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Applications of x-ray magnifier to analyzer-based phase-contrast imaging

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1 Introduction

X-ray analyzer-based phase-contrast imaging is a powerful method for observing the inner structures of biological and soft materials because it has a much higher sensitivity to low-Z elements such as carbon, nitrogen, oxygen, and sulfur than conventional absorption-contrast methods. In this method, the spatial resolution is usually limited by the pixel size of the x-ray area sensor. To solve this problem, we have introduced an x-ray magnifier to analyzer-based phase-contrast imaging [1, 2].

In analyzer-based phase-contrast imaging, symmetrically cut crystals are often used for the analyzer. Magnification of a sample image is easily realized by replacing the symmetrically cut analyzer with an asymmetric analyzer. Figure 1 shows a schematic of the magnification process. The magnification ratio, *M*, is given by

$$M = \frac{\sin(\theta_B + \alpha)}{\sin(\theta_B - \alpha)}$$

where θ_B is the Bragg angle and α is the angle between the crystal surface and diffracting plane.

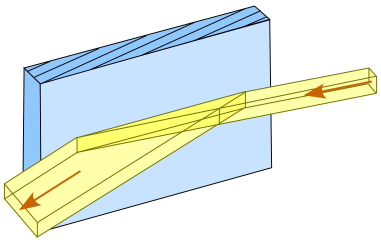

Fig. 1: The process of magnification.

2 Experiment

We performed analyzer-based phase-contrast x-ray computed tomography (CT) experiments at the vertical-wiggler beamline BL-14B. The x-ray wavelength was set to 0.102 nm, and the top-view of the experimental setup is shown schematically in Figure 2. Samples were placed between the two main optical elements: a collimator and analyzer. To maximize the throughput and angular-resolution, the collimator, an asymmetric Si (220) crystal (α = 8°), and analyzer were arranged in the non-dispersive setting. The asymmetric collimator was used to expand the beam in the horizontal direction. To magnify the sample image, an asymmetric Si (220) analyzer (α = 14°, *M* = 20) was used. Sample images were observed using an x-ray CCD camera.

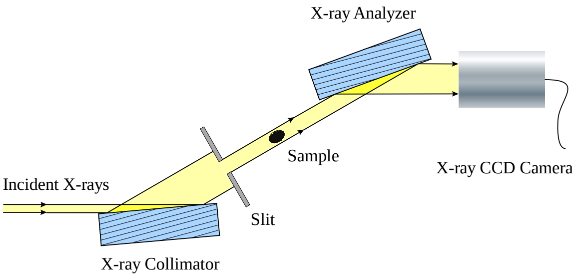

Fig. 2: The top-view of the experimental setup for the x-ray analyzer-based phase-contrast CT.

We used the analyzer scanning method to obtain both phase-contrast and apparent-absorption-contrast images. The samples were rotated around the vertical axis from 0° to 180° in steps of 0.72°. At each angle, 16 images were recorded by the x-ray CCD camera, rocking the analyzer through the Bragg diffraction condition in 1.0 arcsec steps. The exposure time for each image was 2 s.

3 Results and Discussion

Figure 3 shows tomograms of the stalk of *Miscanthus sinensis*, which were much clearer than those obtained at *M* = 1. This result shows that one-dimensional magnification is quite useful for x-ray analyzer-based phase-contrast CT.

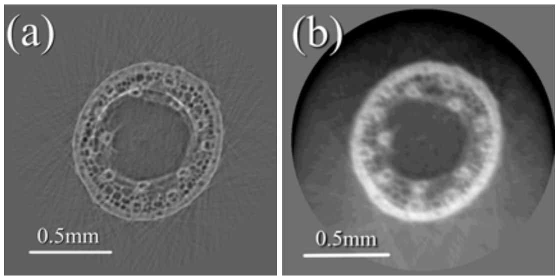

Fig. 3: Magnified (a) apparent-absorption-contrast and (b) phase-contrast tomograms of the stalk of *Miscanthus sinensis*.

References
[1] K. Hirano, *Jpn. J. Appl. Phys.* **50**, 026402 (2011).
[2] K. Hirano and Y. Takahashi, *J. Phys.: Conf. Ser.* **425**, 192004 (2013).

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