ESRF	**Experiment title:** Hard x-ray fluorescence microtomography and scanning microscopy with sub-micrometer resolution using refractive x-ray lenses	**Experiment number:** MI-704
Beamline: ID13	**Date of experiment:** from: April 21, 2004 to: April 24, 2004	**Date of report:** March 1, 2005
Shifts: 12	**Local contact(s):** M. Burghammer	*Received at ESRF:*

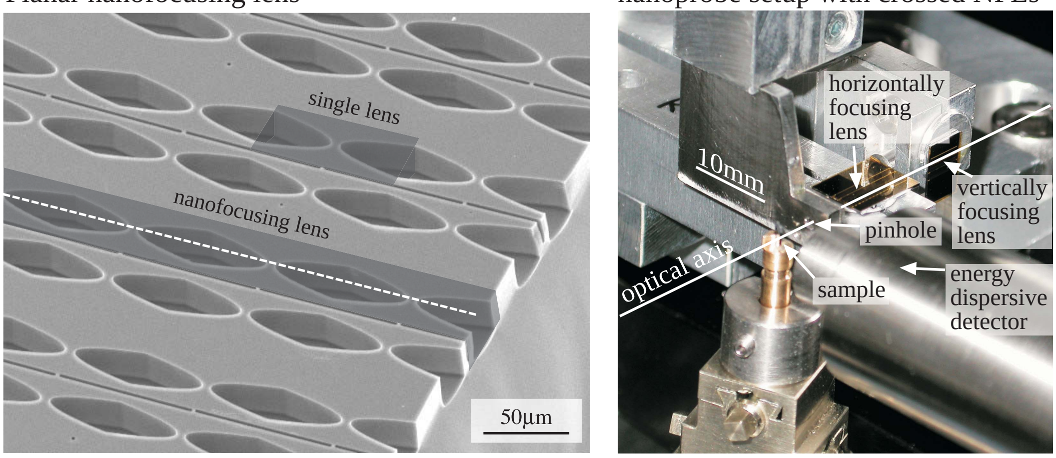
Names and affiliations of applicants (* indicates experimentalists):
Christian Schroer,* Manfred Burghammer,* Bruno Lengeler, Christian Riekel, Anatoly Snigirev, Laszlo Vincze,* Sebastian Feste,* Olga Kurapova,* Jens Patommel*

Report:

During this first beam time of this long term project, the microbeam characteristics achievable with nanofocusing lenses (NFLs, [1, 2]) were determined. The experiments were carried out in EH2 of ID13, where a combined lens – sample stage developed at Aachen University was setup on the microprobe station. Using a high resolution position sensitive detector (provided by Aachen University) two nanofocusing lenses can be aligned in crossed geometry in order to produce a point focus (cf. Fig. 1). The beam profile was determined using a fluorescence knife-edge technique. The flux in the nanobeam was determined with a calibrated PIN diode.

Figure 1

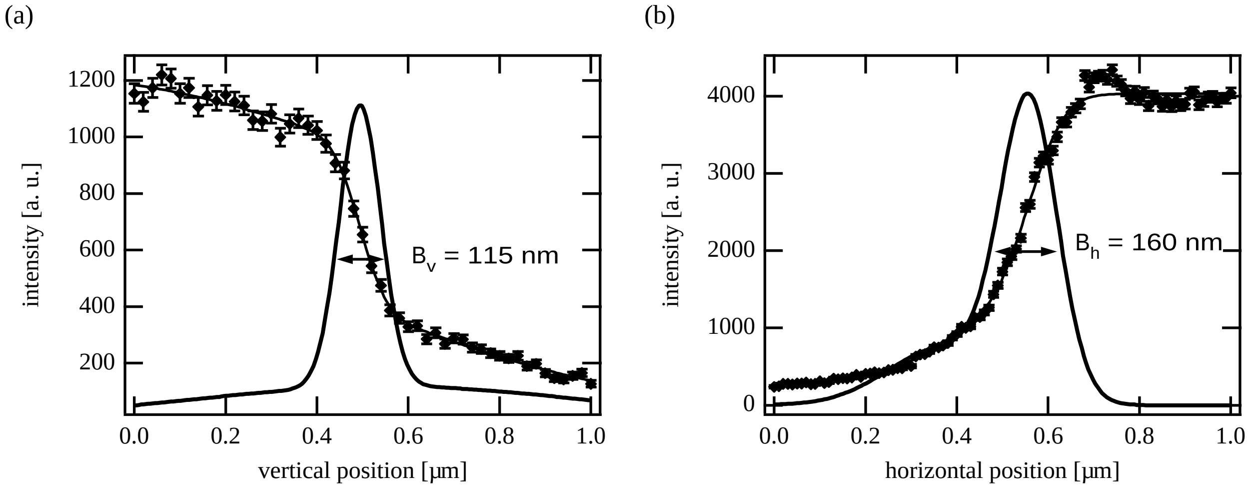
Planar nanofocusing lens　　　nanoprobe setup with crossed NFLs



Besides the prototypical nanofocusing lenses (NFLs) made of silicon (Fig. 1 (left)), lenses made of pyrolitic graphite and boron were also tested. Although the graphite lenses were structured with high precision, they did not generate a small focus, the

reason being strong small angle scattering of the material. The substrates for the boron lenses were not flat enough to generate each a homogeneous one-dimensional focus over the whole depth of the lens. Flat boron substrates are ordered and the lithographic techniques for boron lenses are established by now. Tests with boron lenses will be repeated as soon as they become available. Boron allows one to generate intensive nanobeams (flux well above 10^9ph/s) down to below 10keV [3].

Figure 2



For silicon lenses, the microbeam characteristics were determined at $E = 15.2$keV. Fig. 2 shows the microbeam profiles in vertical and horizontal direction. They were generated by two crossed NFLs with a horizontal and vertical focal distance of $f_h = 17.75$mm and $f_v = 27.1$mm, respectively, reducing the low-β source (size $\approx 150 \times 60\mu\text{m}^2$ (FWHM)) by a factor 2630×1750 at a distance of 47m from the source. In this geometry, the nominal focal size is $90 \times 90\text{nm}^2$. Experimentally, a lateral focal size of $160 \times 115\text{nm}^2$ was achieved. At the time of the experiment, this was a new record focus for nanofocusing lenses. The discrepancy may be assigned to slight spherical aberrations present in these optics due to the fabrication process. The flux in the nanobeam was measured to $8 \cdot 10^8$ph/s. These results are published in [3]. In conclusion of this first beam time of the long term proposal, two major routes to improve the setup were identified. Firstly, the remaining aberrations in the nanofocusing lenses were to be removed by optimizing their fabrication using standard 4"-wafer technology [4]. Secondly, the setup was to be upgraded to include more degrees of freedom, in particular a high precision rotation for fluorescence tomographic scanning.

References

[1] C. G. Schroer *et al.*, Appl. Phys. Lett. **82**, 1485 (2003).

[2] C. G. Schroer *et al.*, in *Synchrotron Radiation Instrumentation*, No. 705 in *AIP Conference Proceedings*, edited by T. Warwick, J. Arthur, H. A. Padmore, and J. Stöhr (AIP, Melville, NY, 2004), pp. 740–743.

[3] C. G. Schroer *et al.*, in *Design and Microfabrication of Novel X-Ray Optics II*, Vol. 5539 of *Proceedings of the SPIE*, edited by A. S. Snigirev and D. C. Mancini (SPIE, Bellingham, 2004), pp. 10–19.

[4] O. Kurapova *et al.*, in *Design and Microfabrication of Novel X-Ray Optics II*, Vol. 5539 of *Proceedings of the SPIE*, edited by A. S. Snigirev and D. C. Mancini (SPIE, Bellingham, 2004), pp. 38–47.