ESRF	**Experiment title:** **Spatially resolved diffractometry by using extremely asymmetrically cut analyzer crystals**	**Experiment number**: MI−434
Beamline: ID11	**Date of experiment**: from: 29.11.2000 to: 04.12.2000	**Date of report**: 22.2.01
Shifts: 15	**Local contact(s)**: Gavin Vaughan	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

* Rolf Köhler, * Peter Schäfer, * Tobias Panzner,

Institut für Physik − AG Röntgenbeugung, Humboldt−Universität zu Berlin,
Hausvogteiplatz 5−7, D−10117 Berlin, Germany

Report:

We have kept the original title of proposal MI−400 for the resubmission. However, the main intention was to check the feasibility of two−dimensional high resolution magnification by two subsequent extremely asymmetric Bragg reflections. About twenty yours ago one−dimensional magnification by a factor of 150 at an spatial resolution of better than 0.1 µm was reported [1]. To our knowledge this was never critically checked. In a preceding experiment (see report HS−1043) one−dimensional magnification was already checked. Because of problems with the structures used for checking only resolution of line−structures with 1 µm period could be demonstrated.

Two−dimensional magnification by a factor of 100 by means of Bragg reflections requires rather high intensity. This holds especially in case of high spatial resolution. Therefore an intense undulator source was used for the experiment. The beam was unfocused in order to keep the beam divergence low.

By means of electron beam lithography two−dimensional structures (’dots’) were produced in our institute (courtesy of M. Rabe and S. Rogaschewski) from 70 nm thick layers of ZnSe on GaAs with periods of 0.5 µm, 1 µm and 4 µm. These are rather precise structures and provide an interesting example for potential application of such magnification by Bragg reflection. However, in this case three subsequent Bragg reflections at close distances are necessary. This is hardly possible with a conventional diffractometer. Therefore we had constructed and build a ’magnifier box’, which contained the sample and two analyzer crystals and the mechanics for adjusting these crystals (fig.1). Setting up the analyzer crystals is not very critical because the accepted halfwidth is comparatively large due to low glancing incidence angles. For the sample adjustment the Bragg angle could be adjusted with a angular resolution better than 0.01 arcsec.

According to our experimental observations the distance between sample and analyzer crystal(s) plays an important role (Fresnel diffraction). In case of periodic sample structures there is a strong influence of the talbot effect. There is, however, also a rather significant contribution of the x−ray diffraction influence function at the analyzer crystals. Its effect shows by strong interference fringes towards the direction of energy flux in the analyzer crystal (Kato fringes). This effect is especially strong in case of rather abrupt contrast changes in the sample.

In case of semiconductor sample structures with a period of 4x4 μm^2 there is only a weak influence of above mentioned effects (fig.3). For a period of 1x1 μm^2 (fig.3b) the period is well visible in one direction, but

partially obscured by beam inhomogeneities in the other direction (see indicated periods in fig.3b). We have also investigated a sample with gold mask (courtesy of the microscopy group at ID21) in direct trans−mission. This mask with dimension 70x70 μm^2 consists of lines with width and distance decreasing towards one side which allows to directly check resolution. According to the smallest line distance close to one border of the mask (arrow in fig.3c) the spatial resolution corresponds with a smallest line distance of 0.7µm at the sample. Due to Fresnel diffraction the pattern extends beyond the mask!

As already indicated above, the images reveal inhomogeneities of the synchrotron beam. These can be attributed to the mirror of the beamline optics (fringes to the projected mirror plane; depicted in fig.2 as vertical fringes) and to some small obstacles in the beam path which show up by Fresnel diffraction (see e.g. the nearly circular interference fringes to the lower right in fig.2).

A numerical simulation of the observed contrast is precently under preparation and will be published soon together with our experimental findings. A more general statement is, however, already possible now: in case of gaussian contrast profil the ultimate spatial resolution is achieved if the Fourier transformed profil just fits into the reflection curve (entrance side) of the analyzer crystal. Under such optimum conditions resolution down to about 0.1 µm should be possible. Based on above shown results a resolution of about 1 µm is realistic (i.e. without much further data treatment). A large magnification can be used without spoiling much of the available intensity and makes such a system attractive in that it spans the gap between this one micrometer resolution and the (direct) resolution of CCD−cameras of about 10−20µm. An application to a practical problem, the structures of bone close to an implanted Ti−cylinder, is shown in fig.2.

[1] W.J. Boettinger, H.E. Burdette, M. Kuriyama; Rev. Sci. Instr. **40** (1979) 26

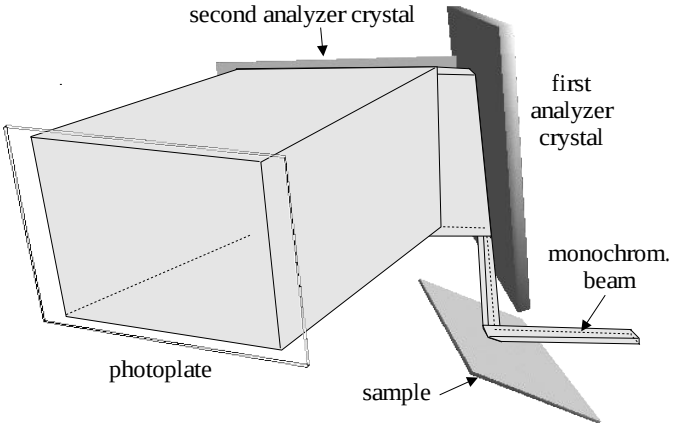

Fig.1: *Ray path in the 'magnifier box'*

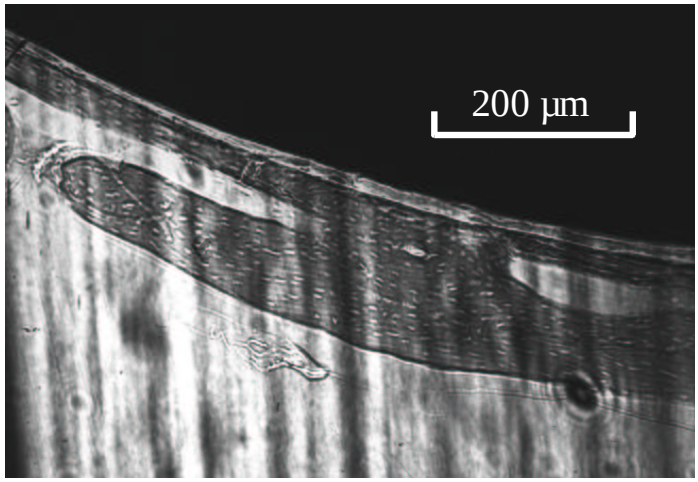

Fig.2: *Bone tissue close to a Ti−implant (black) taken at a magnification of about 40.*

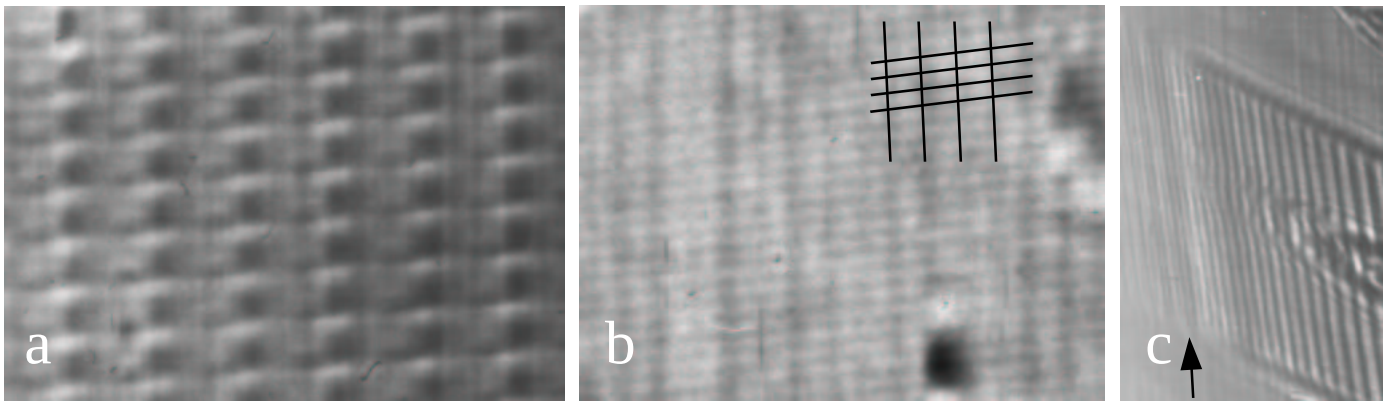

Fig.3: *Bragg−magnified structures: (a) 4x4µm² and (b) 1x1µm² semiconductor structures (Bragg diffraction contrast), the magnification amounts to 180 (horizontal) and 100 (vertical), resp.; the horizontal contrast in (b) is blurred due to beam inhomogeneities; (c) gold mask in transmission, magnification 220 (horizontal) and 80 (vertical), resp.; the picture shows in the horizontal direction only1/4 of the 70x70µm² mask and the picture is distorted due to misalignment of the second analyzer crystal. Please note that the fringes in (c) extend beyond the mask border (marked by an arrow), their smallest distance in the mask area corresponds to 0.7µm on the sample.*