# *HIGH RESOLUTION GRATING-BASED PHASE-CONTRAST FOR SYNCHROTRON RADIATION SOURCES*

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**Summary:** Synchrotron X-ray imaging is constantly achieving higher spatial resolution. In the field of grating-based phase contrast imaging, these developments allow to directly resolve the interference patterns created by a phase grating without the need for an analyser grating. In this study we studied the performance of a single-grating interferometer and compared it to a conventional double-grating interferometer.

## 1. INTRODUCTION

Differential phase-contrast imaging (DPC) has proven to be a valuable tool when investigating weak absorbing materials like soft tissue, due to its increased contrast compared to conventional absorption-contrast imaging. The most common type of grating interferometer consists of two gratings, a phase grating and an analyser grating. Although a two-grating interferometer comes with a high sensitivity its performance is limited by the feasible aspect ratio of the analyser-grating structures. The period of these structures (state of the art are 2.4 µm) has to be smaller than the used pixel size and the structures have to be highly absorbing which strongly limits the usable energy range. To produce grating structures with the necessary aspect ratio is still critical. In contrast to this, a single-grating interferometer comes with several advantages: The absence of an analyser grating increases the photon flux at the detector plane by almost a factor of two and at the same time allows for using this type of interferometer at any energy. Additionally, the setup itself is more stable and easily adjustable. With a single-grating interferometer it is also possible to use two different modes of phase-retrieval: The so-called stepping approach and the single-shot or fringe analysis approach. These two modes make the same interferometer usable for high-resolution phase-contrast imaging and for very fast measurements. Main requirement for this type of setup is a detector system with a high spatial resolution. This allows resolving the interference pattern directly.
We will present our implementation of a grating interferometer at the PETRA III beamlines P05 and P07. To show the performance of the DPC instrument and especially the advances of the single-grating interferometer we will present a study comparing the single-grating and double-grating setup installed at the beamlines. Focus of the investigation is on the achievable sensitivity, as well as on the spatial resolution of the setup.

## 2. EXPERIMENTAL METHOD

As sample for this study we prepared a test phantom consisting of several polymer and metal rods embedded in hot-melt glue (composition not known). The used materials are Polyamide 6.6, Polymethylmethacrylate, Magnesium, Polychlortrifluorethylene, Polytetrafluorethylene and Aluminium. Using rods of well-defined materials as phantom allows for easily determining the signal to noise ratio due to large homogeneous regions and to verify the quantitative results. The camera used for this experiment is based on a CMOSIS CMV20000 image sensor with 5120 x 3840 pixels and a pixel size of 6.4 x 6.4 $\mu m^2$ and a depth of 12-bit. The camera was developed by the Institute for Data Processing and Electronics at the Karlsruhe Institute of Technology. The phase grating had a period of 10 µm for the single-grating setup and a period of 4.8 µm for the two-grating setup. The analyser grating required for the two-grating setup had a period of 2.4 µm and gold structures with a height of roughly 100 µm. All these gratings were produced by the Institute for Microstructure Technology at the Karlsruhe Institute of

Technology in the frame of the Karlsruhe Nano Micro Facility using a LIGA-process. The experiment was performed at a photon energy of 20 keV. At this energy the gratings induce a phase shift of $3\pi/2$ for the single-grating setup and a $\pi$-shift for the two-grating setup. With the single grating setup, the detector was positioned 40 cm from the phase grating, which corresponds to half of the first fractional Talbot distance, to avoid too strong blurring occurring from a strong signal and the beamsplitter characteristics. For the two-grating setup the tomogram was taken at the third fractional Talbot distance (13.9 cm). For each scan 900 projections were taken covering a rotation of 180°, with each projection consisting of a stepping series with three steps (four images in total).

## 3. RESULTS

To compare the performance of the single-grating setup with a conventional two-grating setup, we analysed the reconstructed volume of the test-phantom. As main performance indicator the quantitative values obtained from the different phantom materials were taken together with the achieved signal to noise ratio. The comparison of the results shows, that both setups reach a comparable precision in the retrieved values. The signal to noise ratio on the other hand is clearly stronger for the single-grating setup. Main reason for this is the absence of the analyser-grating. Without this second grating the photon flux at the detector plate is almost doubled. An additional effect is that grating imperfections of the analyser grating are imprinted to the single projections and therefore cause artefacts in the reconstructed slices.
To compare the spatial resolution of the two systems, we measured the modulation transfer function (mtf) at the edge of one of the rods inside the phantom. The resulting values show that the single-grating setup can reach a higher spatial resolution (~5µm) than the two-grating setup (~10µm). The results also show that the reachable spatial resolution is highly dependent on the sample material.

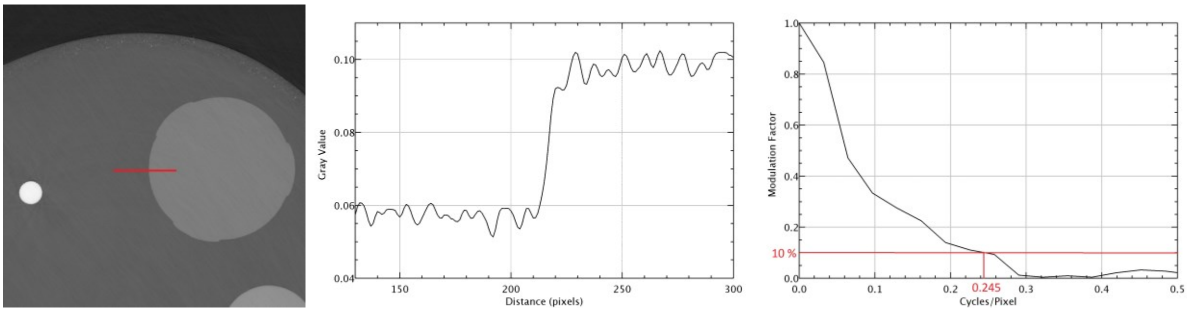


**Figure 1**, Determination of the spatial resolution: In order to estimate the spatial resolution of the system we measured a test phantom (left) and calculated the mtf at the edge of a magnesium rod (red line). The resulting mtf-value of 0.245 at the 10% threshold corresponds to a spatial resolution of 5.2 µm. The example shows data retrieved with the single-grating setup.

## References

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