Ptychographic Imaging of Fossil Diatom Structures with Soft X-Rays.

M. ROSE[1], P. SKOPINTSEV[1], D. DZHIGAEV[1,6], T. SENKBEIL[2,3,4], A. von GUNDLACH[2,3,4], T. GORNIAK[2,3,4], O. GOROBTSOV[1,5], A. SHABALIN[1], J. VIEFHAUS[1], A. ROSENHAHN[2,3,4] and I. A. VARTANYANTS[1,6]

[1] Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany
[2] Applied Physical Chemistry, University of Heidelberg, Heidelberg, Germany
[3] Institute of Functional Interfaces, Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany
[4] Analytical Chemistry – Biointerfaces, Ruhr-University Bochum, Bochum, Germany
[5] National Research Center, Kurchatov Institute, Moscow, Russia
[6] National Research Nuclear University MEPhI, Moscow, Russia

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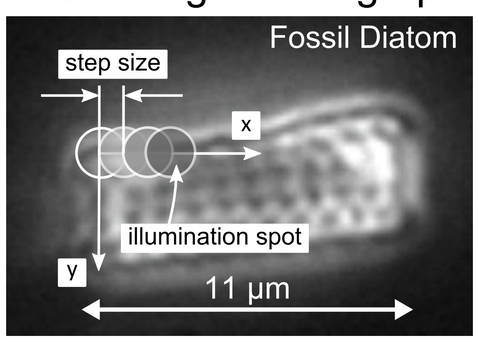
Abstract

Imaging of biological samples in the water window [1] offer high chemical contrast between Oxygen and Carbon. To avoid resolution limitations due to lens based microscopy techniques the coherent diffractive imaging (CDI) method is favourable for high resolution imaging.

In order to measure extended samples the ptychographic coherent diffractive imaging technique (PCDI) is applied. Images of a test pattern and a fossil diatom are reconstructed [2] with the extended ptychographic iterative engine (ePIE) [3] at 55 nm and 286 nm resolution respectively.

Ptychographic Imaging

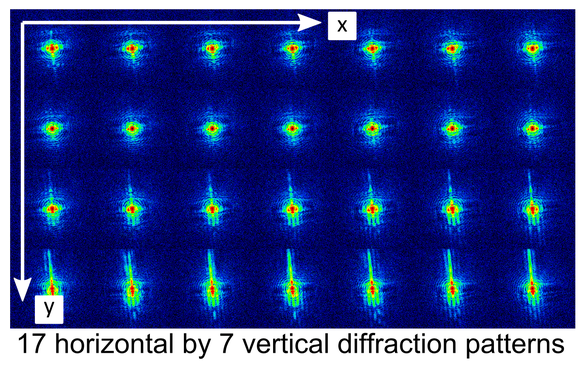
Visible Light Micrograph



Ptychography is a scaning coherent diffractive imaging method to measure extended objects at high spatial resolution

Diffraction patterns are collected from the sample with 60 % overlap of adjacent positions. A step size of 800 nm was used.

Set of Diffraction Patterns



17 horizontal by 7 vertical diffraction patterns

(only 7 by 4 patterns are shown here)

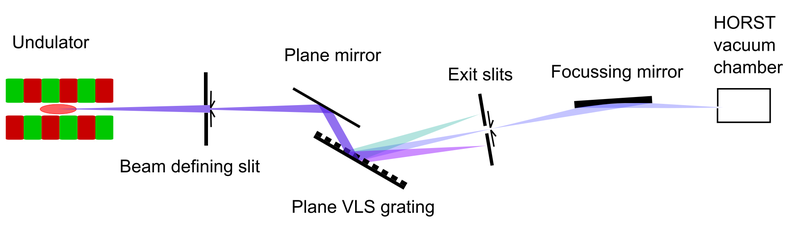
Experiment

Soft X-Ray Beamline @ 500 eV

PETRA III P04 Beamline for soft X-ray diffraction experiments

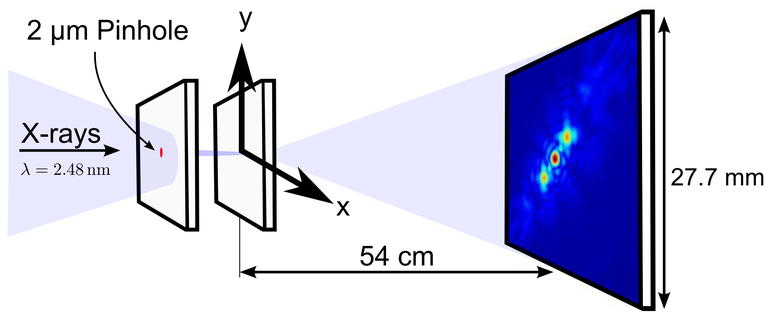
Monochromator resolving power $\frac{E}{\Delta E} = 6000$

Temporal coherence length $l_t = 15\,\mu m$



Soft X-Ray Scattering Chamber

HORST - Holografische Röntgen Streuapparatur (Holographic Röntgen Scattering Chamber) [4]

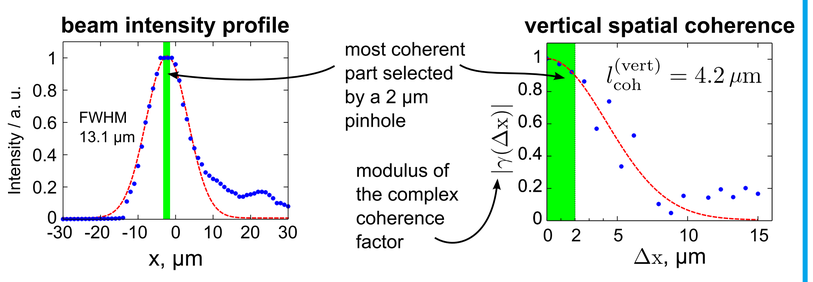


X-Ray Coherence Properties

The complex coherence factor was measurement with the non-redundant array (NRA) method [5]

$$|\gamma(\Delta x)| = \frac{\Gamma_{12}}{\sqrt{I_1 \cdot I_2}}$$

Γ_{12}: Mutual intensity; $I_1 \cdot I_2$: Intensities at two different x positions



Ptychographical Reconstructions

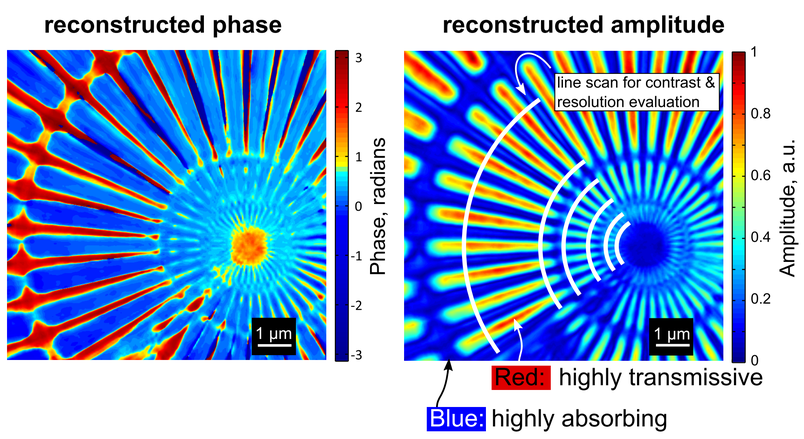
The reconstruction was performed with the extended ptychographic iterative engine (ePIE) [3]. The reconstructions were obtained after running up to 500 iterations.

The reconstruction yields the complex object function.

$$O = \underbrace{\exp\left[-k\beta\Delta z\right]}_{\text{amplitude}} \cdot \exp\left[-\mathrm{i}\underbrace{k\delta\Delta z}_{\text{phase}}\right]$$

The resolution obtained by the reconstruction process depends on the scattering strength (i.e. of the complex refractive index) of the object. For the test pattern and the diatom 55 nm and 286 nm resolution have been achieved.

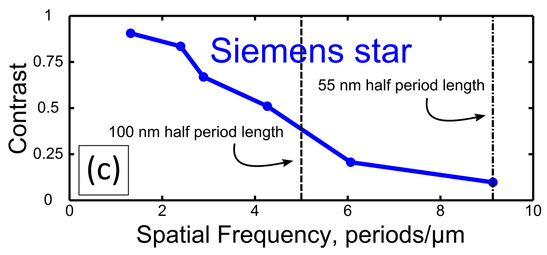
Test Pattern



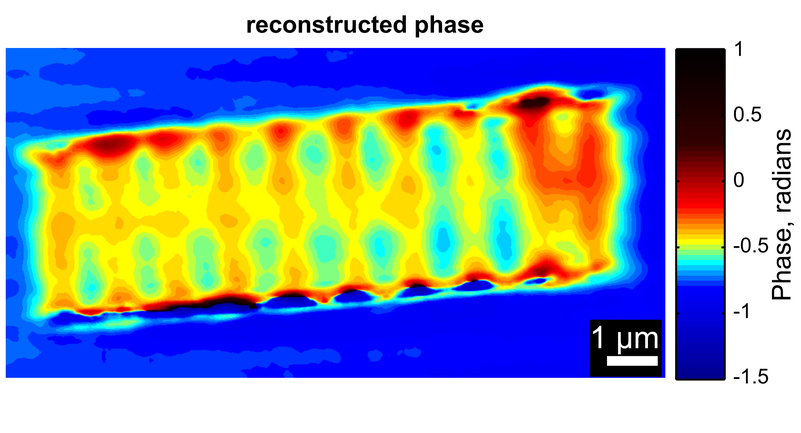
The edge contrast is an one dimensional merit of resolution which is plotted as a function of spatial frequency

$$C = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$

maximum amplitude; minimum amplitude



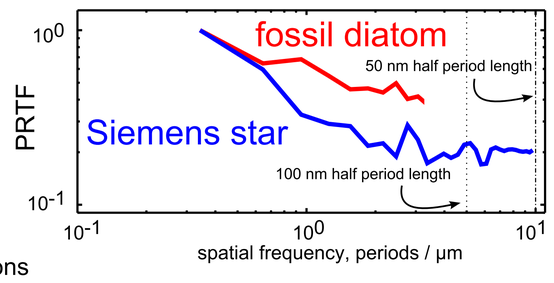
Fossil Diatom



The phase retrieval transfer function (PRTF) [6] is an one dimensional merit of resolution in frequency domain

$$\mathrm{PRTF} = \frac{\left\langle \left\langle \sqrt{I_j^{rec}} \right\rangle_j \right\rangle_\phi}{\left\langle \left\langle \sqrt{I_j^{meas}} \right\rangle_j \right\rangle_\phi}$$

reconstructed intensities; azimuthal average; measured intensities; average over positions



References

[1] K. Gieweckemeyer *et al.*, Opt. Express 19, 1037 (**2011**)
[2] M. Rose *et al.*, in preparation (**2014**)
[3] A. M. Maiden and J. M. Rodenburg, Ultramicroscopy 109, 1256 (**2009**)
[4] T. Gorniak and A. Rosenhahn, Z. f. Phys. Chem. online, 2196 (**2014**)
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[6] R. N. Wilke *et al.*, Acta Crystallographica Section A 69, 490 (**2013**)

Summary

The dedicated vacuum camber HORST has been used

High spatial coherent X-rays have been selected by a pinhole

Resolution is evaluated by edge contrast analysis and PRTF

Ptychography shows diatom structures in the water window

Outlook

Data with extended resolution down to 25 nm will be evaluated

Data with beam stop will be evaluated. It is expected to yield reconstructions with larger contrast at 50 nm and 25 nm resolution

Max.Rose@DESY.de +49 40 8998 4505