneities can be exploited as a form of structured illumination in near-field ptychography.

The samples are measured in vacuum and correlative phase contrast – fluorescence microscopy is feasible. Furthermore, the beamline has been recently upgraded to perform both the fluorescence and phase contrast measurements under cryogenic conditions to preserve the biological samples close to their native hydrated state while performing nanoscale imaging. The cutting edge capabilities of this instrument enable unprecedented research studies in biomedicine, materials science, environmental sciences and nanotechnology, thus opening new scientific frontiers. We present the specifications and the performance evaluation of the beamline together with unique experimental results from several fields.

References

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