Inline edge illumination through sample mask misalignment: a proof of concept

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Summary: Edge illumination (EI) is an X-ray phase contrast imaging setup that allows measuring two additional complimentary contrasts. The setup consists of two absorbing masks with slit shaped apertures. Typically, one of the masks is stepped during scans, complicating the application of EI in inline settings. Current solutions exist, but require either limiting the number of retrieved contrasts or fabricating specialized masks. In this work, an EI scanning method with purposely misaligned conventional EI masks is proposed to enable inline EI. Good agreement is found between conventional and inline EI flatfield parameters, and first inline scan results are presented.

Abstract: Edge illumination (EI) is an X-ray phase contrast imaging setup that allows, apart from the conventional attenuation contrast, retrieval of both the phase and dark field contrasts, the former providing enhanced contrast for low absorbing materials compared to attenuation contrast and the latter providing information on the material microstructure distribution [1]. The EI setup employs two absorbing masks with slit shaped apertures, placed in front of the sample and detector. During an EI scan, so-called illumination curves (ICs) are sampled by laterally stepping the sample mask, hence changing the alignment between sample and detector mask apertures. Comparing sample and flatfield IC fit parameters allows retrieving the attenuation, phase, and dark field contrasts [2].

Current inline EI solutions consist of either performing single-shot acquisitions [3] or using an asymmetric sample mask [4]. The downside of the former is that it only allows for two of the three contrasts to be retrieved, while the latter requires installing new hardware.

The asymmetry of these EI masks refers to the aperture pitch, which is symmetric for a conventional EI mask but changes over consecutive detector columns for an asymmetric mask. This changing sample mask aperture pitch modifies the aperture alignment with the (regularly spaced) detector mask apertures and hence also the measured pixel intensities. Asymmetric sample masks thus allow ICs to be measured directly on the detector, instead of having to step the mask.

The same principle can be applied to conventional EI masks, which are designed to be used at a specific geometric magnification (typically between 1.5 and 2). The projected sample and detector mask aperture pitch only match when the source, masks and detector are placed at positions satisfying the mask design magnification.

Misaligning the sample mask along the optical axis will cause its projected pitch to deviate from that of the detector mask, with the resulting shift in aperture alignment causing an IC profile over the detector columns, as in the asymmetric mask EI setup. Scanning a sample inline across this IC allows retrieving the three EI contrasts through the same means as in conventional EI. This approach to inline EI, while mentioned in [5], has to the best of our knowledge never been validated experimentally.

In this work, a proof of concept for inline EI scans based on sample mask misalignment is demonstrated. The ICs of a conventional and inline EI setup are compared, and the first results of all three contrasts for an inline scanned test sample are presented.

All scans were performed using the EI setup detailed in [6]. Two experiments were performed. First, a conventional EI IC was compared to an IC of the inline EI setup. The conventional EI IC consisted of 11 projections, taken at equally spaced sample mask steps in the [-50 µm, 50 µm] interval (relative to perfect mask alignment). For the inline EI IC, the sample mask was misaligned 25 mm along the optical axis, resulting in an IC profile stretched out over 48 detector columns.

For the second experiment, an inline EI scan was performed for a test sample that consisted of a plexiglass cylinder wrapped in a rubber band and mounted on a wooden stick (see Figure 2). The sample mask was misaligned 10 mm along the optical axis and the sample was stepped across an inline EI IC in 251 steps of one (demagnified) pixel width.

The resulting IC profiles of the first experiment are shown in Figure 1, where the intensity is plotted in function of the sample mask aperture shift, relative to perfect aperture alignment. Good agreement is found between the two IC profiles.

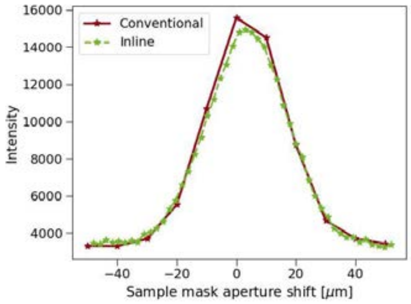

Figure 1: Comparison between an IC of a conventional and misalignment-based inline EI setup.

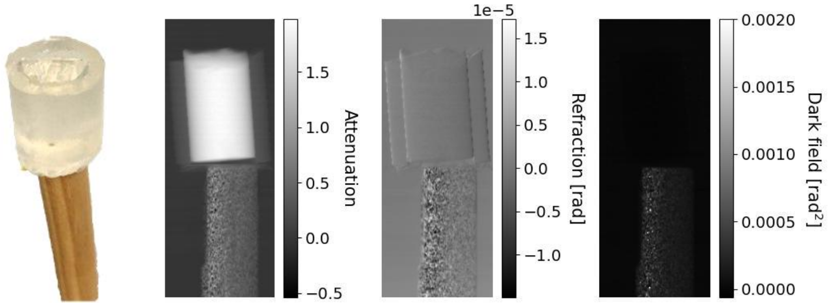

Figure 2: From left to right: test sample and retrieved attenuation, refraction and dark field contrasts.

The retrieved contrasts of the inline EI scan are shown in Figure 2, with the rubber band edges clearly visible in the refraction contrast and the fiber structure of the wood showing up in the dark field contrast.

In conclusion, these results show the potential of performing inline EI scans by purposefully misaligning the sample mask of a conventional EI setup.

Acknowledgments

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