MI 7: Poster: Microanalysis and Microscopy

Chair: Enrico Langer (TU Dresden) and Hartmut S. Leipner (Martin-Luther-Universität Halle-Wittenberg)

Time: Wednesday 18:00–20:00 Location: P4

MI 7.1 Wed 18:00 P4

Anisotropic X-ray optics for laboratory-based X-ray Imaging — •Toni Schiller, Malte Vassholz, and Tim Salditt — Institut für Röntgenphysik, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, Göttingen

Recently, we proposed a technique for high resolution x-ray tomography with anisotropic source conditions [1]. This technique combines higher photon-flux of an extended source in one dimension with high spatial resolution of a point-source in the other. In that way imaging and tomography with a spatial resolution limited to the point-source direction can be achieved, applying modified Radon-Transform for reconstruction.

The content of this work presents technical solutions building and improving such a laboratory-setup. The aim is to push spatial resolution further from 100μm to several microns. Main parts of the setup are a liquid-jet Gallium alloy x-ray-source and a high-performance mirror-optic. The mirror-optic focuses chromatic Ga-Kalpha light at 9.2keV to a focal spot of 70μm FWHM . Within the focal plane a slit aperture of a few microns in height and >100μm in width generates a virtual anisotropic source spot for 3D-Radon-Tomography. Characterizing source parameters as well as mirror-optic performance leads to geometric optimization of the setup applying theoretical models of wave propagation. Furthermore sampling and reconstruction routines are optimized to reduce acquisition as well as processing time.

[1] M.Vassholz, B.Koberstein-Schwarz, A.Ruhlandt, M.Krenkel and T.Salditt; Phys. Rev. Lett. 116, 088101 * Published 24 February 2016

MI 7.2 Wed 18:00 P4

Ultra-narrow Germanium-slits and waveguides for laboratory and synchrotron x-ray applications — •Ferdinand Döring, Sarah Hoffmann-Urlaub, Mike Kanbach, and Tim Salditt — Institute for X-Ray Physics Friedrich-Hund-Platz 1 37077 Göttingen Germany

Modern nano-beam x-ray diffraction and imaging applications are based on accurately manufactured elements. Recently we developed x-ray waveguides to facilitate coherence beams with flat wavefrontsconfined down to below 20nm. To open a new oppotiunity for beamshaping, we adapted the known processes of waveguide fabrication to slit production. For a larger angular acceptance, the optical thickness has to be reduced while the absorption (in the cladding) needs to stay sufficiently high. Therefore, we replaced silicon by germanium as cladding material. We use a lithographic manufacturing processes at UV 400nm in combination with reactive ion etching and germanium wafer bonding of 500um thick 20mm x 20mm sampels. Along the vertical direction, the slit size is varied from 100nm up to 1000nm, while the horizontal size is in the rage between 1um and 1000um. Germanium slits showed a prominent modification of the challes during cross-section bonding. The growth of an interlayer inside the channels decreases the wall roughness resulting in round boundaries. That is why we applied the improved germaniumprocess to waveguide fabrication with the result of approximately round waveguid channels exhibiting a diameter of 100 nm and a multimodal exit field of hight transmission. The fabrication is guided by finite differences simulation.

MI 7.3 Wed 18:00 P4

Simulation and Reconstruction of Coherent Modes for Near Field Imaging — •Johannes Hagemann and Tim Salditt — Institut für Röntgenphysik, Friedrich-Hund-Platz 1, University Göttingen, 37077 Göttingen

In X-ray near field imaging experiments the probing beam determines the imaging quality in terms of resolution and artifacts. Distortions in the probe from optical elements such as focusing optics can easily spoil quantitative contrast. Thus characterizing the probe is an important issue. In previous work [1] we have reconstructed the probe under the assumption of full coherence. In this contribution we extend the reconstruction scheme to include also the partial coherent case, by extending the ptychography approach proposed for far field detection [2] to the near field. The reconstruction scheme uses the measurements from multiple detection planes. Experimentally this is achieved by moving the detector to different distances. The reconstruction is numerically quite demanding since the modes have to be individually propagated and orthogonalized in each iteration of the reconstruction algorithm. Without the use of GPUs this would be a time consuming process. By numerical simulations and a suitable representation of modes, we show how to take into account partial spatial coherence, both in image formation and in reconstruction. Our results show that the occupation numbers of the modes and the degree of coherence can be reconstructed.

[1] J. Hagemann et al., J. Synchrotron Radiat., (in review).
[2] P. Thibault, A. Menzel, Nature 494, 68-71(2013).

MI 7.4 Wed 18:00 P4

Improving Holographic Image Reconstruction by Statistical Multi-resolution Estimation — •Stephan Kramer[1] and Johannes Hagemann[2] — [1]Fraunhofer ITWM, Fraunhofer-Platz 1, 67663 Kaiserslautern — [2]Institut für Röntgenphysik, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

We study the applicability of statistical multiresolution estimation (SMRE) to the problem of phase reconstruction in X-ray near-field holography. X-ray imaging experiments essentially yield near-field holograms. Despite their high quality they still contain noise and blur due to imaging errors. To get the final image of the object of interest its phases have to be retrieved from the measured hologram. To improve the input to this phase reconstruction we deconvolve and denoise a hologram either with our implementation of SMRE [1,2] or with Matlab's Richardson-Lucy (RL) algorithm, where the latter serves as reference. To assess the quality we study the number of fringes restored and the sharpness of edges after the phase reconstruction. Our results show that, in contrast to RL, our SMRE method is able to improve the holograms and thus the phase reconstruction.

[1] Kramer, S.C., Hagemann, J., Künneke L. and Lebert, J., 2016. SIAM Journal on Scientific Computing, 38(5), pp.C533-C559.
[2] Kramer, S.C. and Hagemann, J., 2015. ACM TOPC, 1(2), p.15.

MI 7.5 Wed 18:00 P4

Pre-Studies towards phase-contrast imaging in the field of laboratory astroparticle physics — •Max Schuster, Veronika Ludwig, Jens Rieger, Maria Seifert, Andreas Wolf, Georg Pelzer, Thilo Michel, Gisela Anton, and Stefan Funk — ECAP - Erlangen Centre for Astroparticle Physics, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen

Laboratory astrophysics is an emerging field in astroparticle physics with the aim to prepare, control and investigate systems which behave similar to those of astrophysical origin.

Shock acceleration, e.g., is a candidate mechanism for the origin of cosmic rays. Therefore, the production of laser-induced shock fronts and the imaging of the resulting density distribution is of great interest.

X-ray phase-contrast Imaging (PCI) is an x-ray imaging method which is sensitive to local variations in the electron density distribution.

PCI of the shock front region with high intensity x-ray beams such as beams from free electron lasers can be used to acquire images of the projected electron density gradients in the shock.

High spatial resolution measurements of shock waves at an X-ray free electron laser have already been performed using propagation-based PCI. Compared to this, grating-based PCI promises better sensitivity to small variations in the densities.

In this contribution we will present a comparison between propagation and grating-based PCI with regard to their requirements on the experimental setup and on the image reconstruction.

MI 7.6 Wed 18:00 P4

Adaption of conventional CCD cameras for grazing-emission X-ray fluorescence spectroscopy in the laboratory — •Steffen Staeck, Veronika Szwedowski, Jonas Baumann, Ioanna Mantouvalou, and Birgit Kanngiesser — TU Berlin

X-ray fluorescence spectroscopy (XRF) is a well-established, non-destructive technique for analyzing the element distribution in a sample. Additional depth information can be gained by introducing an angle variation regarding incident or emitted photons and so changing the information depths. In grazing-incidence and grazing-emission X-ray fluorescence spectroscopy (GI/GEXRF) the angle of the incident beam or the emission angle is varied close to the angle for total reflection. Though these methods have proven to be reliable when analyzing multilayer structures or solar cells, the whole angular range has to be scanned. This can be avoided by using scanning-free GEXRF, where a range of emission angles is recorded simultaneously with a 2D-detector. For this scanning-free approach usually an energy-dispersive pixel camera such as the pnCCD has to be used which is optimized for single-photon counting regarding e.g. read-out noise and sensitivity. As these cameras are high prized, it is of interest to perform such experiments with conventional CCD cameras. In this work we present investigations concerning the understanding of charge cloud formation and transport for the optimization of a conventional CCD camera for GEXRF using laboratory equipment.

MI 7.7 Wed 18:00 P4

Correlative Microscopy and Image Fusion of SIMS and Electron Microscopy data — •Florian Vollnhals, Santhana Eswara, Jean-Nicolas Audinot, David Dowsett, and Tom Wirtz — Advanced Instrumentation for Ion Nano-Analytics (AINA), Luxembourg Institute of Science and Technology (LIST), L-4422 Belvaux, Luxembourg

The investigation of complex micro- and nanostructured samples found in many fields of science like materials research, biology and medicine, pose significant challenges both in terms of microscopy and chemical microanalysis. Often, a combination of different imaging and analysis techniques is required to establish a comprehensive picture of the sample and its properties.

Correlative microscopy of high-resolution techniques like SEM or TEM with chemically sensitive techniques like imaging SIMS, can provide such information. These resulting multimodal data sets are commonly evaluated individually or side-by-side, but it is also possible to combine both types of data in a meaningful way to improve or facilitate their analysis. One such approach is derived from remote sensing, where low resolution spectral images are sharpened via a high-resolution pan-chromatic band. We will present two basic image fusion approaches (EM sharpening using IHS transformation and Laplacian pyramid based) and discuss their applicability, advantages and disadvantages in the context of TEM/SIMS, SEM/SIMS and HIM/SIMS correlative microscopy.

[1] T. Wirtz et al., Nanotechnology 26 (2015), 434001

MI 7.8 Wed 18:00 P4

Source, accelerator and micro-beam line upgrade of the Göttingen proton beam writing facility at MaRPel — •Alrik Stegmaier, Hans Hofsäss, Stefan Niessner, Clemens Beckmann, and Ulrich Vetter — 2. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

The MaRPel (Materials Research Pelletron) accelerator was first used successfully for Nitrogen and Hydrogen depth profiling in RNRA [1,2].

Since then it has undergone many upgrades. It currently consists of a 3 MV NEC-Pelletron, a SNICS (Source for Negative Ions through Cesium Sputtering), a station for ion source development and three beam-lines that can be used for RBS, RNRA, in-air-RBS and PIXE, high energy ion implantation and the micro-beam line.

Here we report on the latest upgrades to the source, the accelerator itself and the micro-beam line that is used for continued development of Proton Beam Writing (PBW).

[1] M. Schwickert et al., Surface and Coatings Techn., 151/152, 222, 2002

[2] M. Uhrmacher et al., J. Alloys. Comp., 307, 404-406, 2005

MI 7.9 Wed 18:00 P4

Positioning planar scanning probes by super-resolution microscopy — •Stefan Ernst and Friedemann Reinhard — Walter Schottky Institut and Physik Department, Technische Universität München, Garching, Germany

Scanning probe microscopy (SPM) is traditionally based on very sharp tips, where the small size of the apex is critical for resolution (STM, AFM, MFM). This paradigm is about to shift, since a new generation of planar probes (SQUIDs, scanning SETs, NV color centers in diamond) promises to image hitherto inaccessible quantities such as very small magnetic and electric fields. So far, much effort is put into fabricating these planar sensors on a tip, to be compatible with traditional SPM techniques and to bring the sensor close to the sample surface. This poses a significant engineering challenge, which is mastered by only a few groups.

Here we propose a novel, tipless, approach – a technique to scan a planar probe parallel to a planar sample at a distance of only a few nanometers. The core element of our scheme is a super-resolution microscopy technique to measure both sensor-sample tilt and distance with high accuracy (mrad/nm). In this project, we aim to use shallow NV centers at the planar surface of a bulk diamond as scanning probes. This will simultaneously reduce fabrication complexity, improve the sensor quality and reduce the sensor-sample distance compared to existing tip-based schemes [1, 2].

[1] P. Maletinsky, et al., *Nature nanotechnology*, 7(5):320–324, 2012.

[2] G. Balasubramanian, et al., *Nature*, 455(7213):648–651, 2008.

MI 7.10 Wed 18:00 P4

Construction of Ambient Simultaneous Scanning Tunneling /Atomic Force Microscope (STM/AFM) — •Ipen Demirel, Ahmed Uluca, Majid Fazeli Jadidi, and Hakan Özgür Özer — Istanbul Technical University, Istanbul, Turkey

we constructed an ambient simultaneous STM/AFM using a fiber-optic interferometry setup for cantilever deflection detection. Simultaneous measurements of tunnel current, force, force gradient, tunnel barrier height and energy loss with high sensitivity is possible with our specially designed and modified STM/AFM. Our microscope consists of a home-built STM and AFM head, which implements a TiO2 coated fiber attached to a small tube piezo on a commercial micro-positioner, vibration isolation system and SPM control unit. The frequency spectrum was obtained to determine resonance and phase curves on various cantilevers (Si, W) by PLL card besides lock-in amplifier. Since, interference pattern shows power at the signal photo-diode versus cantilever displacement as sensitivity of the interferometer, the fiber is locked by the controller at the most sensitive point. Working in the off-resonance region and using very small lever oscillation amplitudes, we are able to keep the probe in tunneling range during most of the cycle in simultaneous AFM/STM operation. The microscope was tested in STM mode on gold surface and atomically flat terraces has been imaged. We also conducted frequency modulation AFM imaging on the same surface. We are going to study various 2-D surfaces such as graphene, Bi2Te3 by using the microscope in simultaneous mode in which all relevant channels of information are acquired.

MI 7.11 Wed 18:00 P4

An optical setup for focusing THz radiation on a Scanning Tunneling Microscope tip — Mohamad Abdo[1,2], •Steffen Rolf-Pissarczyk[1,2], Jacob Burgess[1,2], Björn Schlie[1,2], and Sebastian Loth[1,2,3] — [1]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart — [3]Institut für Funktionelle Materie und Quantentechnologien, Universität Stuttgart

Terahertz (THz) radiation lies between Microwave radiation and Infrared light in the electromagnetic spectrum. It can be generated for example by optical rectification of femtosecond laser pulses in non-linear crystals. However, the power of the generated THz is typically very weak. This often stands as an obstacle against measurements with weak signal amplitudes, in particular THz-induced tunneling in a scanning tunneling microscope (STM) where the THz electric field couples to the STM tip and enables highly localized transport measurements at picosecond speed [1,2].

Here we show the development of an optical setup that is optimized for THz-induced transport experiments. We also show how to manipulate the THz pulse shape by de-compression of the excitation pulse.

This setup enables studies of ultrafast physical phenomena with the atomic spatial resolution provided by the STM even in tunneling regimes where significantly less than one electron tunnels per THz pulse.

[1] T. Cocker, et al., Nature Photonics 7 620-625 (2013).

[2] T. Cocker, et al., Nature 539, 263-267 (2016).

MI 7.12 Wed 18:00 P4

X-ray crystallography study of Cu-Ga sputter target alloys for Cu(In,Ga)Se$_2$ thin film solar cells by means of Kossel microdiffraction in the SEM — •Tijani Dmali[1,2], Enrico Langer[1,2], and Siegfried Däbritz[1] — [1]Technische Universität Dresden, Institut für Festkörperphysik, 01069 Dresden — [2]Technische Universität Dresden, Institut für Halbleiter- und Mikrosystemtechnik, 01187 Dresden

Investigation results on polycrystalline Cu-Ga sputter targets by X-ray Kossel microdiffraction will be presented. Materials of this binary system are used for Copper Indium Gallium Diselenide thin film solar

cells. The examined specimens are alloys with varied matrix compositions, which has been manufactured by different methods. The observed microstructures showed to be an eutectic phase in this Gallium concentration range. In each case the first X-ray Kossel microdiffraction analyses by means of a CCD area detector proved the existence of an hexagonal close packed lattice, contrary to other measurements and the Cu-Ga phase diagram in certain Ga concentration ranges. The lattice parameters a and c as well as their variation were precisely measured in the micro range. Interestingly in both limiting cases of the lattice constant a the ratio c/a is exactly c/a= 1.620. In combination with EDX measurements it was found that each matrix consists of the ζ phase which can be distinguished in terms of the chemical composition and lattice constants.
We are greatfull to Marian Böhling for the supply of the sample material and his suggestion to investigate this material.

MI 7.13 Wed 18:00 P4

Investigation of biological structures from fossils and simulation of their optical properties — •Ran Zhang, Enrico Langer, Barbara Adolphi, Andreas Voigt, and Andreas Richter — Technische Universität Dresden, Institut für Halbleiter- und Mikrosysteme

Diffraction gratings and photonic crystals play an important role for smart technical applications. The investigation of photonic structures in biology is an interesting scientific endeavor, because it can contribute to a better biological classification and since it may trigger bio-inspired technological developments. In this work, fossil surfaces from crustaceans were investigated by means of both scanning electron microscopy and energy-dispersive X-ray spectroscopy (EDS) in the low-vacuum mode. On the 150 million years old crayfishes "Eryma modestiformis" and "Palaeastacus fuciformis" we discovered structures with different dielectric constants and similar width (about 200 nm) that are arranged periodically on the surface. Moreover, the investigation by EDS allows to draw conclusions on the composition of the original fossil materials. The detected periodic structures can be regarded as 1D and 2D diffraction gratings. Electromagnetic waves would be reflected depending on the wavelength in different directions. We show calculations of these angles by diffraction equations and the reflection of visible light with various colors. Another unusual structure with a finer and more regular arrangement was observed, which was unveiled as a diatom. It can be treated as a photonic crystal slab. With the measured geometric data and material composition, a biological monoclinic photonic crystal model was built. The photonic bands of this structure (which allows conclusions about the reflectance behavior in the horizontal direction) were calculated by the plane wave expansion method [1]. Future work will include the application of the finite difference time-domain method and rigorous coupled wave analysis in order to calculate the transmission and reflection spectra for arbitrary angles of incidence.

[1] S.G. Johnson and J. D. Joannopoulos, Optics Express 8, (2001) 173-190.

MI 7.14 Wed 18:00 P4

Nanokomposit-Kondensatoren - morphologische und dielektrische Charakterisierung — •Till Mälzer[1,4], Tino Band[2], Sandra Wickert[3,4], Frank Apsel[1,4], Hartmut S. Leipner[1], Martin Diestelhorst[2] und Stefan Ebbinghaus[3] — [1]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg (MLU), 06120 Halle (Saale) — [2]Institut für Physik, MLU — [3]Institut für Chemie, MLU — [4]enfas GmbH, 86668 Karlshuld

Polymere werden häufig wegen ihrer Vorzugseigenschaften einer hohen Durchbruchfestigkeit und kostengünstigen Produzierbarkeit als dielektrische Materialien für Kondensatoren mit hoher Energiespeicherdichte verwendet. P(VDF-HFP) ist mit seiner relativ hohen Energiedichte ein Kandidat mit großem Potential. Durch Hinzufügen von Nanopartikeln mit hoher Permittivität lässt sich die Energiespeicherdichte bei gleichbleibender Feldstärke weiter steigern. Allerdings auf Kosten höherer Leckströme.

Im Rahmen unserer Forschungsarbeit untersuchen wir Nanokomposit-Folienkondensatoren, bestehend aus verschiedenen Bariumtitanat(BTO)-Nanopartikel-Konzentrationen in einer P(VDF-HFP)-Matrix, genauer den Einfluss u.a. der Verteilung, Größe, Form und Struktur der BTO-Partikel auf die dielektrischen Eigenschaften des resultierenden Komposits. Dafür werden die Folien als Kondensatoren charakterisiert, um Energiedichte, Permittivität, Durchbruchspannung und elektrische Leitfähigkeit zu ermitteln. Andererseits werden strukturelle Untersuchungen mittels XRD, ESEM und FIB durchgeführt.