Experiment title:	Experiment number:
Differential Phase Contrast Tomography Using a Shearing Interferometer	MI-711

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Report:

The primary objective of this experiment was to combine a shearing interferometer for hard X rays (C. David *et al.*, APL **81** (2002) 3287) with tomographic imaging and thus obtain the three-dimensional distribution of X-ray refractive index of different samples. For the separation of phase and amplitude information, a phase-stepping technique was used. Figure 1 illustrates the method.

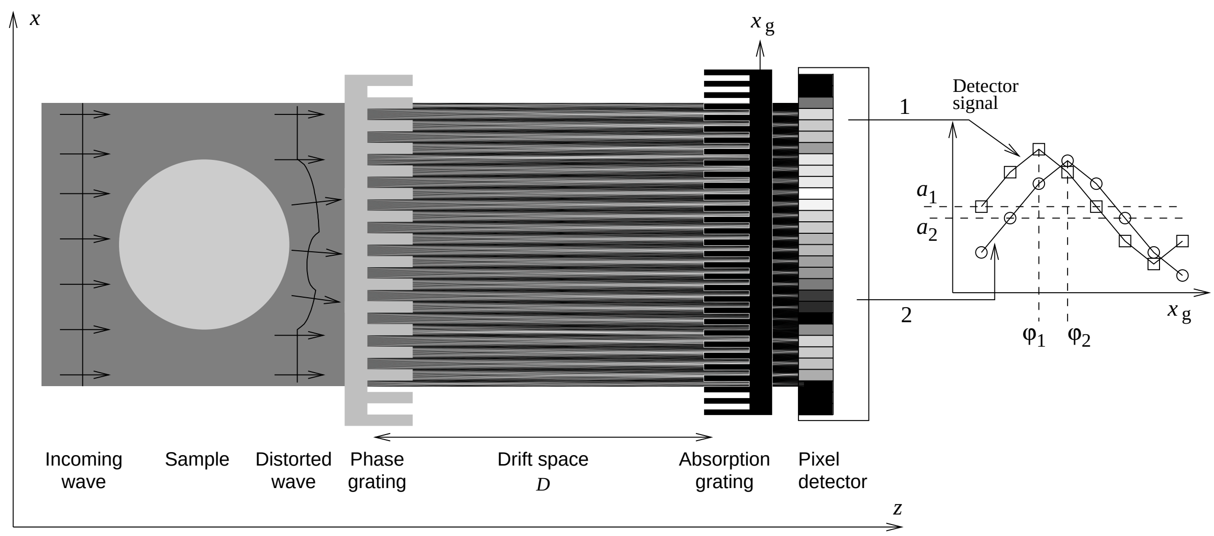

Figure 1: Principle of phase-stepping interferometry with a shearing interferometer. Scanning one of the gratings along x *(phase stepping)* and finding the phase ϕ of the ensuing signal oscillation in each pixel *(right)* allows the extraction of the pure phase contribution. The mean signal a is equivalent to the non-interferometric image, i. e., a combination of absorption and Fresnel edge-enhancing contrast.

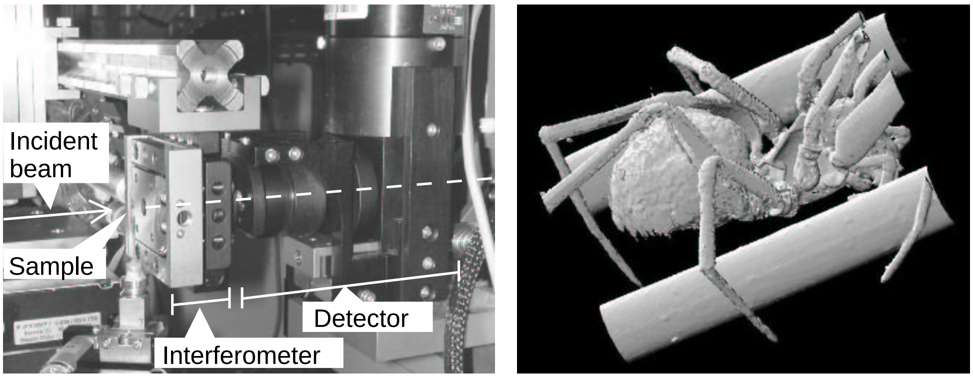

Figure 2: *Left:* Picture of the interferometer setup. The beam enters from the left. The sample is mounted on the tomography sample stage. The two gratings are hidden behind the translation stage and behind the interferometer. *Right:* Isosurface rendering of a reconstructed phase volume dataset of a small spider (reconstructed volume $(1.9\ \mathrm{mm})^3$, 500 projections taken over 180 degrees).

The experiment was carried out with 14.4-keV radiation from the double-crystal monochromator at ID 19. The period of the phase grating was 4 μm, that of the absorption grating 2 μm. The inter-grating distance D was set to the first Talbot distance (23 mm). For phase-stepping scans, 10 images were taken for each projection angle of the samples. A 1024^2-pixel detector with an effective pixel size of 1.9 μm was used. The setup is shown in the picture on the left of Figure 2.
Tomographic datasets of a variety of samples were taken in this configuration. The right panel of Figure 2 shows a three-dimensional isosurface rendering of the reconstructed refractive index of a small spider. Figure 3 shows results for a simple reference sample consisting of polymer spheres glued to the end of a polymer fishing line.

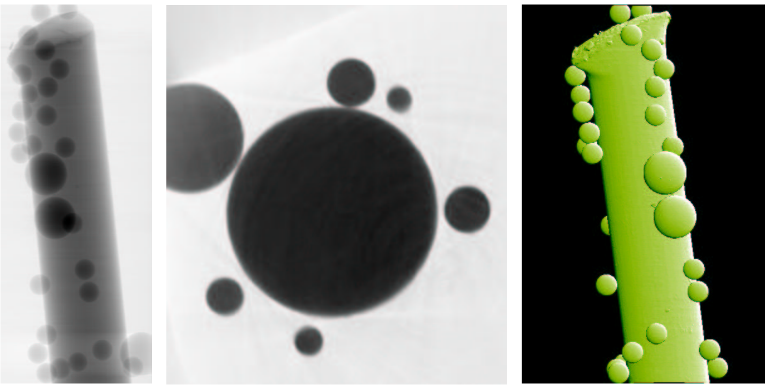

Figure 3: Plastic balls of diameter 100 and 200 μm glued to an end of fishing line. *Left:* Reconstructed phase projection image. *Center:* Phase tomogram, i. e., slice through the reconstructed volume distribution of refractive index. *Right:* 3D isosurface rendering of the reconstructed refractive index.

Biological samples in an aqueous environment were also imaged, but showed only moderate contrast. By choosing longer inter-grating distances, it is possible to increase the sensitivity of the method, but time did not permit to vary the setup in this experiment accordingly.
The data obtained showed, for the first time, that phase tomography with X-ray phase-stepping interferometry is a method that yields high-quality phase reconstructions in two or three dimensions. The experiment goal was thus fully met. The performance limits of the method, especially sensitivity, need to be further investigated.