Coherent microscopy with soft X-rays

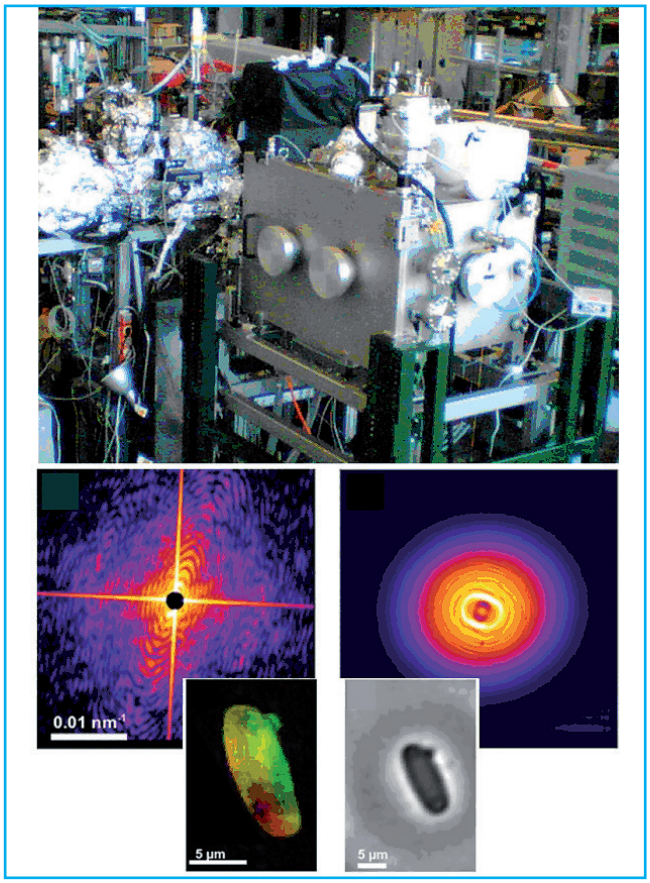
Dr. R. Heine, Dr. A. Rosenhahn, IFG, Karlsruher Institut für Technologie, (September 2010)

Application Note

Researchers from the University of Heidelberg use X-ray CCD cameras for coherent microscopy at synchrotrons (e.g. BESSY, Berlin) and free electron laser sources (e.g. FLASH, Hamburg). Area detection is used to capture scattering information across a large scattering angle which provides high resolution information of microscopic biological objects.

X-rays are a versatile probe to study biological objects due to their specific interaction with matter. Especially in the soft x-ray range, the high intrinsic material contrast allows imaging of non-periodic biological objects with high spatial resolution without staining [1]. To make full use of the highly coherent, brilliant x-ray sources as third generation synchrotrons or free electron lasers, we develop coherent microscopy techniques such as digital in-line x-ray holography (DIXH) and coherent diffractive imaging (CDI) and apply such techniques towards biological samples [2-5].

In contrast to conventional microscopy we do not use any optical elements and directly capture the scattering pattern behind the sample by an Andor DODX436-BN back-illuminated X-ray CCD camera, 2048x2048 pixels, with pixel size 13.5x13.5 µm². This camera has good quantum efficiency in the soft x-ray range and can be mounted completely inside the vacuum chamber HORST (see figure), a development funded by the BMBF. The in-vacuum mounting of the detector allows us to adjust the position and distance between sample and detector during the experiment without breaking the vacuum. The high dynamical range of the CCD of 16 bit is needed in order to detect the finest interference fringes, while the cooling of the chip down to -50 °C minimizes the noise. Exposure times from several minutes down to 200 ms have been realized. Our main application is to image biological objects in order to unravel their internal organization. As an example the figure shows coherent microscopy of the marine diatom *Navicula perminuta* which was recorded with coherent femtosecond pulses provided by the free electron laser FLASH [5].



Coherent microscopy: Top Experiment Middle Examples for scattering patterns recorded [5] Bottom reconstructions from the scattering patterns [5].

[1] G. Schmahl et al., Rev. Sci. Instrum. 66, 1282 (1995)
[2] A. Rosenhahn et. al., Ultramicroscopy, 107(12), 1171-1177 (2007)
[3] A. Rosenhahn et. al., JOSA A, 25(2), 416-422 (2008)
[4] A. Rosenhahn et. al., Optics Express 17(10), 8220-8228 (2009)
[5] A. P. Mancuso et. al., Coherent imaging of biological samples with femtosecond pulses at the free-electron laser FLASH, New Journal of Physics, 12 (2010), Article 035003

Contact:
Dr. Axel Rosenhahn
Applied Physical Chemistry, University of Heidelberg
Mail: rosenhahn@uni-heidelberg.de
www.pci.uni-heidelberg.de/apc/rosenhahn/