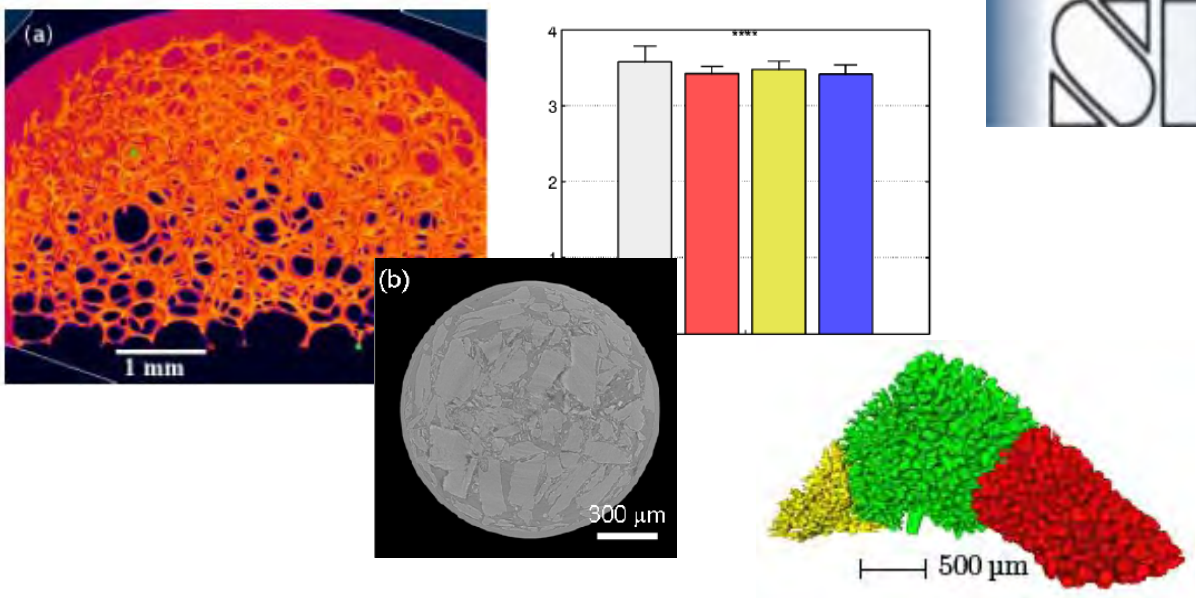

SLS Symposium on Tomography @ TOMCAT

Tuesday, November 3, 2009

10:00 to 12:15, WBGB/019

Program

10:00 Real Time Tomography at the TOMCAT Beamline
Rajmund Mokso

10:30 Towards Real-Time Tomography: Fast Reconstruction Algorithms
Federica Marone

11:00 Coffee

11:15 Small Pixels for Large Samples
David Haberthür

11:45 Evaluation of Dose Dependent Structural Changes in 3D Brain Micro-Vasculature in Response to Heavy Particle Radiation Exposure
Christoph Hintermüller

Real Time Tomography at the TOMCAT Beamline

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The penetrating power of X-rays coupled with the high flux of 3rd generation synchrotron sources makes X-ray tomography to excel among all fast imaging methods of bulky samples. [1] The vision to perform real-time tomography to study the dynamics of processes in biology and material science is the motivation for setting up an ultra-fast tomography endstation at the TOMCAT beamline. Recently, the state of the art tomographic setups at synchrotron sources offer routinely a temporal resolution of several tens of seconds in tomography mode sufficient for the imaging of only slowly evolving systems such as mstabilized liquid foams [2] at pixel sizes of 1-10 microns.
However there is a need to improve the temporal resolution for 3D imaging when addressing non-stabilized liquid foams, in-situ sintering, compression/traction experiment or even biomedical applications where the relevant physiological time scales of breathing or heartbeat cycles are in the range of 0.5-2 seconds. To allow acquiring the full set of projections at sub-second timescale, feasibility tests were succesfully performed recently with a new CMOS with the voxel size of 11x11x11 μm^3.
The current status of the commissioning of the new ultra-fast tomographic setup will be presented. The limitations and possibilities of ultra-fast tomography will be discussed as well as a preliminary study of rapidly evolving liquid foams (Figure 1) will be presented.

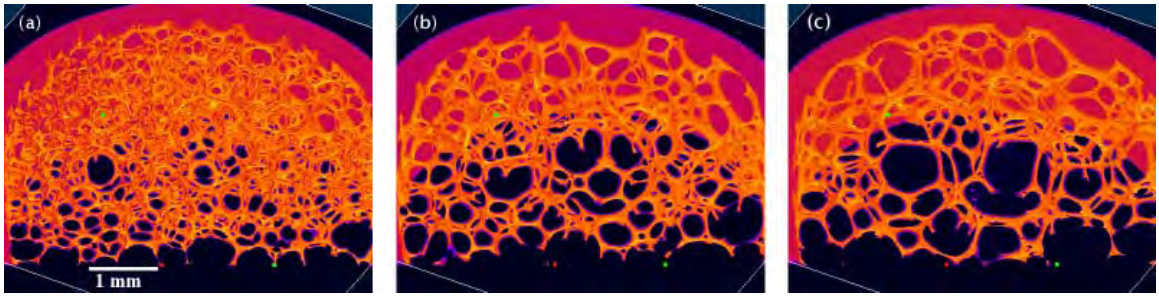

Figure 1. Tomographic images of three stages of a rapidly evolving liquid foam. The acquisition time for each tomographic dataset was 0.5 s.

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[1] A. Fouras, M.J. Kitchen, S. Dubsky, R.A. Lewis, S.B. Hooper, K. Hourigan, J. Appl. Phys. **105** (10), 102009 (2007).

[2] J. Lambert, I. Cantat, R. Delannay, R. Mokso, P. Cloetens, J.A. Glazier, F. Graner, Phys. Rev. Lett. **99** (5), 058304 (2007).

TOWARDS REAL-TIME TOMOGRAPHY: FAST RECONSTRUCTION ALGORITHMS

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Synchrotron X-ray tomographic microscopy is a powerful technique, which allows fast non-destructive, high resolution quantitative volumetric investigations on diverse samples. Highly brilliant X-rays delivered by third generation synchrotron facilities coupled with modern detector technology permit routinely acquisition of high resolution tomograms in few minutes, making high throughput experiments a reality and bringing real-time tomography closer. New solutions for fast post-processing of such large amount of data are mandatory to fully exploit advantages provided by the high acquisition speed.

The TOMCAT beamline [1] is well equipped for high throughput experiments. Here, we will focus on our solutions regarding the reconstruction process. On one hand we will discuss a fast reconstruction algorithm [2], based on the Fourier Transform method. On the other hand, we will also deal with new acceleration possibilities for standard Filter Back-Projection algorithms offered by emerging GPU technology. These solutions reduce the reconstruction time for a 2048x2048 slice (and 1500 projections) down to about 0.5 s on a single CPU (Fourier Transform method) and 2 s on a single GPU (Filter Back-Projection algorithm).

The reconstruction algorithms implemented at TOMCAT also feature several plug-ins, aimed at taming reconstruction artifacts. Here, we will discuss a new approach for removing rings from reconstructed datasets arising from defective detector pixels and/or damaged scintillator screens. This new method is based on a combined Wavelet-FFT decomposition [3]. Another important feature of the presented reconstruction algorithms deals with local tomographic datasets, characterized by incomplete data. We show here that ad-hoc padding of the sinograms prior to reconstruction significantly reduces typical artifacts related to data incompleteness, making local tomography a valuable acquisition mode when small volumes in relatively large samples are of interest.

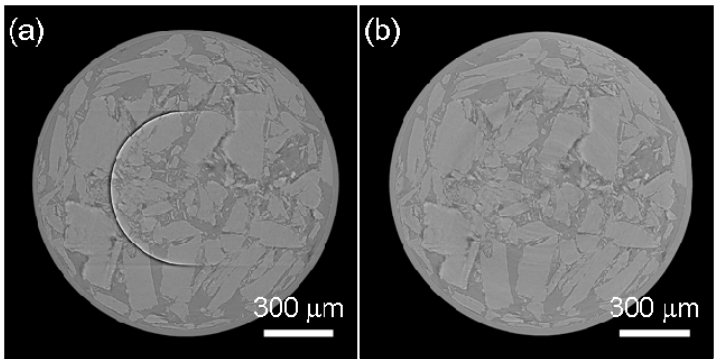

Figure 1: Removal of a wide strong ring artifact from a reconstructed slice with the wavelet-FFT filter [3]
(a) Original image
(b) Post processed image.
Sample: compacted purified smectite, pixel size: 0.74 μm.
Sample courtesy: D. Prêt, Poitiers University, Poitiers, France [4].

[1] M. Stampanoni et al., Proceedings of SPIE, Developments in X-ray Tomography V, **6318**, doi:10.1117/12.679497 (2006).

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Small pixels for large samples

David Haberthür* Christoph Hintermüller† Federica Marone†
Johannes C. Schittny* Marco Stampanoni†‡

Ventilation and particle deposition is directly linked to the three-dimensional structure of the lung acinus, the functional lung unit in the mammalian lung.

Until now the investigation of the three-dimensional structure of an entire acinus was either limited by the resolution of the imaging method or the sample volume. One focus of our work deals with the lung structure. Since we are interested in the structure of the terminal airways in the lung, we need high resolution and high quality images that which are provided by TOMCAT. One drawback of this high resolution images is the relatively low field of view, which does not always contain one single acinus.

To overcome this limitation we developed a new scanning protocol to combine three to five lateral tomographic scans to one large three-dimensional image perpendicular to the rotation axis of the sample. Reconstructing these merged projections leads to a 9–25-fold increase of the visible sample volume as compared to the standard scanning procedure at TOMCAT, while keeping the voxel size at the desired level. The required number of projections for each of the 3–5 subscans was calculated based on a balance between the requested resolution versus total scanning time, which also opens the path for tomographic scans with low radiation dose.

Stacking multiple wide field scans results in large three-dimensional samples easily containing more than one acinus—all at a resolution permitting an automated segmentation between airspace and tissue in heavy metal stained, paraffin embedded rat lungs. We are using this technique as a basis to study lung development, for the simulation of acinar air flow and the deposition of nanoparticles in the mammalian lung.

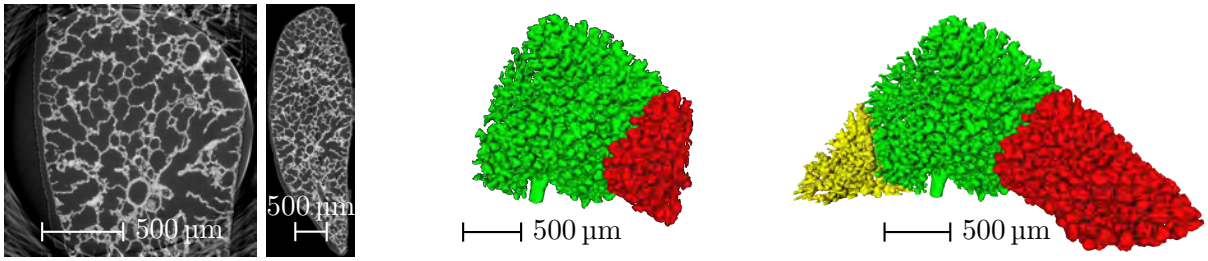

Figure 1: Rat lung sample, obtained at postnatal day 4. From left to right: Original slice of conventional tomographic dataset with a total field of view of approx. 1.5×1.5 mm. Cropped slice of WF-SRXTM dataset with a field of view of approx. 1.3×3.8 mm (notice the different scale bars). Three-dimensional visualization of conventional dataset, only partial acini are contained in the dataset. Three-dimensional visualization of WF-SRXTM dataset with full acini inside the dataset.

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Evaluation of dose dependent structural changes in 3D brain micro-vasculature in response to heavy particle radiation exposure

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Space radiation with high energy particles (cosmic rays) presents a significant hazard to spaceflight crews. Recent reviews of the health risk to astronauts from ionizing radiation concluded that there is a need to establish a level of risk which may indicate the possible performance decrements and decreased latency of late dysfunction syndromes of the brain. A hierarchical imaging approach developed at ETH Zürich and PSI, which relies on synchrotron based X-ray Tomographic Microscopy (SRXTM), was used to visualize and analyze 3D vascular structures down to the capillary level. Various morphological parameters, such as overall vessel volume, thickness and spacing, are extracted to characterize the vascular structure within a region of interest. Three weeks after irradiation a first quantification of the effect of high energy particles on the vasculature was done on a set of 14 animals, all the same age. The animals were irradiated head-only with 1Gy, 2Gy and 4Gy of 600MeV/n 56 Fe heavy particles simulating the space radiation environment. We found that with increasing dose the diameter of vessels and the overall vessel volume are decreased whereas the vessel spacing is increased. As these parameters reflect blood flow in three-dimensional space they can be used as indicators for the degree of vascular efficiency which is thought to have an impact on the function and development of the central nervous system.

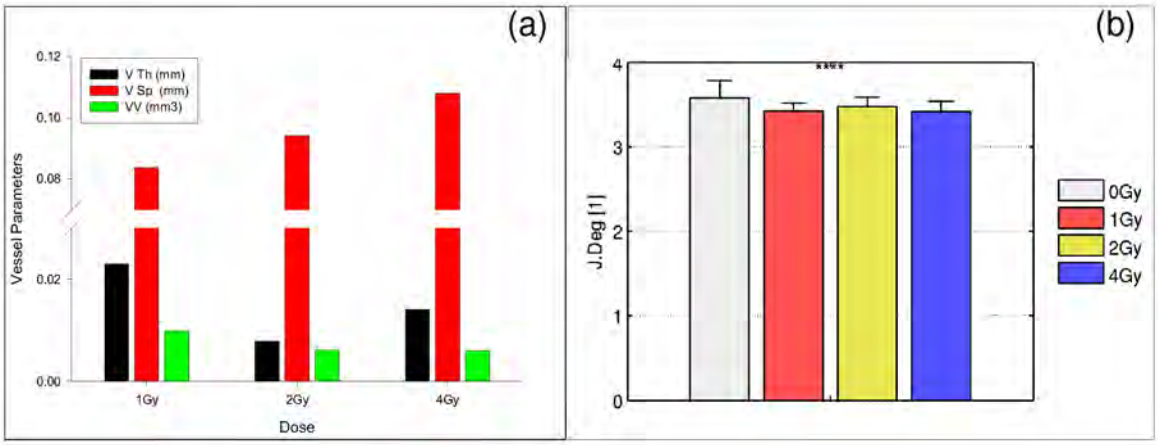

Figure 1: Dose dependent changes in brain vasculature: (a) Vessel spacing (V Sp) increases with dose while vessel volume (VV) and thickness (V Th) decrease; (b) The average number of vessels per branching point is decreased in irradiated animals compared to controls.

References:

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