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Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office using the **Electronic Report Submission Application:**

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Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

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- 1st March for experiments carried out up until June of the previous year;
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Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** Blazed zoneplates for high diffraction efficiencies	**Experiment number**:
Beamline: BM05	**Date of experiment**: from: **27.03.02** to: **31.03.02**	**Date of report**:
Shifts: 12	**Local contact(s)**: Joanna Hoszowska	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Name(s): Bernd Nöhammer*
Christian David*

Address: Laboratory for Micro- and Nanotechnology
Paul-Scherrer-Institute
CH-5232 Villigen-PSI
Switzerland

Report:

Previous to this experiment we have demonstrated, that a one dimensional focusing of hard x-rays using linear silicon fresnel zone plates (FZPs) can be achieved [1]. By using a tilted arrangement of the FZP, the effective height of the diffractive structures can be increased by a significant factor (10 or more) to match the optimum phase for a given photon energy (see Fig 1, left). For a binary FZP, the diffraction efficiency is limited to about 40% even for zone structures with negligible absorption. To obtain higher diffraction efficiencies, so-called blazed zone plates with asymmetric zone structures are needed. Di Fabrizio et al. [2] were able to obtain more than 50% diffraction efficiency in the multi-keV region using electroplated Nickel zone plates with 4-level zone structures.

The aim of this experiment was to test linear Si zone plates with 4-level structures applying the above mentioned tilted arrangement to access a much higher energy range (10-15 keV) and to exceed the existing efficiency record. A SEM micrograph of such a lens is shown in Fig 2, right.

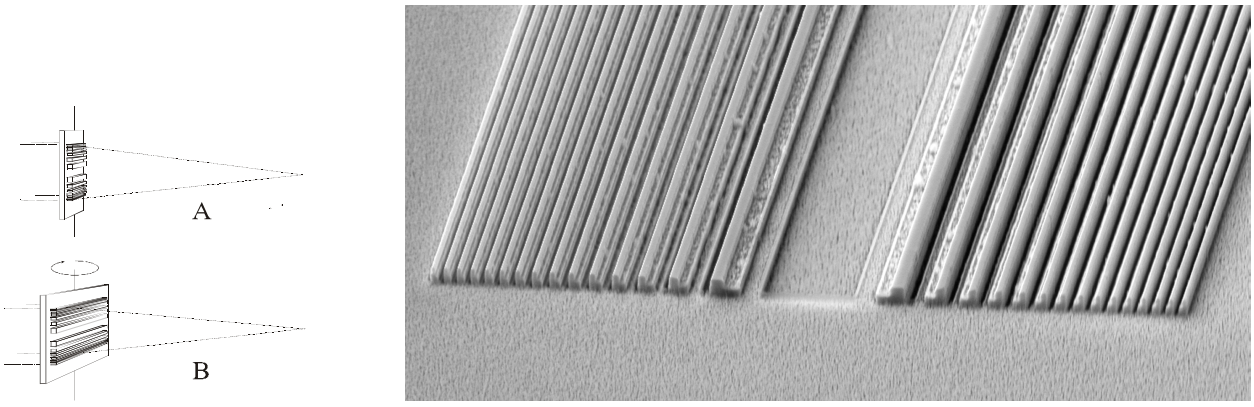

Fig. 1: By a tilting of a linear FZP with respect to the x-ray beam, the diffraction efficiency can be tuned to maximum (left). SEM image of a linear 4-level Si FZP with 800 nm outermost zone width (right)

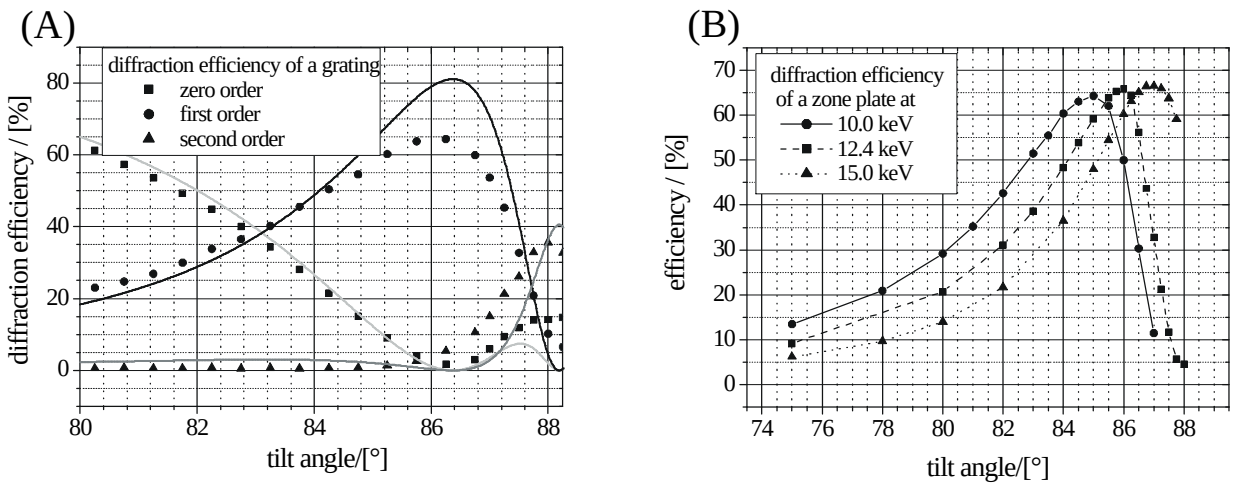

Fig. 2. (A) Measured diffraction efficiencies of different orders and theoretical results (solid lines) for a grating with 1 μm period and a height of 1.5 μm at 12.4 keV photon energy. (B) Measured diffraction efficiencies of a zone-plate for different tilt angles and energies.

We performed efficiency measurements of several 4-level diffraction gratings and FZPs. In case of the gratings it was possible to record the diffraction efficiency of several diffraction orders to be able to perform a Fourier analysis of the diffraction structures. Figure 2A shows, that the measured results are in good agreement with the theoretical predictions, which indicates the excellent structure quality. Figure 2B shows the measured diffraction efficiencies of a zone plate with 200 μm aperture, a focal length of 0.75 m (at 12.4 keV photon energy) and a minimal grating period of 800 nm. For optimum tilt angles efficiencies between 64% and 67% were obtained in the energy range from 10 to 15 keV. This is already very close to the theoretical limit and higher than any efficiency value reported so far for x-ray optics. Limited by the vertical source size of the dipole beam line, the spatial resolution of the lenses could not be tested. These results have been presented at the XRM2002 Conference in Grenoble [3].

In addition to the initially planned experiments, we were able to perform efficiency and resolution mesurements on planar refractive lenses etched 40 μm deep into CVD-diamond substrates (see Fig 3). We obtained transmission values of up to 78% spot sizes of down to 3 μm and gains up to 17. This work is of special relevance for the planned X-FEL sources, a publication has been submitted to J. Syncrotron Rad. [4].

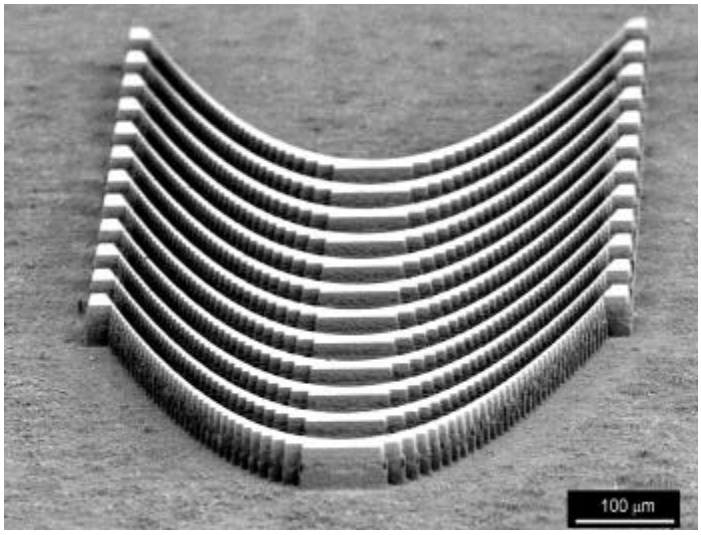

Fig.3. SEM image of a diamond planar refractive lens

Future work will focus on the implementation of blazed Fresnel lenses for coherence-matched 2-dimensional micro-focusing. We gratefully acknowledge the excellent support of Joanna Hoszowska in this experiment.

[1] C. David, B. Nöhammer, E. Ziegler: Appl. Phys. Lett. **79** 1088 (2001)

[2] E. Di Fabrizio et al., Nature **401** (1999) 895

[3] Bernd Nöhammer, J. Hoszowska, H.P. Herzig, and C. David, 7th International Conference on X-Ray Microscopy, Grenoble, 29.7.-2.8.2002

[4] B. Nöhammer, J. Hoszowska, A. Freund, C. David *Diamond planar refractive lenses for third- and fourth-generation x-ray sources* submitted to: Journal of Synchrotron Radiation (2002)