Phase-contrast imaging above 100 keV

Grating interferometry on a conventional X-ray tube

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Introduction

Grating interferometry [1] can perform phase-contrast imaging on conventional X-ray sources [2]. This technique is sensitive to attenuation, refraction and scattering of the radiation. Imaging at energies between 80 keV and 150 keV is particularly relevant for medical computed tomography and material science. Here we show the design of Talbot-Lau interferometers with edge-on illumination and a target energy of 100 keV and 120 keV. The edge-on approach can achieve the large aspect ratio needed to block the high-energy radiation in the absorption gratings with the currently available fabrication technology.

Aspect ratio and edge-on illumination

The aspect ratio of a grating with pitch p and depth h is given by

$$R = \frac{2h}{p}.$$

This quantity is critical since a small pitch is needed for high sensitivities, and a large depth is required to effectively block the high-energy radiation. Thus, R increases with the target energy of the interferometer. The aspect ratios for a high-energy system (at least 120) are not available with current technologies [3], but edge-on illumination can be used to overcome this limitation.

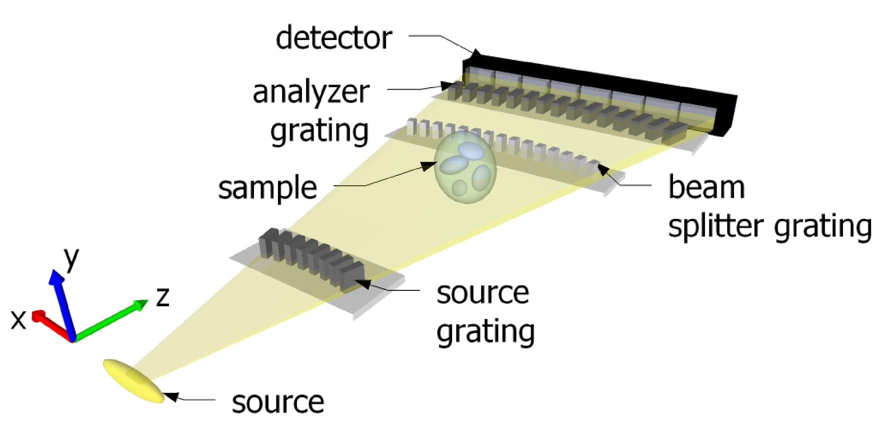

Figure 1: schematic of the grating interferometer with edge-on illumination. The grating structures are circularly aligned in order to match the fan beam.

In the edge-on configuration, the object is scanned along the vertical y direction as one line at a time can be acquired.

Grating design

The gratings were manufactured by Microworks GmbH, Germany, using a LIGA process. The absorption gratings have a thickness of 800 µm. All gratings have a pitch p of 2.8 µm. The interferometers are operated at the first Lohmann distance $d = p/8\lambda$.

design energy	100 keV	120 keV
intergrating distance	15.8 cm	18.9 cm
total length	54 cm	61 cm
beam splitter	gold	nickel

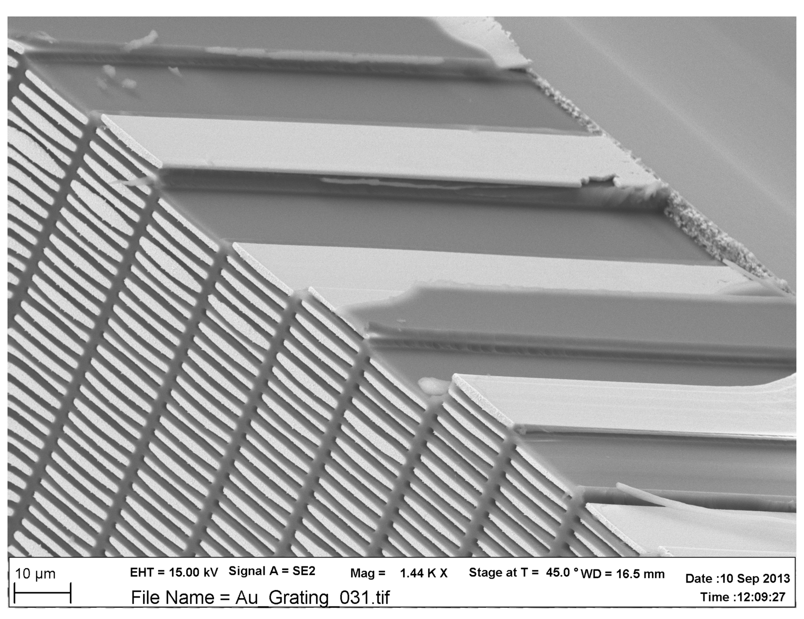

Figure 2: scanning electron microscope image of the grating structures.

Results

The setups have a rather low average visibility ($\sim$ 6 %) caused by the low quality of the gratings. The first images show the three complementary contrasts retrieved from the phase-stepping procedure [4].

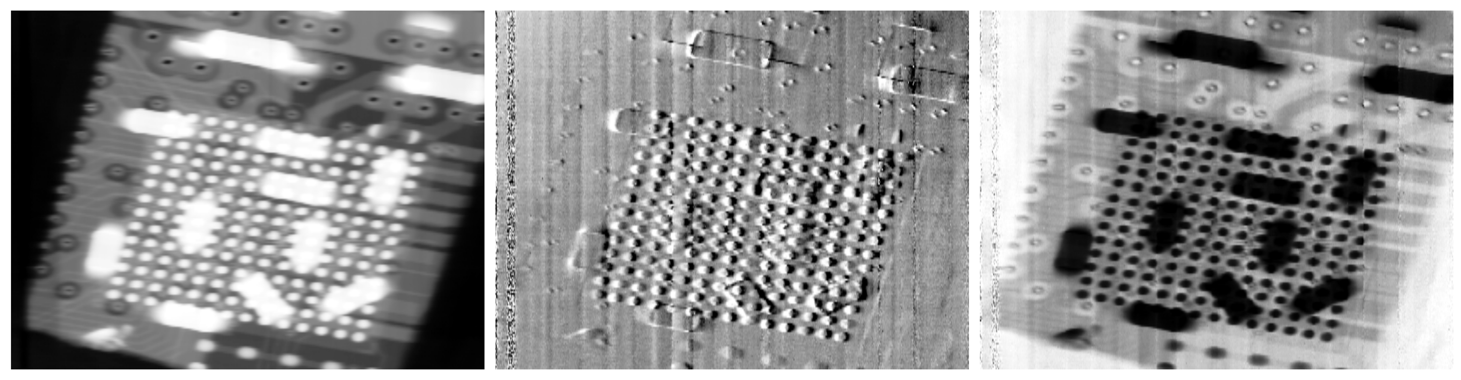

Figure 3: Absorption, differential phase and dark-field image of a metal chip scanned in 100 µm steps. Field of view 2 cm × 2 cm. 100 keV setup.

The exposure time has to be very long (24 phase steps × 15 s per line) in order to reduce the noise given by the low visibility.

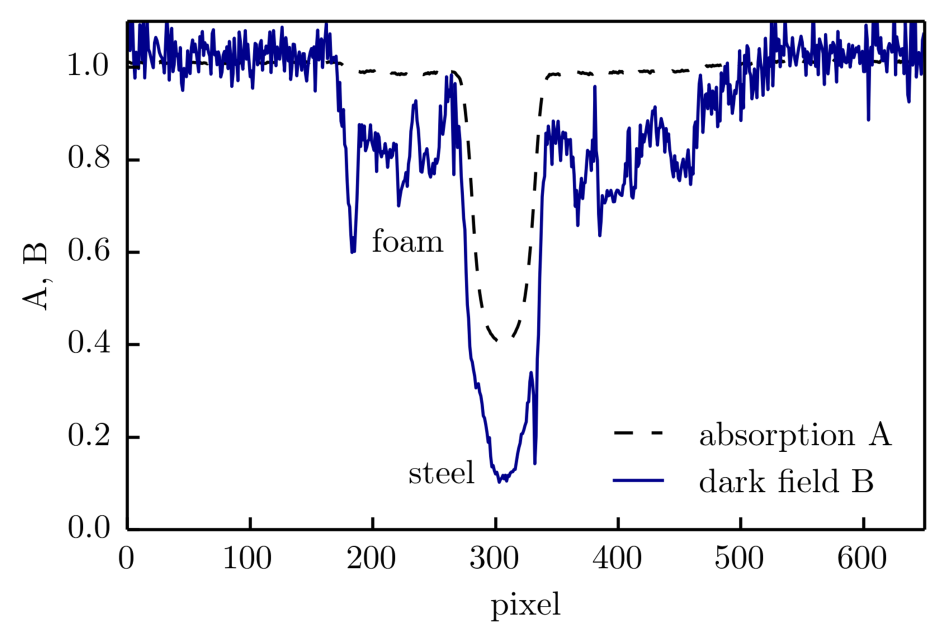

Figure 4: Comparison between absorption and dark field of a polystyrene foam with a steel rod with the 120 keV setup. The dark-field contrast is about 20 % while the soft material only absorbs about 2 % of the radiation.

Outlook

- This setup demonstrates the feasibility of grating interferometry and the availability of the three complementary contrast mechanisms at high energies and compact setups.
- The technique is very promising for applications on conventional sources in the diagnostic energy range between 80 keV and 150 keV, relevant for material science and medical imaging.
- Improvements in the fabrication of the gratings will substantially decrease the exposure time as the visibility increases.

References

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