Computed phase stereo lensless X-ray imaging

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At a nanometer scale, the ability to have access to the 3D structural content of systems is critical in different fields of study. Most imaging techniques provide, however, only bi-dimensional projections along the imaging axis requiring, for a 3D reconstruction, several image recordings [1], extremely high radiation doses [2] and long acquisition times [3]. Moreover, most of the systems entail non-reversible processes or are highly sensitive to radiation damage, requiring single-shot experiments [4]. We propose a technique, which allows retrieving three-dimensional amplitude and phase information from a single acquisition, by focusing two synchronized soft X-ray coherent beams with a calibrated stereo angle, on a nanoscale sample. From the two coherent diffractive imaging (CDI) reconstructions, a 3D reconstruction of the sample is achieved from the computation of quantitative disparity maps. We extend our demonstration to phase contrast X-ray stereo imaging and reveal hidden 3D features of a sample [5].

We developed a simple setup composed by a grazing incidence prism and two silicon mirrors to separate into two sub-beams the 33rd harmonic of Argon, focused with an off-axis parabola. These synchronized dual beams are focused on a sample and the respective diffraction patterns recorded simultaneously on a CCD camera. Two stereo views, Fig. 1a and 1b, are this way achieved after phase retrieval. From the CDI images, the depth information of the sample is extracted through a difference map calculation. A quantitative 3D representation of the sample is, then, computed with nanometer resolution, Fig. 1c.

![Fig. 1. a-b, 2D amplitude reconstructions of the sample from the two stereo views. c, 3D reconstruction of the experimental sample. d, 3D reconstruction of a simulated phase sample.](image)

As the sample is a pure amplitude sample, there is a lack of information in the parts where the cross is hidden behind the membrane, responsible for the artefacts of Fig. 1c. By including the information on the phase we have access to more details and reach a more reliable reconstruction, Fig. 1d. The versatility of the proposed method makes it suitable for any HHG, FEL or synchrotron beamline and, using coherent hard-X-rays, paves the way to single-shot 3D imaging of high-impact systems, ranging from structure determination of biological samples to time-resolved dynamics of 3D physical processes.

References