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High sensitivity X-ray phase imaging system based on a Hartmann Wavefront Sensor

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X-ray imaging is an essential tool for non-invasive assessment of various samples, both for biomedical diagnosis and non-destructive testing applications. Many technical approaches have been proposed to enhance the level of information recorded in the X-ray images. When absorption properties are very similar between two components of a sample, it makes it difficult to separate them using X-ray absorption imaging. X-Ray Phase Contrast Imaging (X-PCI) shows great capability to differentiate elements with similar absorption (Bravin, 2013).

We propose a novel, single-exposure X-ray quantitative phase imaging system based on a Hartmann Wavefront sensor (HWS). The system provides high spatial sampling (20µm without magnification) and high sensitivity (~100 nrad) over a 5 to 25 keV energy range. The system can be used to perform tomographic experiments.
Here we present the imaging system (Fig. 1a) installed at the Syrmep beamline at Elettra as well as first images obtained on reference samples. This test sample was composed of four different micro-spheres: Si (480µm in diameter), Al_2O_3 (500µm), quartz (350µm) and soda lime glass (700µm). Each hole in the Hartmann mask generates a bright spot on the camera and the lateral shift of the spot compared to the image without sample is proportional to the deflection generated by the sample. From two acquisitions (with and without sample), both absorption and deflections in the two transverse directions are obtained simultaneously. Since the Hartmann technology is achromatic, it also allows hyperspectral imaging. The figure illustrates the absorption in (1b) and deflections in the X and Y directions (1c and 1d respectively) generated by the samples and measured by the HWS. Our approach provides an alternative to already proposed X-PCI methods. A HWS can be used to discriminate transparent objects. Furthermore, the knowledge of object shapes, when combined to quantitative phase measurements can lead to local density measurements of complex objects, with multiple possible applications in biomedical imaging or material science.

Bravin, A., Coan P. and Suortti, P., X-ray phase-contrast imaging: from pre-clinical applications towards clinics", Phys. Med. Biol. 58, (2013), R1-R35

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