Nanofocus Endstation @ MINAXS Beamline
Status and Potential Applications

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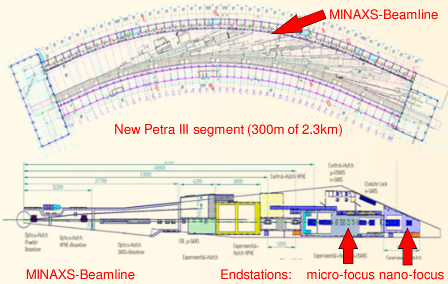
PETRA III, currently in its final state of construction, is going to be a high-brillance 3rd generation synchrotron radiation source, located on the site of DESY in Hamburg, Germany. To achieve this, the existing PETRA storage ring has been refurbished and turned into one of the most brillant x-ray sources worldwide. First beamlines are planned to take up user operation by the end of this year. The "MIcro- and NAnofocus X-ray Scattering" (MINAXS) beamline is equipped with two endstations, out of which the farthest (downstream) is destined to routinely provide a high flux x-ray beam focused to a spot size of about 100nm × 100nm. Experiments with a superior spatial resolution and a flux sufficiently high to study both biological and synthetic materials will become available at this endstation bearing high potential for new, pathbreaking insights in life and materials science.

Beamline

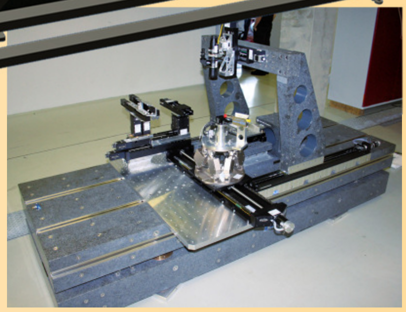


Top: Position of the MINAXS beamline within the layout of Petra III and floor plan of the beamline. The nanofocus hutch is located downstream the microfocus endstation, both of which are fed by a single canted undulator.

Shown **right** are the three types of micro-positioning and nano-positioning devices for the alignment of the sample and nanofocusing optical elements. Two hexapods provide each 3 linear and 3 rotational degrees of freedom with a freely definable pivot point. Two top-mountable XZ-stages (nanocubes) provide superior spatial resolution.

Specs:	**XZ nanocube**	**F-206 hexapod**	**M-824 hexapod**
max. load	1.5 kg	2 kg	10 kg
travel range	±100 µm	±6 mm, ±6°	±22.5 mm, ±12.5°
resolution	< 10 nm	100 nm, 2 µrad	300 nm, 3.5 µrad

Current photographs showing the status of completion of the Petra III experimental hall (**top**) and the experimental hutch for the nanofocus endstation of the MINAXS beamline (**bottom**). The black circle in the middle of the picture is where the synchrotron beam will enter the hutch.

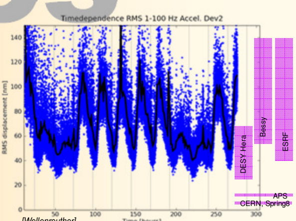


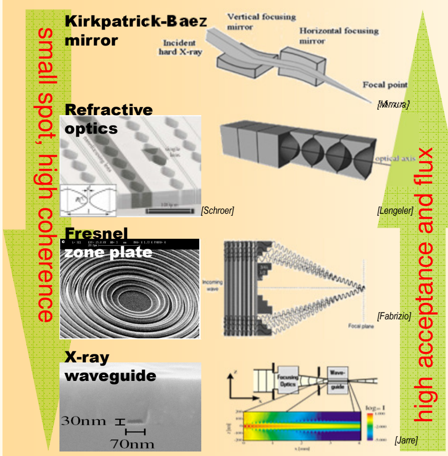
Top: 3D-CAD model of the nanofocus setup, mounted onto a heavy, vibration reductive, two-segment monolithic table (2,5m x 0,8m). Shown at the **right** is a photograph of the actual setup, in ist current state of completion (outside the experimental hutch).

Highlights of the setup: Laser microbeam guided sample observation, two simultaneously operating video microscopes viewing at orthogonal directions for convenient sample observation, up to 10nm precision for sample positioning, hexapod based sample positioning and optics adjustment allowing for highly flexible integration of custom sample environments. Note the low height of beam above ground (90cm) being a consequence of the used large offset monochromator. The resulting low center-of-mass is expected to decrease vibrations hence increase the mechanical stability.

Optics

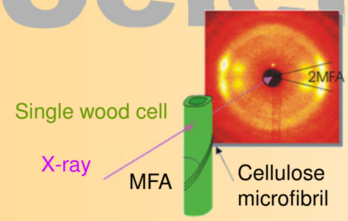
Focusing x-rays down to the sub-µm range requires not only high precision optical elements and a well defined incident x-ray. Only when vibration issues are carefully taken care of, the incoming beam can be focused to a size close to the diffraction limit, ~20nm. Shown to the **right** is the vibration amplitude (integrated for 1-100Hz) measured over 11 days on the Petra III monolith floor during construction work.



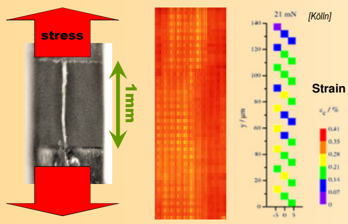


As shown **left** many types of optics exist, the choice of which depends on the main concern of the experiment – always being a trade-off between conserving flux, spatial resolution and coherence. At the MINAXS beamline a combination of different types of optics will be used, starting with a waveguide-based system and subsequent conversion to a mirror system.

Science

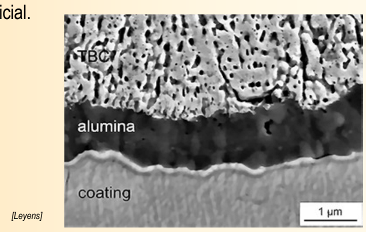


Top: Microdiffraction experiment on a wood cell with the cellulose (200) reflection being an indicator for the microfibril angle (MFA). **Bottom:** (left) Actual experiment, the cell is exposed to lateral stress during irradiation. Combined with a µm-sized x-ray spot the intracellular strain distribution (right) can be determined from the measured MFA-distribution (middle). Yet smaller foci allow for investigation of more finely structured materials, such as fibres, smaller cells etc.



Nanofocus diffraction is complementary to electron microscopy (TEM, SEM) and small angle x-ray/neutron scattering (SAXS/SANS). For example it allows for *in situ* experiments (e.g. temperature, mechanical load) to access single grains of polycrystalline materials on a sub-µm length-scale. **Right:** Microstructure of Mg-Al-Zn alloy with & w/o SiC [courtesy of GKSS].

Bottom: A thermal barrier coating (TBC) deposited onto aluminidecoated TiAl alloy Ti-45Al-8Nb. TEM evidenced protective alumina scale formation on TiAl3, providing good adherence of the TBC. If crystallisation or composition of such structures is in question, sub-µm diffraction and spectroscopy methods are beneficial.



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