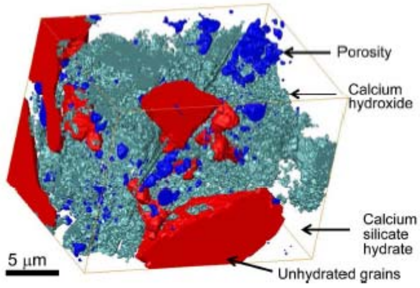
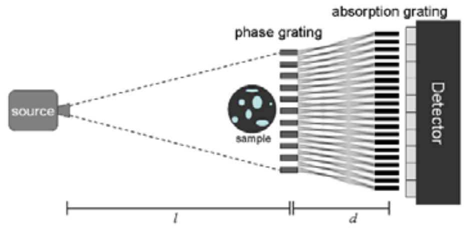
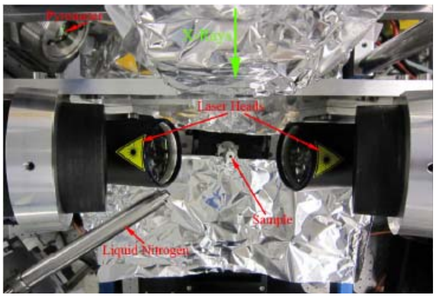
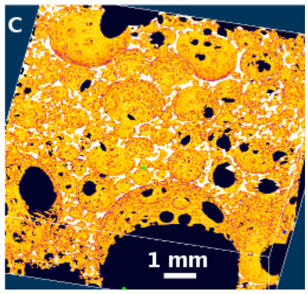








SLS Symposium on

Tomographic Microscopy

Tuesday, May 3, 2011

10:00 to 12:15, WBGB/019

10:00 Phase tomography by coherent diffractive imaging: Methods and applications
Manuel Guizar-Sicairos, A. Diaz, A. Menzel, P. Trtik and O. Bunk

10:30 X-ray differential phase contrast imaging on a compact setup
Thomas Thuering, P. Modregger, B. R. Pinzer, Z. Wang, S. Rutishauser, C. David, T. Grund, J. Kenntner and M. Stampanoni

11:00 Coffee

11:15 Structures and dynamics of complex materials systems unveiled by synchrotron-based tomographic microscopy
Julie L. Fife, M. Rappaz and M. Stampanoni

11:45 New Perspectives for the observation of complex systems in 3D with sub-second X-ray microtomography
Rajmund Mokso, S. Irvine, F. Marone, G. Mikuljan, M. Stampanoni

Phase tomography by coherent diffractive imaging: Methods and applications

M. Guizar-Sicairos,*[1]* A. Diaz,[1] A. Menzel,[1] P. Trtik,[2] and O. Bunk[1]

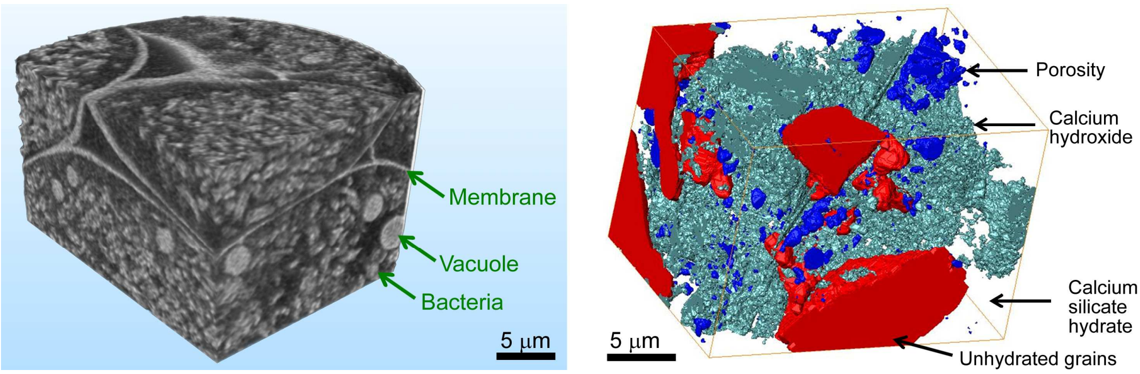
[1] Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland
[2] Empa, Swiss Federal Laboratories for Materials Science and Technology, CH-8600 Dubendorf, Switzerland
** manuel.guizar-sicairos@psi.ch*

Phase tomography provides quantitative three-dimensional maps of electron density for which the image contrast is given by the phase shift induced by the sample on the incident x-rays. For hard x-ray energies phase contrast is significantly more sensitive than absorption and, since contrast is not inherently linked to absorption, it provides a route for imaging with reduced radiation damage.

Scanning x-ray diffraction microscopy (SXDM) is a practical way of measuring the projected phase of the sample [1], and its use for phase tomography in the nanoscale was recently demonstrated [2]. SXDM is a coherent diffractive imaging technique and as such it requires no image forming optics. For SXDM the diffracted x-rays at different sample positions are used by an iterative reconstruction algorithm to provide complex-valued images with a resolution that is finer than both the scanning step and the size of the x-ray illumination. The resolution of SXDM is limited by the maximum angle at which the diffracted x-ray intensities can be measured above the noise. Phase tomography from SXDM projections is not restricted to small phase shifts or negligible absorption, and thus has a wide range of applicability in biology and material science.

Because of their high penetration depth hard x-rays can probe thicker specimens. We exploit this to image samples in the range of a few tens of microns with a 3D resolution of the order of 100 nm. Measuring samples of this length scale is necessary in order to effectively image tissues, cellular networks, or samples that are more representative of bulk materials.

In this contribution we will review the imaging principle of SXDM and current algorithms used for post-processing and alignment of phase projections. Current applications on biology and materials science will also be discussed.



Phase tomography reconstructions. (Left) Bacteria inoculated cellular tissue from root nodules of the mung bean plant *Vigna radiata*. (Right) Hardened cement paste, segmentation was performed based on electron density.

[1] P. Thibault, M. Dierolf, A. Menzel, O. Bunk, C. David, and F. Pfeiffer, “High-resolution scanning x-ray diffraction microscopy,” Science **321**, 379-382 (2008).

[2] M. Dierolf, A. Menzel, P. Thibault, P. Schneider, C. M. Kewish, R. Wepf, O. Bunk, and F. Pfeiffer, “Ptychographic x-ray computed tomography at the nanoscale,” Nature **467**, 436-439 (2010).

X-ray differential phase contrast imaging on a compact setup

T. Thuering[1,2], P. Modregger[1,3], B. R. Pinzer[1], Z. Wang[1], S. Rutishauser[1,2],C. David[1], T. Grund[4], J. Kenntner[4], M. Stampanoni[1,2]

[1] Swiss Light Source, Paul Scherrer Institute, Villigen, Switzerland
[2] Institute for Biomedical Engineering, ETH Zurich, Switzerland
[3] University of Lausanne, Medical School, Lausanne, Switzerland
[4] Karlsruhe Nano Micro Facility (KNMF), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
thomas.thuering@psi.ch

Recent developments in X-ray phase contrast imaging showed that a grating interferometer can be used to extract high resolution absorption, phase and dark-field signals simultaneously. In particular, exploiting phase contrast can lead to a significant contrast enhancement (e.g. in biological soft tissue) compared to absorption based X-ray imaging [1,2].
Recently, a setup has been demonstrated, which allows differential phase contrast (DPC) imaging on conventional X-ray tubes [3], although the source-to-detector length of this setup was well above 1m.
In the lab of the TOMCAT beamline at the SLS, a new DPC demonstrator setup with an extremely short source to detector distance (<40cm) has been built up, i.e. in cone-beam configuration typical of commercially available, absorption-based microCT equipment. The system consists of a low power microfocus tube, a Talbot interferometer and a CCD camera (see Figure). Furthermore, the same setup geometry has also been installed in a SCANCO µCT50 scanner.
In the design process, the two major limiting factors were the critical beam coherence and divergence. Although using a microfocus source, the focal spot size is critical due to the short source-to-detector distance. In this contribution, we report on solving this problem by optimizing the setup parameters (i.e. grating positions and periods).
The extreme beam divergence and the high aspect ratio of the grating structures lead to a decay of the DPC signal visibility at large incident angles and eventually to a reduction of the field of view. The solution to this problem is the usage of gratings with a cylindrical shape. Here, we report on the details of the fabrication of such gratings. Finally, we present first imaging results obtained with the new DPC setup.

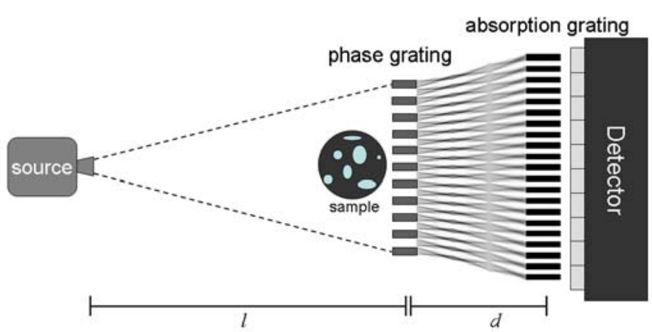


Figure: Compact DPC setup consisting of a microfocus X-ray tube, a Talbot interferometer and a camera.

References
[1] F. Pfeiffer et al., Phys. Med. Biol., 52 (6923–6930), 2007
[2] S.A. McDonald et al., J. Synchrotron Rad., 16 (562-572), 2009
[3] F. Pfeiffer et al., Nature Phys., 2 (258–261), 2006

Structures and dynamics of complex materials systems unveiled by synchrotron-based tomographic microscopy

***Julie L. Fife*[1,2], *Michel Rappaz*[2], *Marco Stampanoni*[1]**

[1]Laboratory for Synchrotron Radiation, Paul Scherrer Institut, 5232 Villigen, Switzerland
[2]Computational Materials Laboratory, Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

julie.fife@psi.ch

Coarsening is a naturally-occurring, diffusion-driven phenomena that decreases the energy of a system by decreasing the overall curvature of the interface between solid and liquid phases. This subsequently increases the size scale of the system. When working with intricate microstructures, such as tree-like structures called dendrites (typically found in metal microstructures like castings), which have spatially-varying mean curvature, simple geometric representations cannot describe their evolution. Extracting the kinematics and dynamics of the coarsening process in these types of systems needs to happen in-situ, meaning at the coarsening temperature and in real-time. Further, understanding the formation of microstructures and defects during solidification also require in-situ studies.

X-ray tomographic microscopy, as performed at the TOMCAT beamline of the Swiss Light Source, is a high-resolution, high-throughput technique for obtaining quantitative three- and four-dimensional information on systems ranging from metals to highly relevant environmental samples to biological materials. In this talk, we focus on the latest developments regarding in-situ, time-resolved experiments. We detail the development of a furnace using two class four, near-infrared lasers as the source of heat. Then, we show the initial in-situ results using the laser system: the first simulates volcanic eruptions in an environmental sample and the second shows the growth of dendrites in a solidifiying metal.

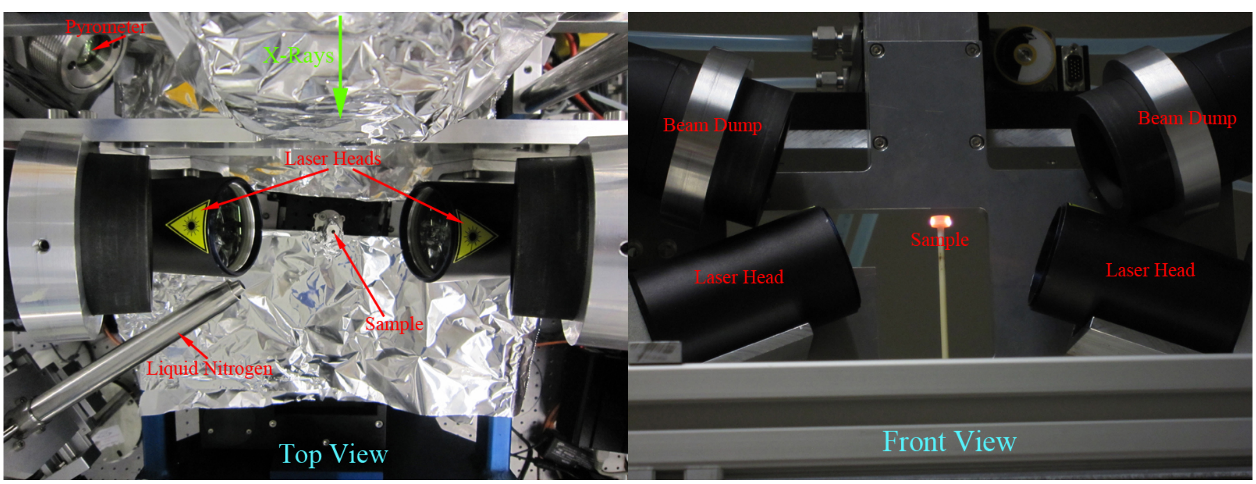


Figure 1. (L-R): Top and front views of the laser system on the TOMCAT beamline and in the lab respectively. The top view shows a sample holder 2mm in diameter at room temperature. The front view shows a sample holder 8mm in diameter being lased to approximately 1100°C.

New Perspectives for the observation of complex systems in 3D with sub-second X-ray microtomography

R. Mokso[a], S. Irvine[a,c], F. Marone[a], G. Mikuljan[a] , M. Stampanoni[a,b]

[a]Swiss Light Source, Paul Scherrer Institut - Switzerland.
[b]Institute for Biomedical Engineering, University and ETH Zurich, Switzerland
[c]Department of Radiology, EPFL Lausanne, Switzerland

Several non-destructive imaging techniques offer the possibility to observe rapid phenomena in real time, yet most of these techniques fail when it comes to bulky samples and micrometer precision in three dimensions. Therefore there is clearly a need to develop approaches that address such conditions. A large potential lies in using synchrotron based X-rays for direct space tomography suitable to provide sub-second temporal resolution with a spatial resolution down to one micrometer. Ultra-fast radiography (2D imaging) has been demonstrated at various beamlines with a number of exciting applications [1]. Nevertheless the extreme requirements on mechanics, synchronization and detectors prevent a straight-forward transition from 2D towards 3D ultra-fast imaging. With the newest results we demonstrate that this important step can now be made.

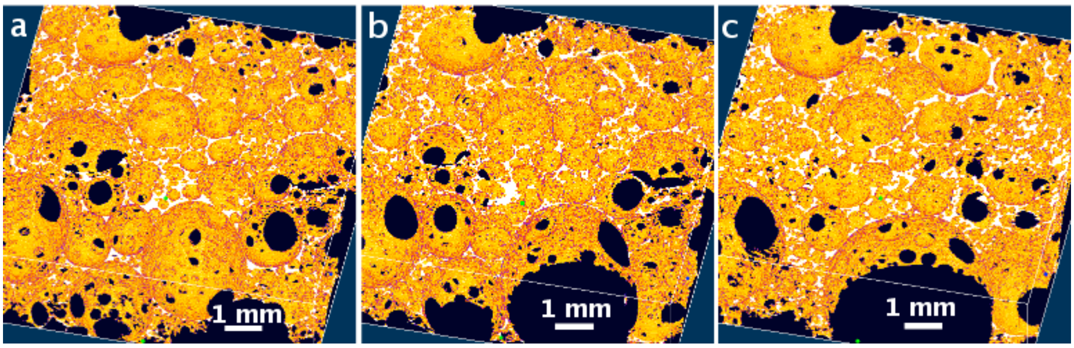


Figure 2 - The 3D dynamics of a rapidly evolving beer foam at three time instances (a: t_0, b: t_0+ 3 sec, c: t_0+7 sec) during natural coarsening. Total scan time was 0.5 s at 20 keV photon energy.

A new fast tomographic data acquisition scheme [2] is being developed at the TOMCAT beamline. We acquire the full set of (500-800) tomographic projections in typically 0.5 seconds with the voxel sizes ranging from 0.5 to 11 μm and a corresponding field of view from 0.7 to 22 mm. An example of the liquid froth (Fig. 1) demonstrates the current capabilities. These liquid foams are rapidly evolving complex systems and can not be studied without adequately matched speed of data acquisition [3]. Moreover X-rays are currently the only successful probe to study the foams in three dimensions. It is the first time that this early stage of rapid foam development can be studied with good statistical weight given the small pixel size (11 μm) and large field of view (22 mm). Other exciting biological and in-situ material science applications will be presented. The contrast mechanism is not limited to absorption, therefore weakly absorbing samples may also be studied using various phase contrast approaches. Some of these approaches are now available routinely, others are yet to be implemented to meet the needs of a large user community.

[1] N. Babcsan, F.G. Moreno, J. Banhart, Coll. Surf. A 309(1-3), 254-263 (2007)
[2] R. Mokso, F. Marone, M. Stampanoni, AIP Conf. Proc. 1234, SRI2009 (2010)
[3] J. Lambert, R. Mokso, I. Cantat, P. Cloetens, J.A. Glazier, F. Graner and R. Delennay, Phys. Rev. Lett. **104**, 248304 (2010).