ESRF	**Experiment title:** Nanometer hard x-ray focussing by reflective off-axis zone plates	**Experiment number:** MI-785
Beamline: BM05	**Date of experiment:** from: 27 February 2006 to: 07 March 2006	**Date of report:** March 2, 2007
Shifts: 21	**Local contact(s):** Eric Ziegler	*Received at ESRF:*

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Report:

The aim of this experiment was the characterization of the focussing properties of reflecting off-axis zone plates (ORZ). The reflection geometry of the zone plates leads to structures with a size of several microns that can be fabricated very easily with e-beam lithography. For the experiment we prepared different types of ORZs with focal distances between 50 mm and 100 mm on silicon and germanium substrates by reactive ion etching, as well as gold structured ORZs made by a lift-off process on silicon substrates.

The focus diameters were measured with a gold knife edge made of a gold wire (200 μm diameter) provided by Anatoly Snigirev. Figure 1 (left) shows the focus diameter of a gold ORZ (focal length 100 mm) at several positions in beam direction. Similar characteristic convergence of the beam was observed for all types of measured ORZs. These Experiments were carried out both at photon energies of 8.05 (defined by Si(111) doubele monochromator in combination with Ru/B_4C multilayer mirrors) and 16.1 keV (defined by Si(111) doubele monochromator).

The focus diameters for all of the characterized ORZs was larger than 2.7 μm FWHM (best value), and thus much larger than the ideal values. The calculated FWHMs of the fabricated ORZs are between 30 nm to 120 nm for the BM05 source parameters, according to simulations. This discrepancy can be explained, when curved substrates are taken into account for the Fresnel-Kirchhoff simulations: curved substrates show an extremely widened focus diameter already for bending amplitudes of several 10 nm [2].

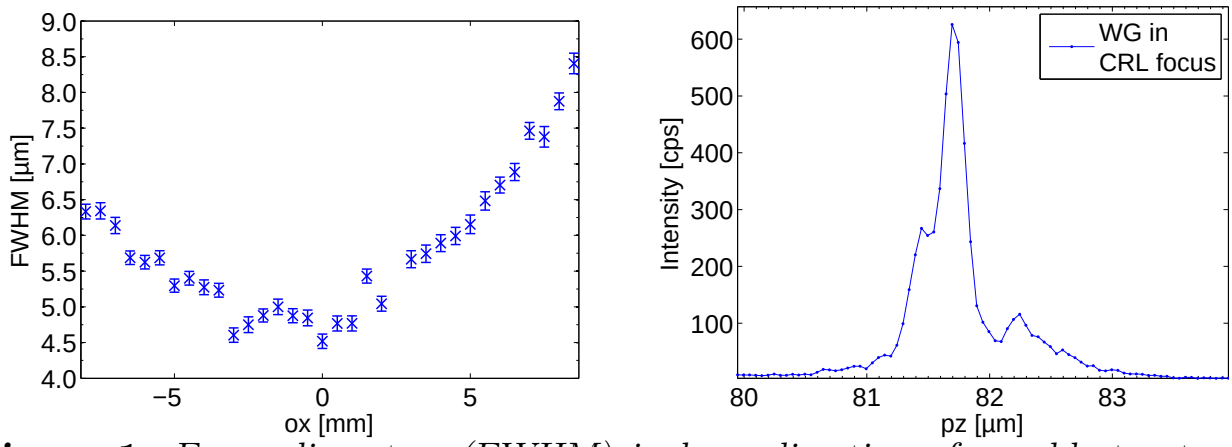

Figure 1: *Focus diameters (FWHM) in beamdirection of a gold structured ORZ with a focal length of 100 mm, $\alpha_i = 0.4°$, structured zones (focus neigh) 918 – 5399 with a length of 18 mm and a smallest zone width of 2.5 µm (left). Focus profile of the CRL measured with a 40 nm waveguide (right).*

In a second part of the experiment we used a one-dimensional waveguide (Germanium cladding, 40 nm Calixarene guiding layer, 2 mm long) to characterize the focus of a silicon nano compound refractive lense (CRL) at an energy of 16.1 keV. The CRL was composed of 35 single lenses with a radius of 5 μm. The width of the focal spot was in the range of 200 nm, and thus about 5 times larger than the resolution of the waveguide. It was demonstrated that waveguides are very suitable optical tools to characterize the width and the form of the focal spot of CRLs (Fig. 1 (right)). The beam coupled into the waveguide, the angular acceptance and the efficiency of the front coupling scheme was characterized by scanning of the far field (Fig. 2).

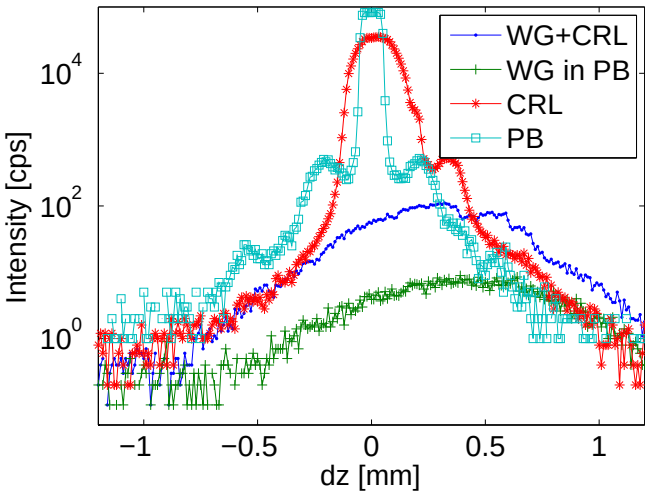

Figure 1: *Comparison of the far-field beam profile with waveguide + CRL, waveguide in primary beam, CRL and the primary beam.*

References

[1] S. Kalbfleisch, T. Salditt, E. Ziegler et al., *Off-axis Reflection Zone Plates for Hard X-Rays, in preparation.*

[2] S. Kalbfleisch, Diploma Thesis, Fakultät für Physik, Universität Göttingen, 2006.

[3] T. Salditt, S. Kalbfleisch, A. Hillmann, C. Schroer, et al., *to be published.*