ESRF	**Experiment title:** Nanofocusing parabolic refractive x-ray lenses	**Experiment number:** MI-649
Beamline: ID22	**Date of experiment:** from: 09/07/2003 to: 15/07/2003	**Date of report:** August 20, 2003
Shifts: 18	**Local contact(s):** Andrea Somogyi, Remi Tucoulou	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):
Christian Schroer* (RWTH), Bruno Lengeler (RWTH), Marion Kuhlmann (RWTH), Til Florian Günzler* (RWTH), Olga Kurapova* (RWTH), Stefan Ziegler* (RWTH), Sebastian Feste* (RWTH), Alexandre Simionovici (ESRF), Andrea Somogyi (ESRF), Michael Drakopoulos* (ESRF), Anatoly Snigirev (ESRF), Irina Snigireva (ESRF)

Report:

Nanofocusing lenses (NFLs) for hard x-rays were extensively tested and put to use in a nanodiffraction experiment. To be able to position the lenses in crossed geometry and the sample in three translational directions with high reproducibility and accuracy (down to a few nanometers), a special setup was designed and built at Aachen University (see Fig. 1). It was commissioned during this beamtime, including the synchronization of the stage motion with the beamline control (SPEC). Nine nanofocusing lenses made of Si and one made of B were tested. With the nanobeam obtained we investigated the possibility of diffraction at the polycrystalline phase of a phase change medium ($Ge_1Sb_2Te_4$). It was possible to record Debye-Scherrer-rings of a sample volume containing about 10^8 atoms (cf. Fig. 2). Future experiments are planned to determine the structure of single bits in a storage medium based on phase change media.

The lenses were setup at a distance $L_1 = 41.8$m from the in-vacuum undulator source in the first hutch of beamline ID22. The experiments were carried out at $E = 25$keV and 22keV. First, the lenses and the aperture defining pinhole were aligned using a high resolution x-ray camera in transmission. Three degrees of freedom (+ one vertical translation from the optical table) are used to align the optical axis of the setup that is defined by the horizontal NFL. The vertical lens is aligned with respect to the horizontal one using 6 degrees of freedom. Two translational degrees of freedom are used to move the aperture defining pinhole in place. After some practice, the full alignment was done in 45 minutes. The focus was found by scanning a gold knife edge through the beam and recording the Lα radiation of gold with an energy dispersive detector. Special gold knife edges were made in Aachen using lithographic nanostructuring techniques. The knife edge scans were done with a special piezo scanning stage (PI NanoCube) that has a nominal resolution below 2nm. The setup was controlled by a separate computer. Motor motion was synchronized with the gate signal of the energy dispersive detector controlled by SPEC of the beamline.

Fig. 1(a)

Fig. 1(b)

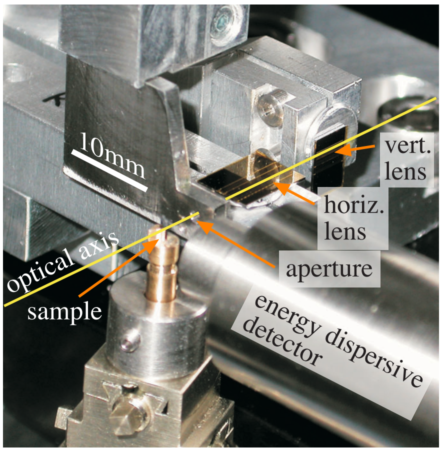
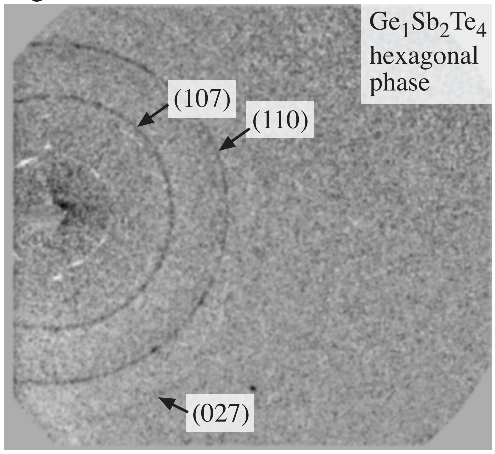
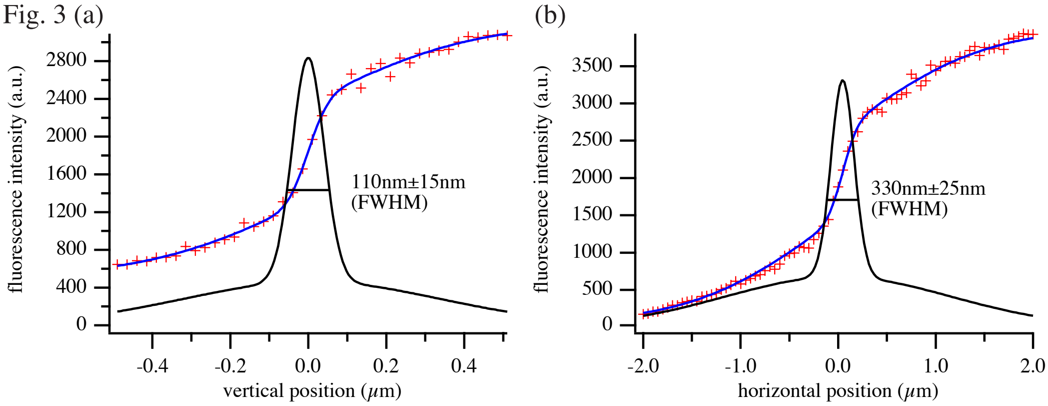


Fig. 2



Nanofocusing lenses with different fabrication parameters were tested. A vertical and a horizontal knife edge scan are shown in Fig. 3. Since vertical focusing is most sensitive to aberrations, the lens characterization was done with vertical scans. All lens foci obtained showed a vertical extension between 100 and 150nm. With ideal lenses focus sizes in the range between 40 and 80nm are expected. Spherical aberration and scattering result in a broadening of the focus and a background around the focus. By comparing the measured focus to the lens shape determined by electron microscopy, different deviations from the ideal cylindrically parabolic shape and their effect on the focusing properties were identified. The data are currently analysed in detail. Future lenses will be corrected for the aberrations encountered here.

Fig. 3 (a) (b)



Horizontally, the beam size is limited from below by the large source size (900μm) at the high-β section of ID22. A focus of 330nm $\pm$ 25nm (FWHM) horizontally was found at L_2 = 12.75mm corresponding to a demagnification of the source of 3280. In the hard x-ray range, no other optic can reach such a demagnification at a short beamline. The flux in the microbeam was between 10^8ph/s and $5 \cdot 10^8$ph/s. Lenses made of diamond and boron will increase this flux by at least one order of magnitude. Using the primary slits at 28.4m from the source as secondary source, the horizontal source size was reduced to 220nm (at the expense of flux).

Some results will be presented at SRI2003 and published in the proceedings. The hard x-ray scanning microscope will be described in Rev. Sci. Instrum.