KR 2: X-Ray Imaging, Holography, Ptychography and Tomography (with MI)

Time: Wednesday 9:30–11:30 Location: MER 02

Invited Talk KR 2.1 Wed 9:30 MER 02

X-ray Microscopy: Imaging the Chemistry Inside — •Christian G. Schroer — Photon Science, DESY, Notkestr. 85, 22607 Hamburg — Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

One key strength of hard X-ray microscopy is that it can image the inner structures of an object without destructive sample preparation. Exploiting various X-ray analytical contrasts, such as fluorescence, diffraction, and absorption, the elemental, structural, and chemical information can be obtained from inside a sample, e. g., a chemical reactor. Conventional X-ray microscopy is currently limited by X-ray optics to a few tens of nanometers. One way to overcome this limitation is scanning coherent X-ray diffraction microscopy also known as ptychography [1]. It can be combined with spectroscopy to obtain chemical information on a given element of interest [2]. In combination with tomography, the three-dimensional structure of an object can be reconstructed with unprecedented spatial resolution [3]. Here, an overview is given over multimodal X-ray imaging for materials research at modern synchrotron radiation sources.

[1] J. Rodenburg, H. Faulkner, Appl. Phys. Lett. 85, 4795 (2004); P. Thibault, et al., Science 321, 379 (2008); A. Schropp, et al., Appl. Phys. Lett. 96, 091102 (2010); A. Schropp, et al., Appl. Phys. Lett. 100, 253112 (2012); J. Reinhardt, et al., Ultramicroscopy 173, 52 (2017).

[2] R. Hoppe, et al., Appl. Phys. Lett. 102, 203104 (2013).

[3] M. Dierolf, et al., Nature 467, 436 (2010); M. Holler, et al., Scientific Reports 4, 3857 (2014).

KR 2.2 Wed 10:00 MER 02

Imaging with hard X-rays and Nanometer Resolution using Multilayer Zone Plates — •Jakob Soltau[1], Christian Eberl[2], Tim Salditt[1], Hans-Ulrich Krebs[2], and Markus Osterhoff[1] — [1]Röntgenphysik, Uni-Göttingen, Friedrich-Hund Platz 1, 37077 Göttingen — [2]Materialphysik, Uni-Göttingen, Friedrich-Hund Platz 1, 37077 Göttingen

The resolution of zone plates is determined by their smallest zone width. Multilayer zone plates (MZP) can be fabricated using the process of pulsed laser deposition, which allows zone width of 5 nm and less and therefore enabling imaging of X-rays on a nanometer scale [1]. The central challenge in the development of hard X-ray nano-focusing MZPs is the fulfilling of the Bragg condition across the zone plate. To achieve this the individual zones need to be tilted. Latest experiments using tilted-MZPs at synchrotron sources demonstrated successfully a resolution of a few nanometer in a wide X-ray energy range from 7 keV at DESY/Petra III and for the first time with photon energies above 100 keV at ESRF. A new setup and a motorized stage significantly reduced the set-up and measuring time in scanning X-ray microscopy allowing high resolution imaging of soft- and hard-matter samples in a shorter time. In addition to the experiments, 3D simulations have been performed. The propagation of electromagnetic waves inside and behind the MZP proved the advantage of circular MZPs to achieve very high photon flux densities in a single focal point. The simulations were revealing interaction processes like e.g. dynamical diffraction inside the MZPs. [1] Eberl, C. et al. Appl. Surf. Sc

KR 2.3 Wed 10:15 MER 02

The Fluence-Resolution Relationship in Holographic and Coherent Diffractive Imaging — •Johannes Hagemann and Tim Salditt — Institut für Röntgenphysik, Friedrich-Hund-Platz 1, University Göttingen, 37077 Göttingen

The simple question "Which resolution do I get for the invested photon fluence?" is extremely important for x-ray imaging of radiation sensitive specimen, such as biological cells and tissues. This work [1] presents a numerical study of the fluence-resolution behavior for two coherent lens-less x-ray imaging techniques. To this end we compare in numerical experiments the fluence-resolution relationship of inline near-field holography (NFH) and far-field coherent diffractive imaging (CDI). To achieve this, we carry out the phase reconstruction using iterative phase retrieval algorithms on simulated noisy data. Using the incident photon fluence on the specimen as control parameter we study the achievable resolution for two exemplary phantoms (cell and bitmap). A survey based on maximum likelihood estimation [2] of CDI and NFH showed in principle no difference in the encoded information of the measured data for a given fluence. In the current approach we assess the actual reconstructability of the CDI/NFH data via direct phase retrieval. We use then the Fourier Ring Correlation as measure of reconstruction quality i.e. the achievable resolution. Our results indicate a superior performance of holography compared to CDI, for the same fluence and phase reconstruction procedure.
[1] J. Hagemann and T. Salditt, Acta Crystallogr. A, (in review)
[2] T. Jahn et al., Acta Crystallogr. A, (2017), 73, 1-11

KR 2.4 Wed 10:30 MER 02

Simulations towards high magnification setups in X-ray Talbot-interferometry — •Andreas Wolf, Veronika Ludwig, Jens Rieger, Max Schuster, Maria Seifert, Georg Pelzer, Thilo Michel, Gisela Anton, and Stefan Funk — ECAP - Erlangen Centre for Astroparticle Physics, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen

Compared with the traditional attenuation contrast, X-ray Talbot-interferometry can yield additional information in terms of the differential phase contrast (DPC) and the dark field contrast (DFC) images.

In this imaging modality, which is primarily pursued in the field of medical diagnostics and soft tissue imaging, the Talbot effect leads to the generation of self images of a grating in the beam path. With respect to the thus created spatial reference pattern and by introducing a second grating, the aforementioned contrast modalities can be retrieved either via a phase-stepping approach or by using Moiré-fringes in a single-shot scheme.

In this contribution, we present simulation studies of Talbot-interferometer-based setups featuring high magnifications towards future applications for imaging at XFEL-beamlines and in the field of laboratory astrophysics where a high magnification of object structures is needed to resolve the generated shocks.

15 min. break

KR 2.5 Wed 11:00 MER 02

X-Ray Phase-Contrast Tomography with Anisotropic Source Conditions — •Malte Vassholz, Leon Merten Lohse, and Tim Salditt — Institute for X-Ray Physics, University of Göttingen, Germany

Hard x-ray tomography offers a unique capability to nondestructively map out the three-dimensional structure of a body or material. A major challenge for high-resolution and/or phase-contrast tomography in the laboratory, is the lack of high-brilliance table-top x-ray sources. By suitable generalization of the tomographic measurement geometry and the reconstruction framework, one can significantly relax the brilliance/coherence condition in one of the two lateral source dimensions [1], opening up new opportunities towards nanoscale resolution with low-brilliance table-top x-ray sources. To this end, the framework of the two-dimensional Radon transform, which is the common basis for most analytical x-ray tomography applications, is replaced by the three-dimensional Radon transform. We show applications for absorption tomography as well as phase-contrast tomography for anisotropic source conditions with aspect ratios larger than two orders of magnitude in the lateral source dimensions.

[1] M. Vassholz, B. Koberstein-Schwarz, A. Ruhlandt, M. Krenkel, and T. Salditt, Phys. Rev. Lett. 116, 088101 (2016).

KR 2.6 Wed 11:15 MER 02

Core-shell-shell nanowires studied by coherent x-ray nanobeam — •Arman Davtyan[1], Vincent Favre-Nicolin[2], Ryan B. Lewis[3], Hanno Küpers[3], Lutz Gelhaar[3], Dominik Kriegner[4], Ali Al-Hassan[1], Otmar Loffeld[1], and Ullrich Pietsch[1] — [1]Faculty of Science and Engineering,University of Siegen,57068 Siegen,Germany — [2]The European Synchrotron,71 Avenue des Martyrs,Grenoble,France — [3]Paul-Drude-Institut für Festkörperelektronik,Hausvogteiplatz 5-7,D-10117 Berlin,Germany — [4]4 Department of Condensed Matter Physics,Charles University, Ke Karlovu 5,121 16 Prague 2,Czech Republic

Core-shell-shell heterostructure nanowires (NWs) with 140nm GaAs core, 10nm In(0.10)Ga(0.90)As inner shell and 30nm GaAs outer shell have been investigated by combining coherent x-ray diffraction imaging (CXDI) and ptychograpy in the Bragg geometry. NWs were grown on a prepatterned substrate. Individual nanowires were measured at the ID01 beamline of the ESRF with coherent x-rays of 9keV energy and 150x200 nm full width half maximum (FWHM). 2D ptychography at GaAs (111) Bragg reflection was applied to investigate the nanowire along the growth axis. Ptychographic reconstruction shows the homogeneous structure of the wire along the growth axis. CXDI was applied to record the 3D reciprocal space maps around the symmetric GaAs (111) reflection at different heights along the NW growth axis.