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Imaging X-ray diffracted echoes with tele-ptychography

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Generation of ultrafast multiple diffraction beams have been observed in Si crystals using the high coherent flux provided by 4th generation synchrotron sources. These multiple wavefields, also known as x-ray diffraction echoes, relate to a process described by dynamical diffraction and are of high importance for x-ray optics at XFELs sources. This phenomenon can be also observed in micro-sized perfect crystals. The echoes are produced by the constructive interference of the x-rays at the exit surface of the crystal in diffraction condition. In this effect only a single lattice plane is excited, which makes all the echoes share same bandwidth and divergence (all the echoes are parallel to each other). The echoes have a temporal delay between each other of a few femtoseconds. The delay between the echoes relates to a displacement of the diffracted beams of few microns in the direction transverse to the x-ray beam propagation [1,2] and can be thus measured, given the proper resolution. This property makes them perfect for future ultrafast beam splitters, as well for use as a streaking method to study ultrafast dynamics in thin crystal structures.

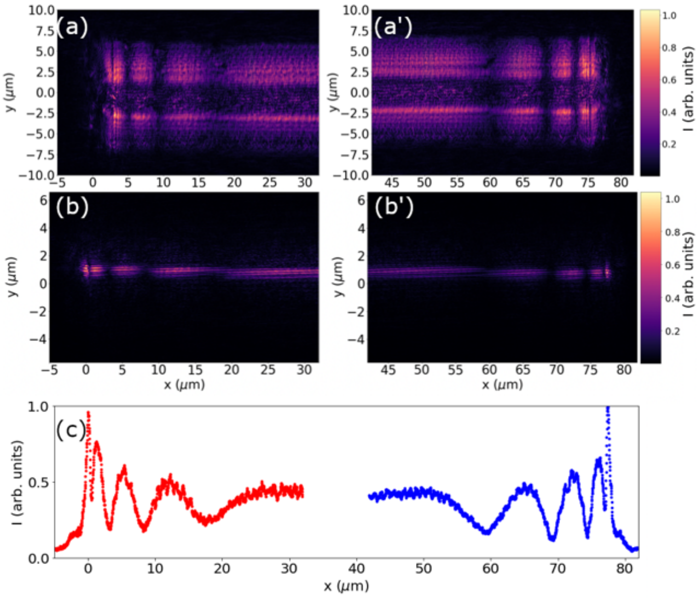

Figure 1. (a) and (a') Amplitude of the reconstructed wavefield at the pinhole plane for two scan areas (a) and (a'). The wavefield was generated by the diffraction of a Si 100 mm thick crystal set to diffraction in the symmetric Laue (220) reflection at 8.4 keV. (b) and (b') Propagation of the wave field to the focus plane. (c) Projection of the y axis from a section around the focus beam for both scans reconstructed.

In this contribution, we present work performed at the beamlines ID01 of the ESRF-EBS and NanoMAX of MAX IV. We use a coherent imaging technique known as tele-ptychography [4,5] to resolve the echoes produced by a 100µm Si wafer [3]. Tele-ptychography is a variant of ptychography in which instead of scanning the sample of interest (the Si wafer in this case), a pinhole located after the sample is scanned with enough oversampling to allow the reconstruction of the amplitude and phase of the wavefront at the pinhole position using a retrieval algorithm. In our study, the incident x-ray beam was focus onto the Si sample to obtain the highest spatial resolution for the echoes. By propagating the reconstructed wavefront from the pinhole plane to the focus plane, we obtained a high-resolution image of the echoes (55 nm pixel size). In this study, we compare measurements and simulations to show how surface strain can modulate the temporal delay of the echoes both in forward and diffraction directions.

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