Coherent X-ray imaging at ID16A: status and plans

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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. The instrument offers exceptional focusing down to 13 nm with a very high photon flux (up to 10^{12} photons/s at $\Delta E/E$~1%) [1]. The selected energies, 17 keV and 33.6 keV, are well suited for applications in biomedicine, materials science and nanotechnology. Two coherent imaging techniques, X-ray holographic [2-4] and ptychographic [5-6] tomography, provide the electron density distribution at length scales ranging from ~130 nm down to ~10 nm, while keeping a relatively large field of view. Complementary, X-ray fluorescence microscopy delivers label-free, highly efficient trace element quantification [7].

The instrument attains its unique properties by combining efficient nanofocusing optics (multilayer coated fixed curvature Kirkpatrick-Baez mirrors) with a carefully designed mechanical device for stable sample positioning and accurate scanning. The optics introduce strong wavefront inhomogeneities, which are handled by a specific holographic acquisition scheme [8]. Alternatively, the inhomogeneities can be exploited as a form of structured illumination in near-field ptychography [9]. The samples are measured in vacuum and the system enables correlative phase contrast – fluorescence microscopy [10-11]. All measurements can be performed under cryogenic conditions to preserve the biological samples close to their native hydrated state and reduce radiation damage. Recently, complementary cryo correlative light microscopy has become available, providing unambiguous identification of specific organelles. The cutting-edge capabilities of this instrument enable unprecedented research studies in biomedicine, materials science, and nanotechnology, thus opening new scientific frontiers.

The new ESRF source is expected to provide up to two orders of magnitude increase in brilliance and coherent fraction of the X-ray beams. This 'Extremely Brilliant Source' will be ideally suited for ultrafast, nanoscale, coherent imaging applications. In this context, we will present the current achievements and possible future directions of the beamline.

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