ESRF	**Experiment title:** X-Ray Microscope Based on Compound Refractive Lenses	**Experiment number:** MI-372
Beamline: ID22	**Date of experiment:** from: 15.2.99 and 19.6.99 to: 18.2.99 and 22.6.99	**Date of report:** August 30, 1999
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Report:
During the beam time allocated for MI-372 two mayor aspects of x-ray microscopy based on compound refractive lenses (CRLs) were investigated. Firstly, enlarging phase contrast imaging using the hard x-ray CRL microscope, secondly, the pink beam imaging abilities of the CRL microscope were examined.

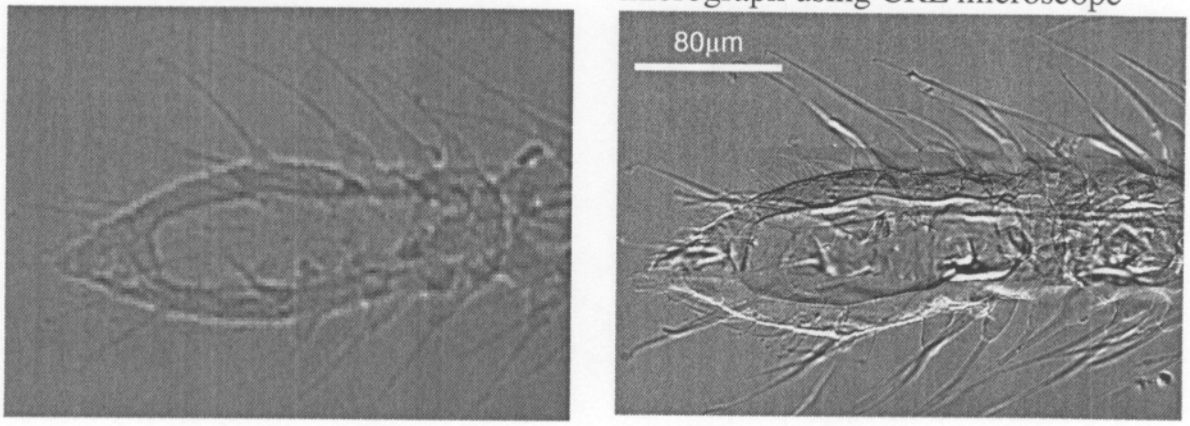
We have evaluated the possibilities of phase contrast imaging using the CRL microscope. The samples were illuminated from behind with the (partially) coherent x-rays from the undulator source at ID22. A compound refractive lens (objective lens) placed a distance $L_1 + L_p$ behind the sample transfers the image of the sample onto a CCD-camera (Frelon2000) placed $L_2 = fL_2/(L_2 - f)$ behind the lens. In this setup, the sample is out of focus by the variable distance L_p and the near field behind the sample is imaged onto the detector in analogy to ordinary phase contrast imaging. The resolution of the images improved as L_p approached zero. As opposed to ordinary phase contrast imaging there is significant phase contrast even for $L_p = 0$mm, for which best imaging results were obtained. The CRL micrographs were compared to ordinary phase contrast images of the same samples. In all cases, the resolution of the CRL micrographs were significantly better.

A variety of samples was imaged, including biological specimens (e. g., insects), electronic devices (e. g., voids due to electromigration in passivated aluminium conductors), and samples from material science. In Figure 1 an ordinary phase contrast image of an insect antenna is compared to its CRL micrograph ($E = 23.3$keV, $f = 1.22$m, $L_1 = 1.30$m, $L_2 = 22.62$m, magn.= 17.5). The resolution of the CRL micrograph is about 0.5μm and significantly higher than that of ordinary phase contrast image.

Figure 1:

(a) Phase contrast image of insect antenna

(b) Full field phase contrast micrograph using CRL microscope



Using appropriate filters (but no monochromator), all but one harmonic of the undulator spectrum can be strongly suppressed. The resulting "pink beam" spectrum has a relative band width of approximately $\Delta E/E = 10^{-2}$ and up to two orders of magnitude more flux than the monochromatic beam ($\Delta E/E = 10^{-4}$). While imaging with the CRL microscope using a pink beam can drastically reduce the exposure time, chromatic aberration of the CRLs can deteriorate the image quality. Choosing an appropriate pink beam filter, short exposure times and high resolution can be combined. We have tested two pink beam filters, both involving a Pd-mirror (reflection angle: 0.15°) suppressing x-rays above 24keV. With an aluminium filter (thickness 2-4mm) the pink beam harmonic (5th undulator harm.) was set slightly below 24keV. The relatively broad spectrum resulted in a fair resolution (above 1μm). Using a molybdenum filter (thickness 250μm) with the pink beam harmonic (5th) slightly below 20keV (Mo K-edge) excellent imaging quality (comparable to that with monochromatic x-rays) was combined with a reduction of the exposure time by about one order of magnitude (see Figure 2).

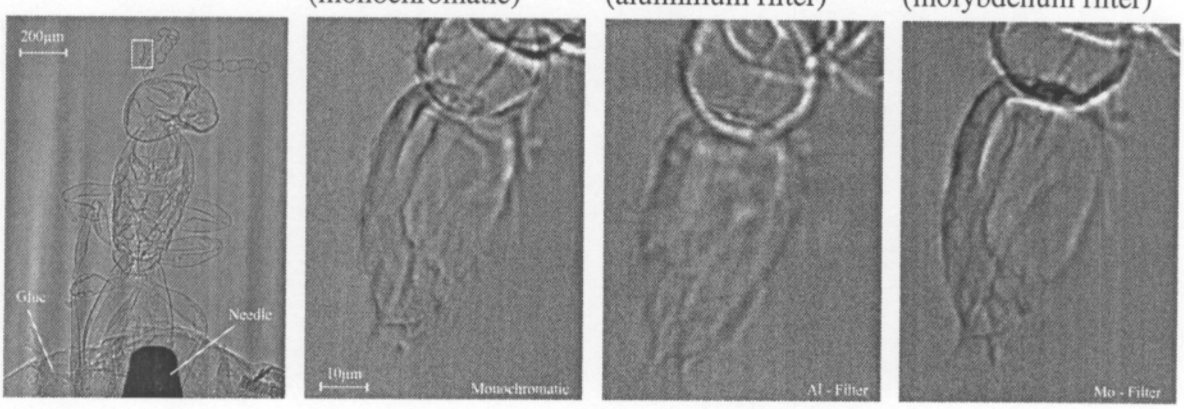
Figure 2:

(a) young wasp

(b) wasp antenna (monochromatic)

(c) pink beam image (aluminium filter)

(d) pink beam image (molybdenum filter)



Publications: B. Lengeler, J. Tümmler, A. Snigirev, I. Snigireva, C. Raven, *J. Appl. Phys.*, **84**, 5855-5861 (1998), B. Lengeler, C. G. Schroer, M. Richwin, J. Tümmler, M. Drakopoulos, A. Snigirev, I. Snigireva, *Appl. Phys. Lett.*, **74 (26)**, 3924-3926 (1999), B. Lengeler, C. G. Schroer, J. Tümmler, B. Benner, M. Richwin, A. Snigirev, I. Snigireva, M. Drakopoulos, *J. Synchrotron Rad.*, **6 (6)**, 1153-1167 (1999)

Publications on phase contrast and pink beam imaging are in preparation.