High Energy Materials Science at PETRA III

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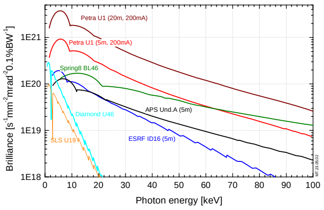
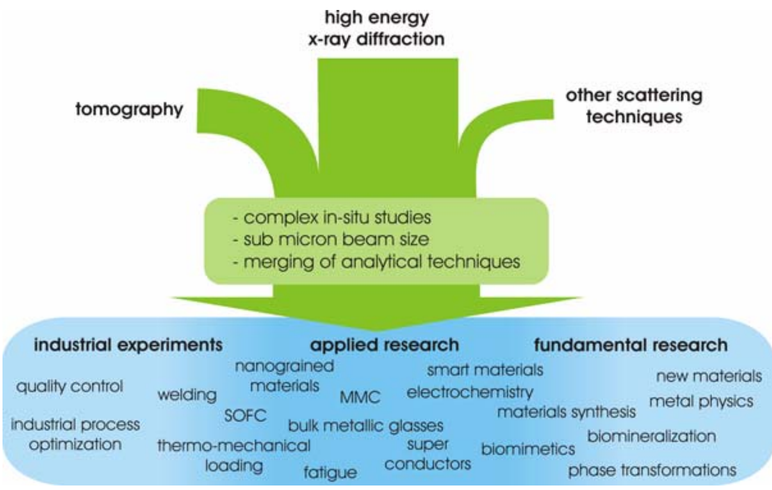
High Energy Experiments at PETRA III

PETRA III with 6 GeV @ 100 mA will be the new high brilliance synchrotron radiation source on the DESY site in Hamburg (total investment 225 M€). The existing storage ring PETRA II will be converted into one of the most brilliant 3rd generation x-ray sources with planned user operation in 2009. [*PETRA III: A Low Emittance Synchrotron Radiation Source, Technical Design Report*, ed. K. Balewski *et al.*, Hamburg, DESY, 2004]

Artist's view of the new 280 m long experimental hall with 14 beamlines and up to 30 experimental stations.



Comparison of PETRA III with current 3rd generation synchrotron radiation sources.



Main analytical techniques and capabilities available at the beamline and research topics addressed.

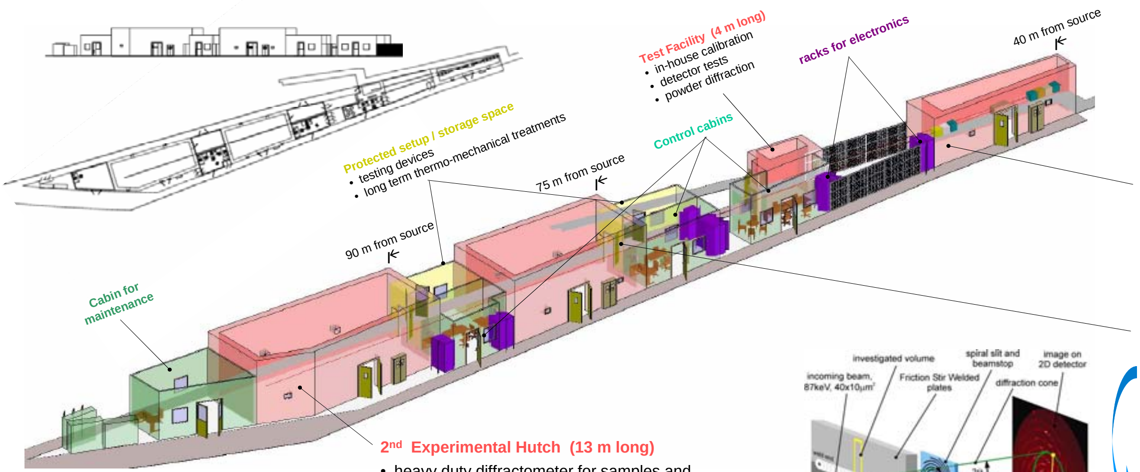
Science at the High Energy Materials Science Beamline

- Experiments targeting the **industrial user community** will be based on well established techniques with standardised evaluation, allowing "*full service*" *measurements*. Environments for strain mapping on large structural components up to 1 t will be provided as well as automated investigations of large sample numbers, e.g. tomography & texture determination.

- **Applied research** for manufacturing process optimization will benefit from high flux in combination with ultra-fast detector systems allowing *complex and highly dynamic in-situ studies of microstructural transformations,* e.g. during welding processes. The beamline infrastructure will allow easy accommodation of large user provided equipment (at present an *in-situ* friction stir welding device for measurements at synchrotron radiation sources is currently in the design phase at GKSS).

- **Fundamental research** will encompass metallurgy, physics, chemistry, biology *etc.* which are more and more merging. First experiments are planned for the investigation of the *relation between macroscopic and microstructural properties of polycrystalline materials*, *grain-grain-interactions*, *recrystallisation processes*, and the *development of new & smart materials or processes*.

Beamline Layout and Instrumentation



Insertion Device

- dedicated 5 m in-vacuum undulator
- high-β section
- σ_{size} = 141/5.5 μm, $\sigma_{div.}$ = 7.7/3.8 μrad
- minimum gap 6 mm
- main energy 120 keV
- energy fully tunable 50-300 keV

Optics Hutch (10 m long)

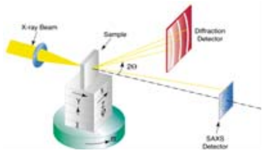
- slits
- filters
- water cooled scanning fixed exit bent Laue monochromator
- collimating Compound Refractive Lenses

1st Experimental Hutch (10 m long)

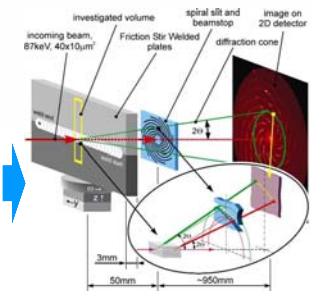
- general purpose diffractometer
- high resolution 3D microstructure mapper
- focussing optics for spot sizes down to ~1 μm (CRLs & KB mirrors)

2nd Experimental Hutch (13 m long)

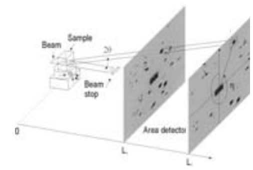
- heavy duty diffractometer for samples and environments up to 1 t (e.g. *in-situ* friction stir welding)
- depth resolved investigations with conical and spiral slit systems
- detector array of two individually positionable area detectors with distances up to 10 m from samples for very high angular resolution [F. Beckmann *et al.*, AIP CP705, Proc. SRI: 8th Int. Conf., American Institute of Physics, 2004, pp. 392-395]
- ultra fast microtomography setup with spatial resolution down to 1 μm
- focussing optics <10 μm (CRLs & KB mirrors)
- SAXS option
- space for user provided experiments



Setup for simultaneous wide and small angle scattering.
[Haeffner *et al.*, Mat. Sci Eng A-Struct 399 (2005) 120-127]



Principle of spiral slit technique for depth resolved phase sensitive analyses.
[R.V. Martins, V. Honkimäki, *Textures & Microstructures* 35, 145-152 (2003)]

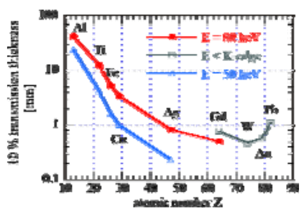


Principle of grain mapping by back-projection applying 3DXRD technique.
[H. F. Poulsen, *Three-Dimensional X-Ray Diffraction Microscopy*, Berlin, Springer, 2004]

Key Properties of High Energy X-Rays

- **High penetration depth**
  → non-destructive bulk properties measurable
  → deeply buried structures accessible
- **Large Ewald Sphere**
  → lines and planes in reciprocal space can be imaged
  → small Bragg angles (typically 5° to 15°), therefore, monitoring of complete diffraction rings with area detectors possible

- **Extinction and multiple Bragg scattering negligible**
- **Focussing to spot sizes in nm range possible**
  → combination of high penetration depth and high flux
  → very short data acquisition times possible (< 1 s)
  → non-destructive observation of highly dynamic processes
  → high spatial resolution narrowing the gap to electron microscopy



10% transmission thicknesses of technologically relevant metals for different x-ray energies.

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