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CHALLENGES IN X-RAY OPTICS FOR MODERN X-RAY SOURCES

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The recently launched ESRF upgrade programme 2009–2018 requires a strong, coordinated development program for X-ray optics. High quality X-ray optical systems are critical enabling technologies for delivering appropriately conditioned beams to the end-stations at new and refurbished beamlines (Fig. 1).

Four key aspects drive the new optics instrumentation development:

- Management of the increased heat load and power density on the optical elements due to brilliance and flux improvements,
- Micro- and nano-focusing,
- Beam stability,
- Preservation of wavefront form, coherence properties, beam homogeneity.

High heat load monochromators based on crystals (silicon and diamond) and on wide band-pass monochromators based on multilayers will represent a direction of strong development.

The various experimental stations need/demand beam dimensions ranging from decimetre size to nanometre size. The upgrade programme aims in particular at improving the focusing capabilities of elements such as mirrors, multilayers, zone plates, and refractive lenses in order to reach the 10nm spot size limit.

To carry out experiments with nanometre sized beams, not only suited optical elements must be available. An environment with high mechanical stability, low temperature fluctuations and low vibration levels will be necessary, including feed back systems using X-ray beam position monitors for white and monochromatic beams.

The quality of the optical elements has to be such that they degrade the beam quality as little as possible.

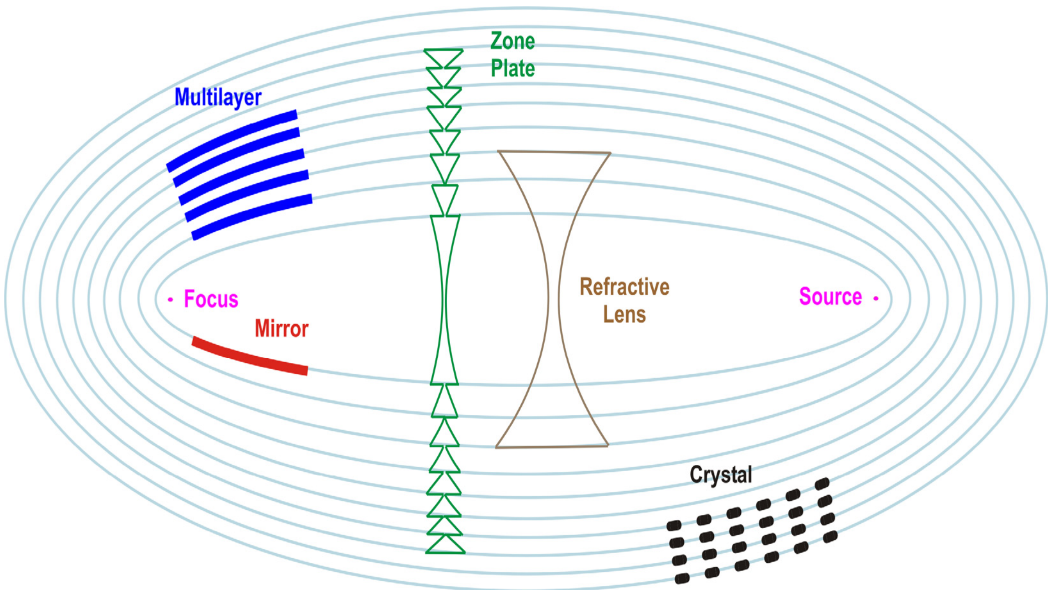
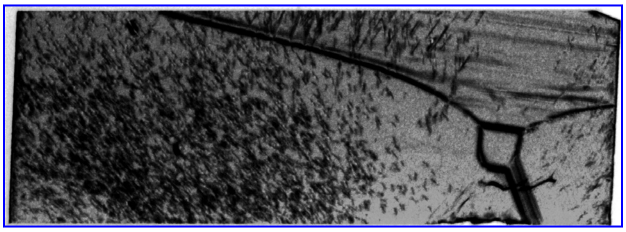
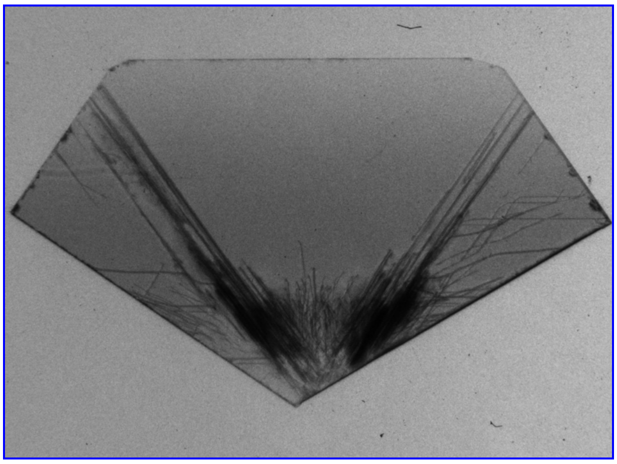


Figure 1. Schematic illustration of various X-ray optical elements for 3rd generation synchrotron beamlines. The upgrade programme aims at improving the focusing capabilities of elements such as mirrors, multilayers, zone plates, and refractive lenses in order to reach the 10 nm spot size limit. High heat load monochromators based on crystals and on multilayers will represent a second direction of strong development



a



b

Figure 2. Comparison of an X-ray topograph of an old, long time ago installed beam splitter out of nitrogen rich type Ib material (a) with an example of a new high quality plate (b).

The lateral (horizontal) dimension of the crystal in (a) is about 5 mm and that in (b) about 11 mm.

Synthetic single-crystalline HPHT-diamond is in principle the best-suited material for Bragg diffracting X-ray optical elements like beamsplitters or monochromators to be used in modern, powerful X-ray sources. Already in the early days of the 3rd generation sources the utilisation of diamonds was discussed, tested and X-ray optical elements were realised. However, a real break through in their application was not reached. The main reasons were, (and partly still are) by comparison with silicon, the low quality (bulk and surface), the limited availability and the small dimensions of the available material.

Since then a substantial effort was undertaken (and needs to be continued) in the fields of crystal growth, crystal processing and crystal characterisation to develop a high-quality diamond material is needed that combines the extremely high perfection of the crystal bulk with an excellent surface finish [1]. With regard to the quality of the crystal bulk, selected samples became available that locally may be dislocation free, with a very low level of local residual strain. However, at the moment the surface quality appears to be the most critical point to both achieve and study.

High quality type IIa (very low nitrogen impurity concentration) HPHT Diamond plates were investigated with white beam X-ray topography and in particular with high strain sensitive non-dispersive double crystal topography [2]. The results showed and confirmed the excellent local quality of present (selected) plates. This means that they contained large (for diamond) dislocation free regions and an extremely low residual strain level in the range below several 10^{-8}. This is a local strain level like in FZ silicon.

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