Commissioning of the Nanofocus Endstation at MINAXS Beamline (P03) of PETRA III

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PETRA III is now in regular operation and proved to be the world's most brilliant synchrotron radiation source. The nanofocus endstation of the MINAXS-beamline (MIcro- and NAnofocus X-ray Scattering) has been successfully commissioned during its very first in-beam shifts in October and December 2010. The beamline is operated at an energy range of 8-23 keV and the nanofocus endstation is designed to routinely provide an X-ray beam with a diameter of ~100nm with a high coherence option for diffraction experiments (SAXS and WAXS). The optical elements to generate the nanobeam are 2D waveguides and will be extended with a KB-mirror-optics later in 2011. Fig. 1 shows an overview of the beamline and of the currently installed setup at its nanofocus endstation, designed and constructed by the University of Kiel within the framework of a BMBF project. A detailed description of the setup can be found in [1]. This contribution presents the highlights of the commissioning results and the waveguide based setup used in the commissioning.

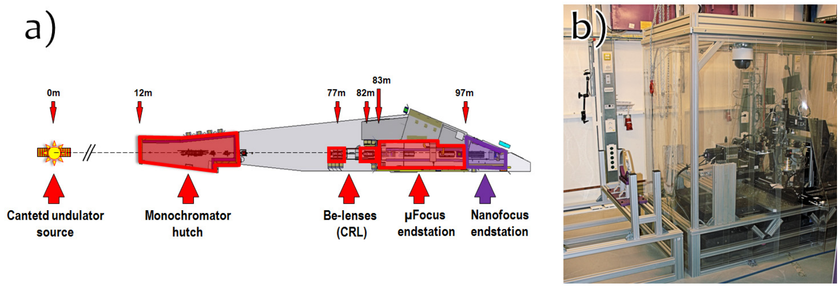

Figure 1: a) Schematic layout of the MINAXS beamline showing the position of the nanofocus endstation **b)** Recent photograph of the finalized experimental setup at the nanofocus endstation.

The beamline is equipped with automatically exchangeable compound refractive lenses (CRL) used for prefocusing in the nanofocus setup. The size of the CRL-focused beam at the nanofocus endstation was determined to be 120 µm × 80 µm (h×v, FWHM) and the total flux in this focal spot was measured with a PIPS-diode to be 3×10^{11} /sec/100mA. As shown in Fig.2 a) the so focused beam is then coupled into a channel of a 2D-waveguide and the exiting, finely collimated waveguided beam can be used for experiments. The employed waveguide (as in [2]) was manufactured and provided by the group of Prof. Tim Salditt, University of Göttingen. It is basically a short Si-wafer with a series of 11 differently sized, hollow channels, all of which have a height of 50 nm and widths ranging from 2 µm to 50 µm. Their common length of 5.6 mm was chosen to best suit the photon energy in the commissioning experiment, being 12.8 keV. The waveguide was mounted onto a hexapod allowing both, the translation of the waveguide (e.g. to select a specific channel) and rotation of the waveguide around a freely definable pivot point (e.g. for in-beam alignment). This also is shown schematically in Fig. 2 b). After the positional and rotational alignment of the waveguide with respect to the incoming beam a lateral scan of all channels was recorded (Fig.3 a) and absolute fluxes of the waveguided beams were measured to determine each channel's transmission. These are shown in Fig. 3 b) along with the calculated values.

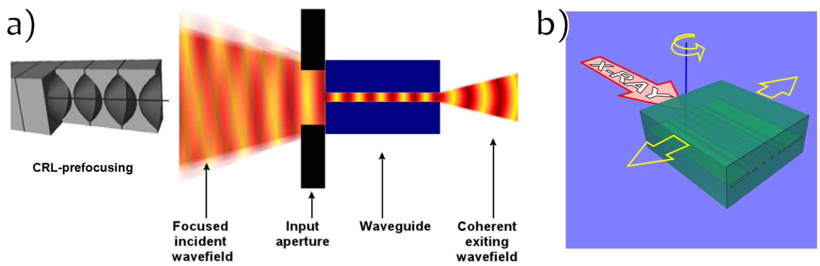

Figure 2: a) Schematic layout of the waveguide based setup used in the commissioning **b)** The waveguide can be moved and tilted.

The beam profile at the exit of a waveguide channel (near field) as well as at a large distance from the waveguide (far field) were also measured. A series of knife-edge scans were recorded at distances of 60 to 700 µm (near field) while 2D images of the beam profile were recorded with a Pilatus300k detector at a distance of 2.4 m. From the derivatives of the knife edge scans the vertical beam width was calculated, as shown in Fig's. 4 a) & b). The divergence is ~1.4 mrad which is an expected value, while the extrapolated beam size at zero distance (at waveguide exit) is ~300 nm, hence 6 times larger than the waveguide dimension. This might be due to smearing caused by vibrations and the roughness of the knife-edge. The far field, as shown in Fig.5 was recorded for both, the waveguide aligned parallel to the beam and with a slight tilt of max 0.05°. In the tilted case a distinct beam splitting occurred where the split angle was directly correlated with the tilt angle.

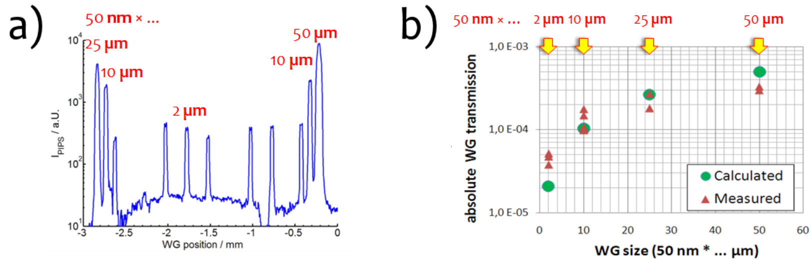

Figure 3: a) Horizontal scan over the entire waveguide showing the beam guided through each of its differently sized channels **b)** Calculated and measured absolute transmissions for the channels.

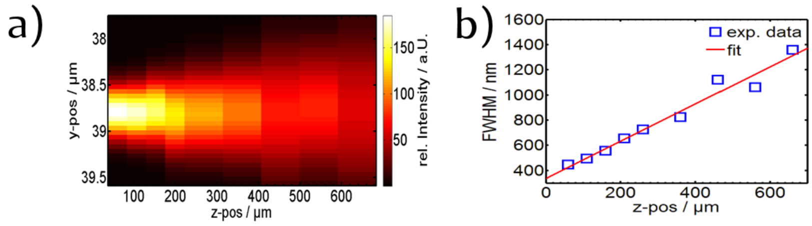

Figure 4: a) Derivatives of knife-edge scans recorded at increasing distances from the exit of a 50 nm × 50 µm channel (y × x) **b)** Half-widths (FWHM) of the derivatives and a linear fit to the data

The first performed experiment was a proof-of-principle to demonstrate that a 2D-waveguide beam can be used for diffraction experiments and was performed on a friction-stir-welded aluminium sample. Friction stir welding is a novel welding method based on friction heat caused by a high speed rotating tool and subsequent stirring the plastic metal. We scanned the waveguide beam (50 nm × 50 µm) across the weld with a step size of 1µm. When entering the weld, the isolated spots in the WAXS spectra turn into almost continuous, powder-diffraction-like rings, indicating that the crystal grain size dramatically drops in the weld. Further data analysis is in progress.

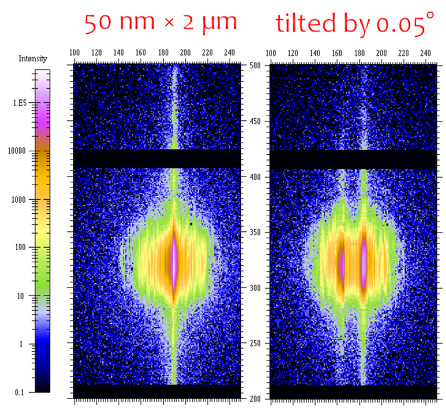

Figure 5: The waveguide beam at a distance of 2.4 m. When the waveguide is aligned parallel to the incoming beam its beam is symmetric - when it's tilted (see Fig.2 b) a split beam occurs. Recorded with a Pilatus300k detector, pixel size ~ 178 µm

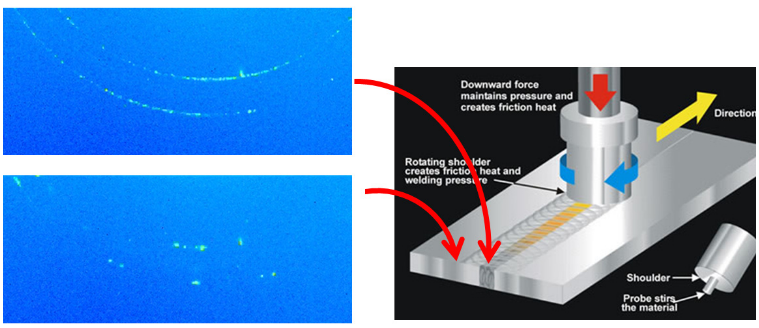

Figure 6: Diffraction patterns from aluminium recorded in a stir-friction-weld (top) and in material not affected by the welding process (bottom), using a waveguide beam (50nm×50 µm). The reflections correspond to the (111) and (200) lattice planes. Stir weld schematic picture taken from [3].

References

[1] C. Krywka et al., *SRI 2009, AIP Conference Proceedings,* **1234** (2010) 879-882
[2] K. Giewekemeyer et al., *New Journal of Physics,* **12** (2010) 035008
[3] Image from www.esabna.com, "Friction stir welding"