ESRF	**Experiment title:** Test of cylindrical and parabolic refractive X-ray lenses	**Experiment number:** MI 190, MI 245
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Report:

During the beamtime allocated within the proposals MI-190 and 245 we have tested x-ray refractive lenses with circular and with parabolic profile. Lenses with parabolic profile are far superior in performance to the lenses with drilled cylindrical holes aligned in a row. We will therefore concentrate in this report on the results obtained on the parabolic lenses. The lenses are made out of aluminium by means of a pressing technique which has been developed at the 2.Physikalisches Institut at the University of Technology RWTH in Aachen. Modern CNC tooling machines allows for the fabrication of pressing tools which have a parabolic profile with a radius of curvature at the tip of the parabola of 0.2mm. The precision of the pressing tools is 1μm and the individual lenses in the stack, forming the Compound Refractive Lens (CRF), are aligned in a row with the same precision. The experiments done with the new lenses were very successful and the results may be summarized as follows:

- The parabolic lenses are imaging devices able to image the source or an object illuminated by the source
- The focal length achieved varies between 0.5 and 2m.
- The smallest spot size achieved on the high β undulator of beamline ID22 was 1.3μm vertical times 7.1μm horizontal for 83 lenses in the stack and a focal length of 0.51m at 15keV
- The energy range covered by the lenses is from a few keV to about 8OkeV.
- They are free of spherical aberration.
- They are very robust, easy to align and to operate.
- X-ray refractive lenses are at least 1000 times less sensitive to surface roughness than mirrors, an aspect which alleviates considerably the requirements set on lens manufacturing.
- The gain of the Al lenses is between 50 and 100, depending on the focal length.
- It is possible to image an area of 200μm in diameter. The image is almost free of distortion.

- The resolution of the Al lenses is 1μm.
- The lenses withstand the white beam of the undulator without loss in performance.
- Besides imaging the lenses generate a small spot size which can be used as a secondary x-ray source with an outstanding lateral coherence.
- We have developed the full theory of imaging by refractive x-ray lenses. When using Be rather than Al as lens material we expect an improved performance. The gain may be as high as 1000 and more. The resolution is expected to be 0.2μm.

We expect the new parabolic x-ray refractive lenses to be a vital part of a new microscope working in the hard x-ray range. The microscope will be complementary to other microscopes. We expect it to be especially helpful for opaque samples where sample preparation is detrimental to the state of the object.

References:

1. A.Snigirev, V. Kohn, I. Snigireva, B. Lengeler A compound refractive lens for focussing high energy X-rays, Nature 384, 49 (1996)
2. A. Snigirev, V. Kohn, I. Snigireva, A. Souvorov, B. Lengeler Focusing high-energy X-rays by compound refractive lenses, Applied Optics 37 653 (1998)
3. B. Lengeler, J. Tuemmler, A. Snigirev, I. Snigireva, C. Raven Transmission and gain of singly and doubly focusing refractive X-ray lenses, accepted for publication in J. Applied Physics
4. B. Lengeler, M. Richwin, C. Schroer, J. Tuemmler, A Snigirev, I. Snigireva, M. Drakopoulos, submitted to Nature