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:**

http://193.49.43.2:8080/smis/servlet/UserUtils?start

Reports supporting requests for additional beam time

Reports can now be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

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.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

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:** Diffractive hard x-ray lenses for coherence-matched microfocusing	**Experiment number**: MI 530
Beamline: ID13	**Date of experiment**: from: Dec. 5th 2001 to: Dec. 9th 2001	**Date of report**:
Shifts: 15	**Local contact(s)**: M. Burghammer	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

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Report:

Previous to this experiment we have demonstrated, that a one dimensional focusing of hard x-rays (10-30 keV) 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 could be tuned to match the optimum phase shift over a wide range of photon energies (see Fig 1, left). For a FZP with 350nm zone width, a diffraction efficiency of up to 40% was measured. The aims of this experiment were:

- To test lenses with 100nm outermost zone width (and thus improved spatial resolution) at energies around 12 keV photon energy.
- To combine two linear lenses in an orthogonal arrangement for two-dimensional focusing.
- To test the spatial resolution of such an arrangement by scanning test objects.
- To match the FZPs geometries to the transverse coherence lengths of the ID13 undulator beam line, in order to collect all coherent photons.
- To demonstrate a flux of 10^8 phot/sec and a flux density in the order of 10^{10} phot/sec/μm^2 in the 1 A wavelength range.

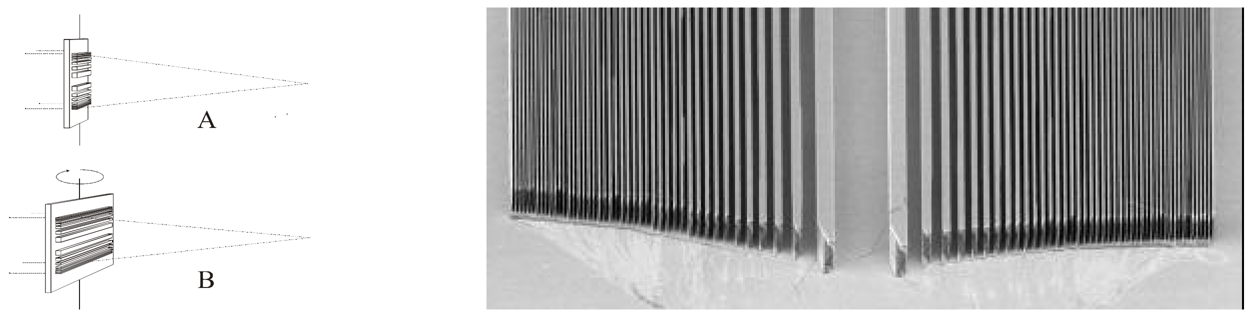
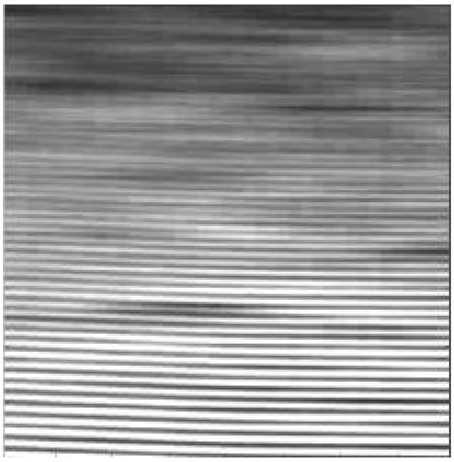


Fig. 1: By a tilting of a linear FZP with respect to the x-ray beam, the diffraction efficiency can be tuned to maximum (left). SEM image of a linear Si FZP with 100 nm outermost zone width (right)

Figure 1 shows an example of a linear FZP with 100nm zone width fabricated by electron beam lithography and selective wet chemical etching of <110> oriented Si substrates. To match the transverse coherence of the ID13 undulator source at 12.4 keV photon energy, the apertures of the two orthogonally mounted linear lenses was chosen to be 200 µm in horizontal and 50 µm in vertical direction, resulting in focal lengths of 200 mm and 50 mm repectively. By scanning a test object with electroplated gold structures (made by M. Panitz, Univ. of Göttingen), we were able to determine the spatial resolution of the setup. Although the absorption of the test structures was only in the order of 6%, structures down to 200 nm in both scanning directions could be resolved. An evaluation of line scans across the test object revealed the modulation transfer function of our set-up (see Fig. 2). A cut-off frequency of approx 2.5 μm^{-1} corresponding to 200nm lines and spaces can be derived. The fact that resolution does not match the expected resolving power of the FZP, which should correspond to it's outermost zone width, may be due to mechanical instabilities of the set-up (piezo-scanner, monochromator).



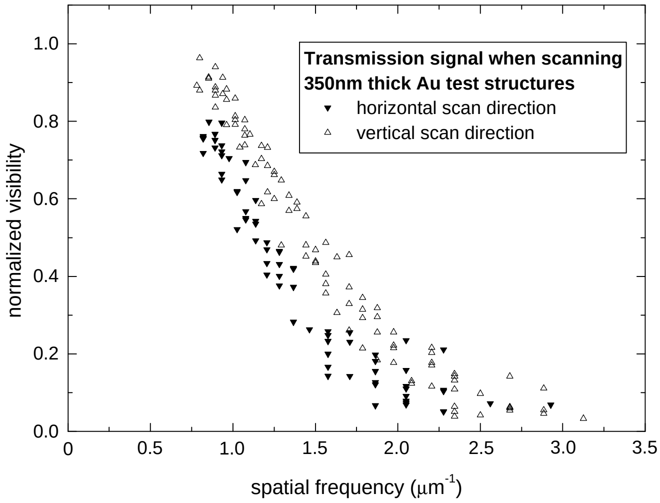


Fig. 2: Scanning transmission x-ray micrograph of a Au test object consisting of 350 nm thick electroplated Au structures. Structures with widths ranging from 500 nm to 150 nm width are shown (left). From line scans accross this test object we determined the modulation transfer function of the coherence-matched FZP-assembly. The visibility was normalized to the theoretical maximum value obtainable with 350 nm Au at 12.4 keV photon energy (right).

The efficiency of each of the two lenses was measured to be 24%, meaning that the complete set-up has a diffraction efficiency of just below 6%. Due to good match to the beamlines coherence properties, a flux of around 10^9 photons per second was achieved. This gives a flux density in the order of 10^{10} phot/sec/μm^2, which corresponds to a gain of 10^5 compared to the incoming flux density of the beam line.

In addition to the initially planned experiments, we also used the two-dimensionally focused spot to perform micro-diffraction experiments on kevlar fibres. The obtained information about the radial arrangement of the kevlar microcrystals is in good agreement with previous investigations done at ID13 using one-dimensional focusing wave-guides, and proved the usefulness of the tested focusing device. A pre-aligned assembly of the tested lenses is now available at ID13 for further user experiments.

A publication on these experiments to be submitted to Applied Physics Letters is presently under preparation. Future work will focus on the implementation of blazed Fresnel lenses with greatly improved efficiency into the coherence-matched focusing scheme.

We gratefully acknowledge the help of beamline scientist Manfred Burghammer in this experiment.

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