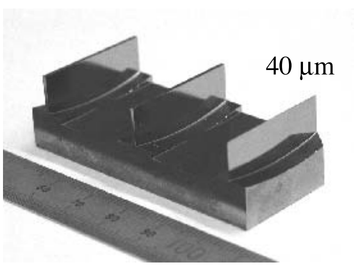
Phase-contrast Tomography using X-ray Interferometer having 40-µm Lamella

Recently, various imaging techniques that produce contrast images from X-ray phase information have been proposed. Biological imaging is their main target because of expected sensitivity up to 1000 times higher than absorption-contrast X-ray imaging, whose performance is insufficient for soft tissues. Three-dimensional tomographic imaging using X-ray phase information has also been achieved [1,2] using an X-ray interferometer [3]. Its high sensitivity enables us to observe tissue structures, such as vessels, cancerous lesions, fibrous tissues, without the use of contrast media.

The method's spatial resolution (roughly 30 µm × 30 µm × 60 µm), however, was not satisfactory for histological observation; the spatial resolution was not limited by our image detector, but by the X-ray interferometer itself, which was made by cutting the body out of a crystal. The interferometer produces interference fringes by generating and recombining two coherent X-ray beams using the dynamical diffraction at a set of lamellae. A blurring mechanism is involved in this process; that is, the wave field of X-rays downstream of the sample is altered by the third lamella, which functions as an X-ray half-mirror, due to the process of dynamical diffraction. We therefore fabricated a new X-ray interferometer with a 40-µm lamella (Fig. 1(a)), which was effective for suppressing the image blurring.

The interferometer successfully produced interference fringes and was installed at beamline **BL20XU**, where we developed an apparatus for phase-contrast tomography. In the measurements, we used 12.4 keV X-rays with a CCD-based image detector, whose pixel size was 6.5 µm × 6.5 µm. Tissue pieces (2 ~ 3 mm in diameter) were observed in a cell filled with formalin. The experimental setup shown in Fig. 1(b).

Figure 2(a) shows tomographic images obtained for a piece cut out of the cortex of a rat kidney fixed in formalin [4]. Convoluted tubules and vessels are revealed. Figure 2(b) shows an optical image of



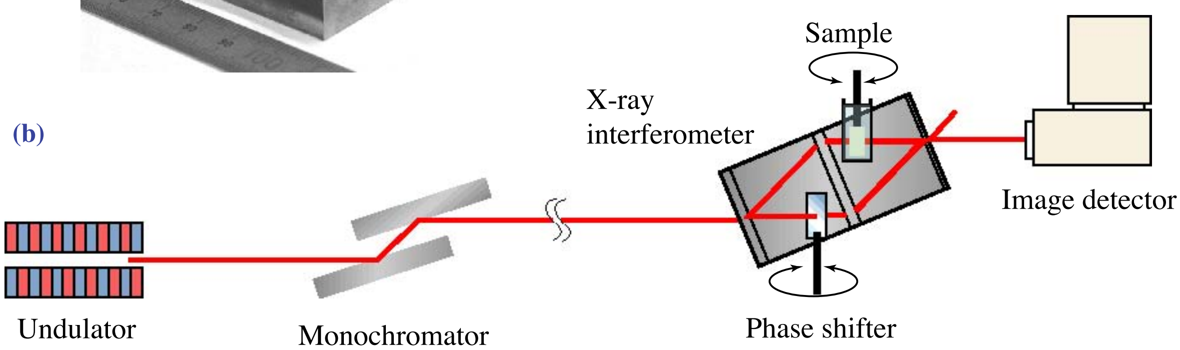


*Fig. 1. X-ray interferometer with a 40 µm lamella **(a)** and experimental setup for phase-contrast X-ray tomography **(b)**.*

the corresponding specimen sliced after the X-ray measurement for comparison. Glomeruli can also be identified in Fig. 2(a) in comparison with Fig. 2(b). Figure 2(c) shows a 3-D rendered view of the tomographic data. In earlier experiments [5], the structures could not be revealed as clearly as the present image.

Structures corresponding to 2 or 3 pixels could be resolved in the tomogram. Thus, present spatial resolution is estimated to be between 13 μm and 20 μm. It is speculated, however, that the influence of the detector's spatial resolution was not negligible; therefore, in parallel with employing a better image detector, X-ray interferometers will be further improved to achieve higher spatial resolution.

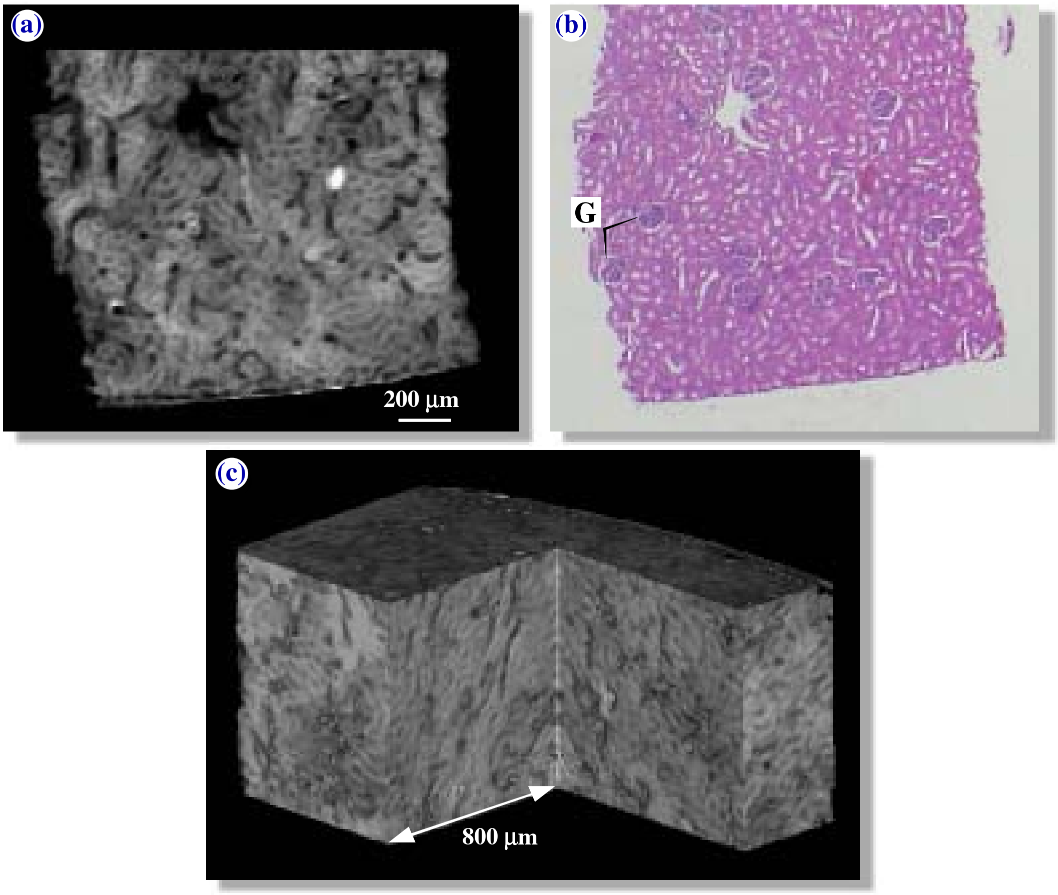


Fig. 2. Phase-contrast tomographic image of a cortex part of a rat kidney ***(a)*** *and an optical image of the corresponding specimen sliced after X-ray measurement* ***(b)****. G: glomeruli.* ***(c)*** *3-D rendered tomographic view.*

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