X-ray phase-contrast imaging and metrology using periodic and random wavefront modulators

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In the past years, grating-based [1,2] and more recently speckle-based [3,4] methods have attracted increased interest for X-ray phase-contrast imaging and wavefront sensing. Despite the great potential and rapid development of the two techniques, a number of challenges impede their wider use under more difficult conditions, including the limited spatial resolution for the single-shot mode and the need for a large number of nm-spaced equidistant steps for the scanning mode. We here present a technique that overcomes the main limitations of existing implementations of both X-ray grating- and speckle-based imaging in a unified approach [5]. The proposed Unified Modulated Pattern Analysis (UMPA) can be applied to periodic as well as random reference patterns and is easily adapted to existing setups.

The UMPA approach is based on computationally demodulating the sample-induced modulations of a reference interference pattern produced by a phase modulator (PM) by combining the information from different PM positions to obtain the refraction (horizontal and vertical), absorption and small-angle scattering signals of the sample, as shown for a small flower bud in Fig. 1. The previous requirements on the number and spacing of the PM steps are lifted and the signal sensitivity, spatial resolution and scan time can be flexibly tuned by adjusting the number of steps and the size of the analysis window in the reconstruction.

We expect UMPA to significantly advance the wide implementation of grating- and speckle-based methods for a broad range of applications such as biomedical imaging and metrology.

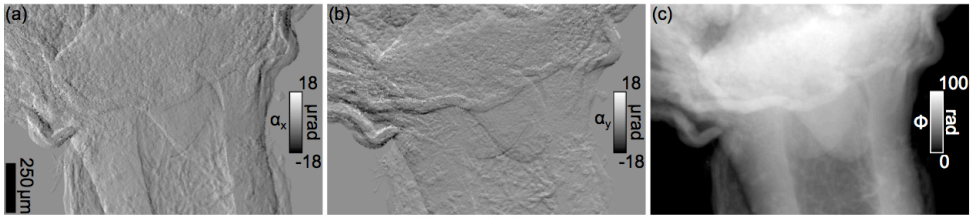

Figure 1: Differential phase signals in (a) the horizontal, (b) the vertical direction, and (c) total integrated phase shift of a flower bud obtained with UMPA at Diamond I13 (energy: 19 keV, 24 steps, window size: 5x5 pixels).

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