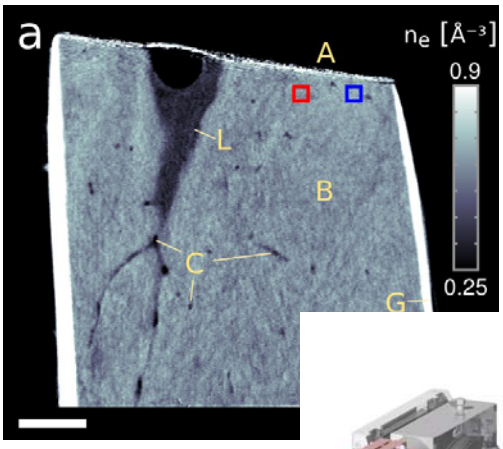

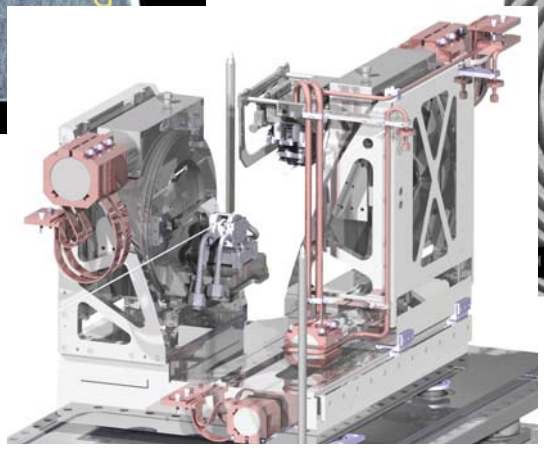

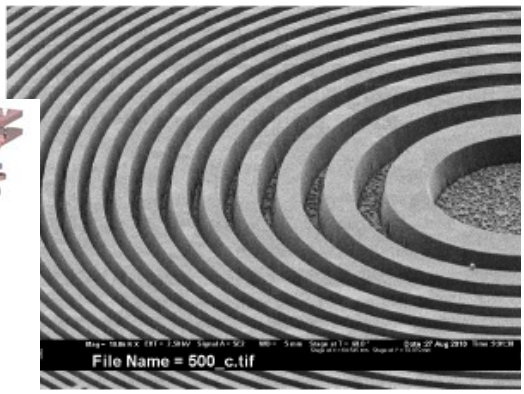

SLS Symposium on

Coherent X-Ray Imaging

Tuesday, October 5, 2010

10:00 to 12:15, WBGB/019

10:00 X-Ray Diffraction Microscopy: turning the rather esotheric into a usable technique
Andreas Menzel, M. Dierolf, P. Thibault, F. Pfeiffer, C.M. Kewish, M. Guizar-Sicairos, A. Diaz and O. Bunk

10:30 The Materials Science Upgrade
Philip Willmott, D. Meister and M. Lange

11:00 Coffee

11:15 Diamond Fresnel zone plates for high power X-ray beams
Sergey Gorelick, J. Vila-Comamala, V. Guzenko, R. Barret, B. Patterson and C. David

11:45 Biological soft X-ray tomography
Carolyn A. Larabell

X-Ray Diffraction Microscopy
turning the rather esoteric into a usable technique

Andreas Menzel,[1] Martin Dierolf,[2] Pierre Thibault,[2] Franz Pfeiffer,[2] Cameron M. Kewish,[1,3] Manuel Guizar-Sicairos,[1] Ana Diaz,[1] and Oliver Bunk[1]

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X-ray diffraction microscopy (XDM), also called coherent diffractive imaging (CDI) or lensless imaging, analyzes the distribution of light scattered by the specimen in order to obtain highly resolved micrographs. Three-dimensional (3D) information can be gained by either analyzing directly the scattering distribution in three dimensions [1] or by combining XDM with tomographic methods [2]. As originally introduced [3], XDM requires the illumination to be coherent and the specimen to be isolated. These stringent experimental constraints have been successfully relaxed in recent years [4–6], rendering the technique significantly more practicable.

This talk aims to clarify—without reverting to too many French names or Greek terminology—how XDM can yield quantitative 3D information with high resolution, high specificity, and high dose efficiency in in a reliable and robust manner.

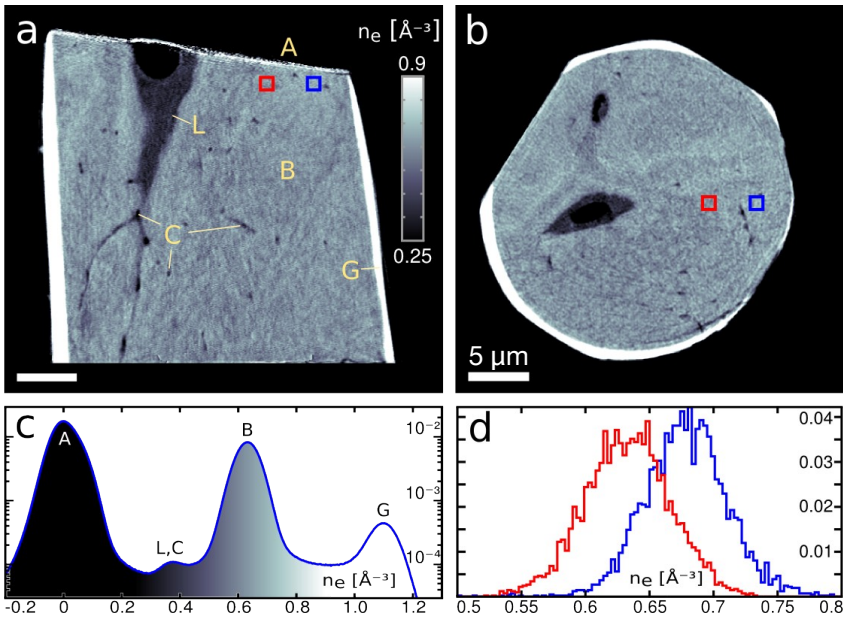

Figure: Tomographic reconstruction of a murine bone sample [7]. **(a,b)** Cuts parallel and perpendicular to the rotation axis, respectively. The phase values have been converted to quantitative electron density n_e. The labelled structures are (A) air, (B) bone matrix, (C) canaliculi, (G) Gallium coating, (L) osteocyte lacuna. **(c)** Histogram of electron density values in the reconstructed volume. **(d)** Comparison of the bone peak (label B) of the histogram for two volumes of 1 µm^3 indicated by the red and blue boxes in (a) and (b). At the micron scale, the detection threshold of density fluctuations is about 0.2% of the mean density.

References:

[1] H.N. Chapman *et al.*, *J. Opt. Soc. Am. A* (2006) **23** 1179, doi: 10.1364/JOSAA.23.001179
[2] J.W. Miao *et al.*, *Phys. Rev. Lett. (*2006) **97** 215503, doi: 10.1103/PhysRevLett.97.215503
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The Materials Science Upgrade

Phil Willmott, Dominik Meister, and Michael Lange

The Materials Science beamline is to undergo a major upgrade, beginning at the end of October 2010. The present insertion device, a 61-mm period minigap wiggler, will be replaced with a cryogenically cooled, permanent magnet undulator (CPMU) with a 14 mm period. The brilliance should increase by over a factor of 100 (Fig. 1) up to 20 keV, and remain comparable or superior than the present device up to 40 keV. A consequence of this is that the major optical components, in particular the double-crystal monochromator (DCM) and mirror system, must also be changed (see Fig. 2). The DCM is based on the design already implemented at several hard x-ray beamlines at the SLS, although the producer is Cinel and not Kohzu. The two-mirror system has been designed and constructed by AMI, PSI.
Design aspects in relationship to the types of experiment that will be available after the upgrade are discussed. A potentially very interesting development will be the possibility of carrying out coherent lensless imaging far from the direct beam around Bragg peaks, which is made possible by using the surface diffractometer and the new Eiger detector.

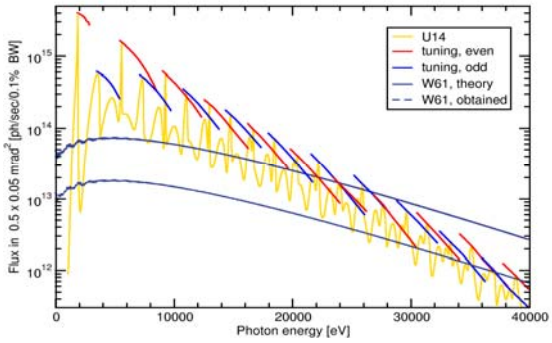

Fig. 1: the flux of the W61 wiggler compared to that of the U14 undulator

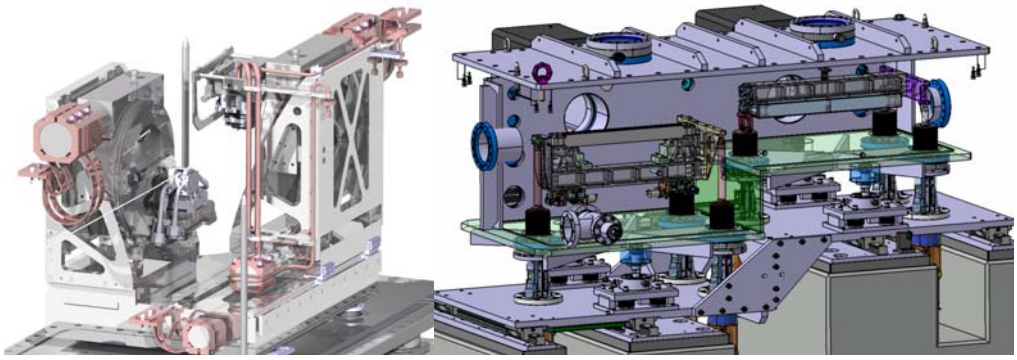

Fig. 2: The DCM (left) and double-mirror system (right)

Diamond Fresnel zone plates for high power X-ray beams

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Focusing of intense beams from X-ray free electron lasers (XFELs) by Fresnel zone plates (FZPs) is attractive because they can provide very high spatial resolution and, at the same time, accept a full, coherent millimeter sized XFEL beam. In addition, the wave-front can be preserved or manipulated using FZPs. However, since FZPs consist of nanostructures on thin support membranes, they are prone to suffer from radiation damage. FZPs, and they may even be destroyed after a single XFEL pulse [1].

Unique properties of diamond, such as extremely high thermal conductivity, low thermal expansion, in addition to its low X-ray absorption make diamond the most thermally stable material which is likely to survive intense XFEL beams. Making FZPs of diamond is, therefore, an excellent solution for wave-front preserving focusing of intense X-rays with a high spatial resolution. Efficient focusing of hard X-rays by diamond FZPs is difficult because the zones must be sufficiently tall (>>1 µm) to provide a phase-shift as close to π as possible for the best diffraction efficiency. Diamond can be structured by oxygen plasma etching, however, because of very slow etching rates of diamond, erosion of the etch-mask becomes an issue, and achieving sufficiently tall structures in diamond is challenging. By using 100 keV electron beam lithography, we were able to fabricate thick etch-masks that were more resistant to the erosion processes. Using these thick masks and an optimized reactive ion etching (RIE) process in inductively coupled plasma (ICP) allowed us to etch deeper (down to 2-3 µm) into the diamond layers. We present first ever fabricated FZPs made entirely off diamond, discuss the fabrication details and present first resolution and efficiency tests. A possibility to enhance the efficiency of diamond FZPs by coating them with Ir is also discussed.

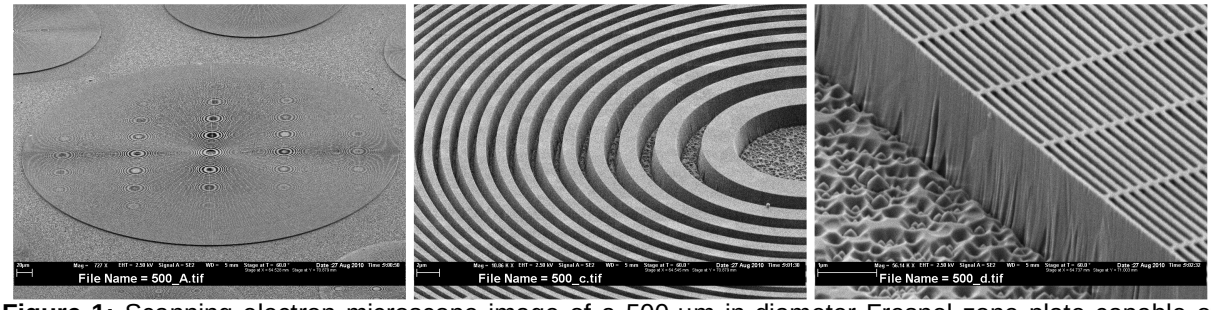

Figure 1: Scanning electron microscope image of a 500-µm in diameter Fresnel zone plate capable of collecting a full coherent XFEL beam. The FZP has a 100 nm outermost zone and etched 2.2 µm deep into a CVD diamond layer. (from left to right) Overview of the zone plate, central zones and outermost zones.

References:

[1] V. Ayvazyan et al., Eur. Phys. J. D 37 (2006) 297.

Biological soft X-ray tomography

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Physical Biosciences Division, Lawrence Berkeley National Laboratory

Soft X-ray tomography (SXT) generates 3-D views of whole, hydrated cells at better than 50 nm resolution[1]. SXT utilizes photons in the 'water window,' with energies between the K shell absorption edges of carbon (284 eV, λ=4.4 nm) and oxygen (543 eV, λ=2.3 nm). These photons readily penetrate the aqueous environment while encountering significant absorption from carbon- and nitrogen-containing organic material. In this energy range (referred to as the "water window") organic material absorbs approximately an order of magnitude more strongly than water, producing a quantifiable natural contrast and eliminating the need for contrast enhancement procedures to visualize cellular structures[2]. I will show examples of biological applications of SXT including the architectural organization of yeast cells and structural changes during the cell cycle, effects of chemotherapeutic agents on pathogenic organisms, host-pathogen interactions, and nuclear organization during cell differentiation.