ESRF	**Experiment title:** Hard x-ray scanning microscope based on refractive x-ray lenses: diffraction contrast and coherence	**Experiment number:** MI-817
Beamline: ID13	**Date of experiment:** from: Feb. 21, 2007 to: Feb 27, 2007	**Date of report:** August 31, 2007
Shifts: 18	**Local contact(s):** M. Burghammer	*Received at ESRF:*

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Report:

This beam time was used to characterize our scanning microscope setup based on nanofocussing lenses (NFLs [1, 2]) in view of coherence and wave front properties of the beam, leading to new insights of how to improve fabrication of NFLs. The experiment was performed at the recently extended beamline ID13 in about 100m from the source. We were the first users operating in EH3.

The setup consisted of the scanning microscope as described in detail in the report of experiment MI-704-4 and in [2]. A high resolution position sensitive detector was used to align the lenses (detecting the near field of the lenses) and to measure the intensity of the farfield of the focus. With a calibrated pindiode and with an energy dispersive fluorescence detector (XIA from the detector pool) it was possible to perform absorption and fluorescence knife-edge-scans to determine the vertical and horizontal beam size. In addition we inserted beryllium parabolic refractive lenses into the beamline at about 40m from the source to prefocus the beam and match the lateral coherence length to the aperture of the microscope.

We first determined the effective vertical and horizontal source size, recording the fringes of a boron graticule with an x-ray film. From the visibility of the fringes an effective source size of $\sigma_v \times \sigma_h = 55 \times 160\ \mu\text{m}^2$ was determined following [3].

According to Quiney [4] the farfield image of a focus can be used to characterize the wave field in the focus. With a detailed model of the optical system we were able to simulate the wave fields including shape errors and roughness of the lenses. Each distinctive feature of the recorded farfield image could be associated with a characteristic property of the setup like slits, pinholes, lens shape, lens roughness, etc. This way we could retrieve quantitative data of the shape errors of our NFLs.

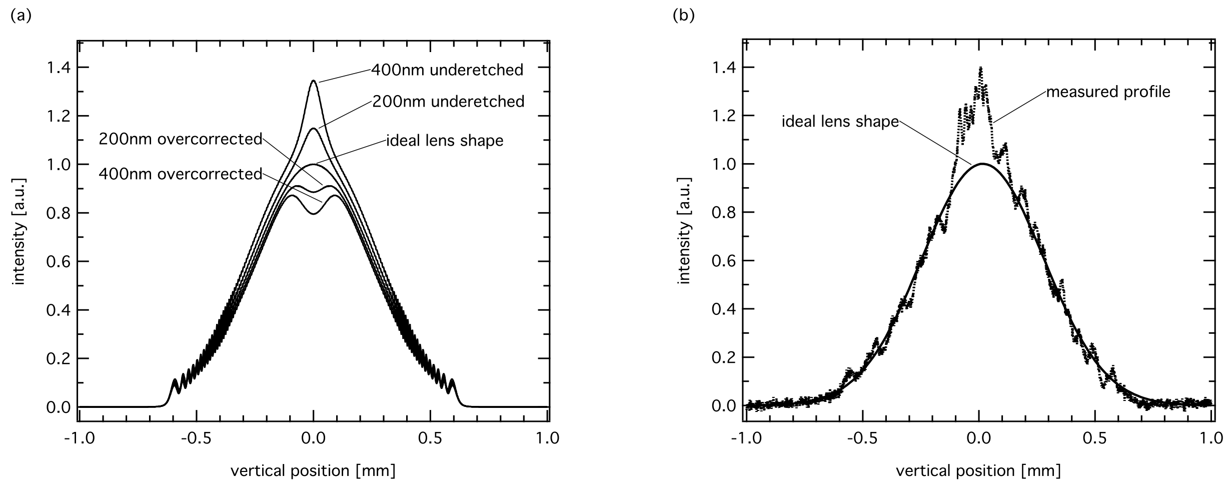

Figure 1 Vertical line profiles of the farfield image of the focus (distance of 1m between focus and detector). (a) Simulated data for different lens shape errors. the steep curves are the result of underetched lenses, whereas the broadened curves are caused by lenses of which the correction for underetching is too large. (b) Measured data. The curve shows a steep peak at the center indicating that the lens is not corrected enough for underetching.

The knife-edge-scans around the focus revealed some deviations from a gaussian intensity distribution expected for perfect lenses. Again, we were able to simulate those aberrations, thus identifying lens shape errors as their source. These results are conform with those detected with the farfield method. Even though the NFLs showed shape errors, the measured focus size was smaller than 100nm in both directions (between 80nm and 90nm).

As the experiment was performed 100m from the source, the lateral coherence length was larger than the aperture of the NFLs. In this way, diffraction limited focusing is possible even for future optics with larger apertures. Prefocusing by the refractive lenses allowed one to better match the lateral coherence length to the current apertures and to increase the flux in the focus. As the focus size of 80nm was dominated by aberrations, the flux could be increased by a factor 10 without compromizing the focus size.

In conclusion of this experiment we can state the following three main results. Firstly, we have developed two independent methods to determine aberrations in NFLs using knife-edge-scans and farfield images of the focus. The gained knowledge about lens shape errors will be used to correct for those aberrations when fabricating the next generation of NFLs. Secondly, we have successfully tested prefocusing devices for matching the lateral coherence length to the effective aperture of the NFLs. Thirdly, we have set up the scanning microscope that we used for experiments performed during MI-704-5 following right after MI-817.

References

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

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[3] V. Kohn, I. Snigireva, and A. Snigirev, Phys. Rev. Lett. **85**, 2745 (2000).

[4] H. M. Quiney *et al.*, Nature Physics **2**, 101 (2006).