Synchrotron-radiation Tomographic Microscopy

Non-destructive 3D visualization and quantification of your samples

Introduction

Tomographic Microscopy is a powerful non-destructive technique used to visualize and study the three dimensional (3D) internal structure and material properties of a variety of opaque samples. Thanks to very intense and coherent beam available nowadays, X-ray imaging has experienced a true revolution at third generation synchrotrons. The unprecedented photon density reached by novel sources such as the Swiss Light Source at PSI brings tremendous advantages, compared to more traditional X-ray laboratory instruments.

The high brilliance of synchrotron light enables detection of details as small as one (1) micron (μm) in millimeter-sized samples within few minutes. In addition, the monochromaticity of the used X-ray beam makes quantitative measurements of material properties possible and the identification of different phases easier. With phase contrast techniques, enabled by the coherence of the beam, both low and high absorbing samples can be optimally investigated.

Method

In absorption contrast tomographic microscopy, radiographic projections are acquired, showing the selective attenuation of the X-ray beam traversing the sample. For fixed beam energy, the number of absorbed photons depends on the composition of the sample material, its density and the atomic number.

In phase contrast imaging, the diffraction of the beam and the resulting interference phenomena are instead exploited. Radiographic projections, however, only provide 2D cumulative information on the structure along the beam path. 3D internal structural details are, though, unraveled if radiographies for different sample orientations are acquired and the obtained data combined using sophisticated algorithms for tomographic reconstructions.

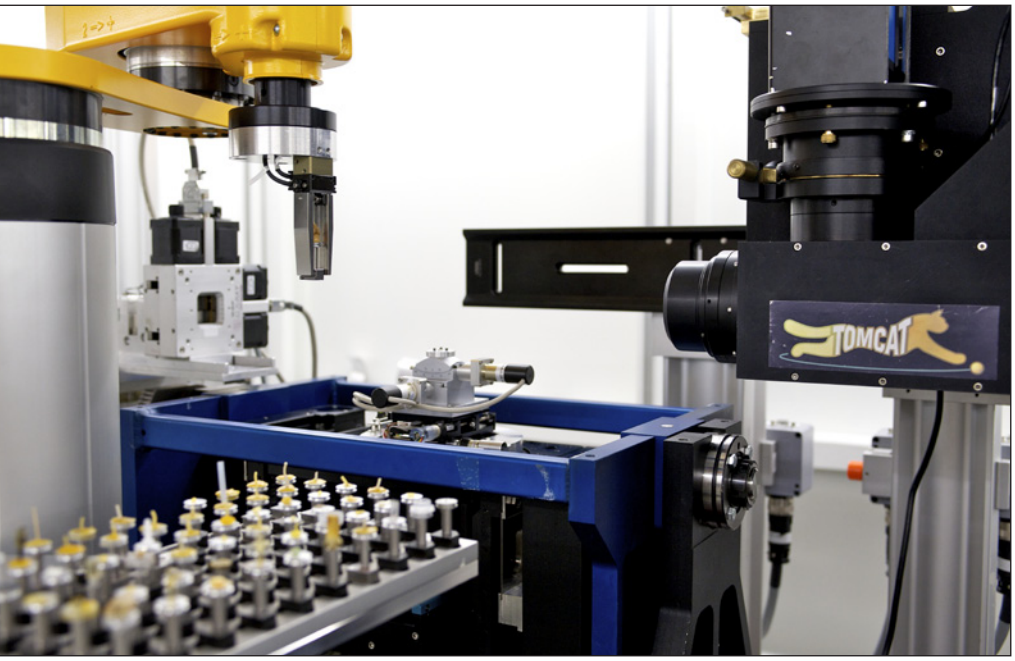

Figure 1: **Automatic sample mounting at TOMCAT.**

The instrument – TOMCAT

The beamline for Tomographic Microscopy and Coherent Radiology Experiments (TOMCAT) at the Swiss Light Source enables fast non-destructive, high resolution quantitative volumetric investigations. The standard TOMCAT detector offers field of views ranging from 0.75×0.75 mm^2 up to 15×15 mm^2 with a theoretical resolution of 0.37 μm and 7.4 μm, respectively.

A complete dataset is acquired during few minutes, depending on the required energy and resolution. The specific beamline design and flexible end station setup make a large range of investigations possible.

Spacious sample stage space allows installation of diverse devices for in-situ experiments. Currently available at the beamline for such experiments are a cryojet, a compression-tensile device and a furnace.

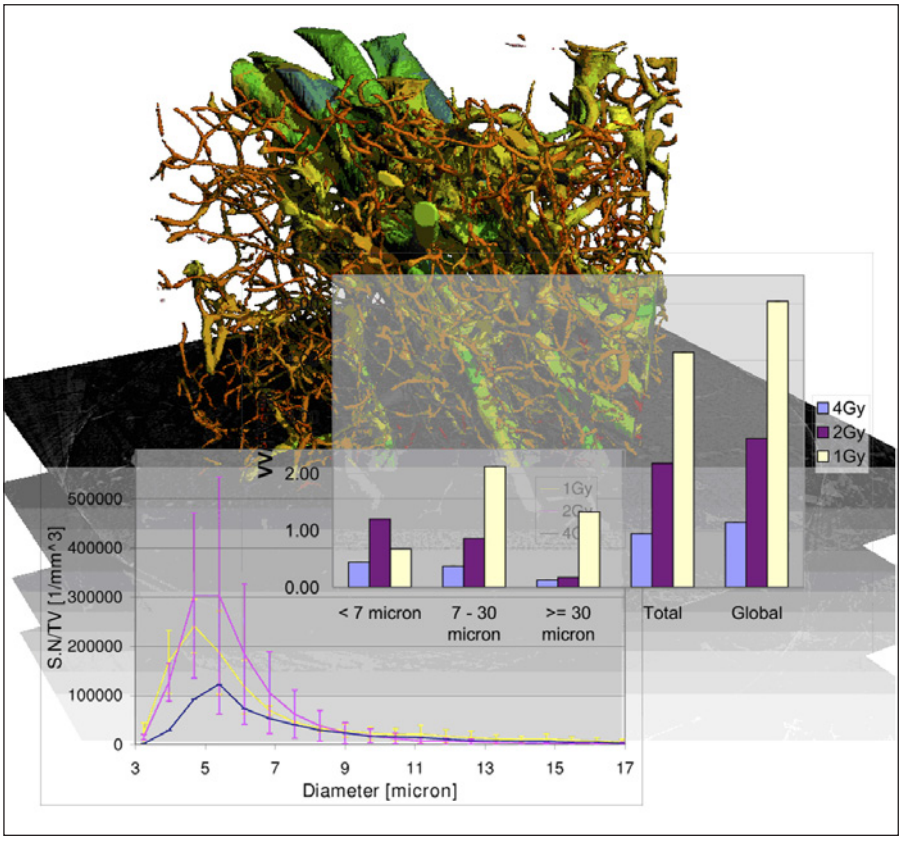

Figure 2: **Visualization and quantitative morphometric analysis of murine brain microvasculature. In the background, the high-resolution microvasculature structure of a selected region of interest (1 mm³) is shown. In the foreground, 2 typical morphometric analyses are illustrated (in collaboration with Prof. Greg Nelson, NASA and Loma Linda University, USA).**

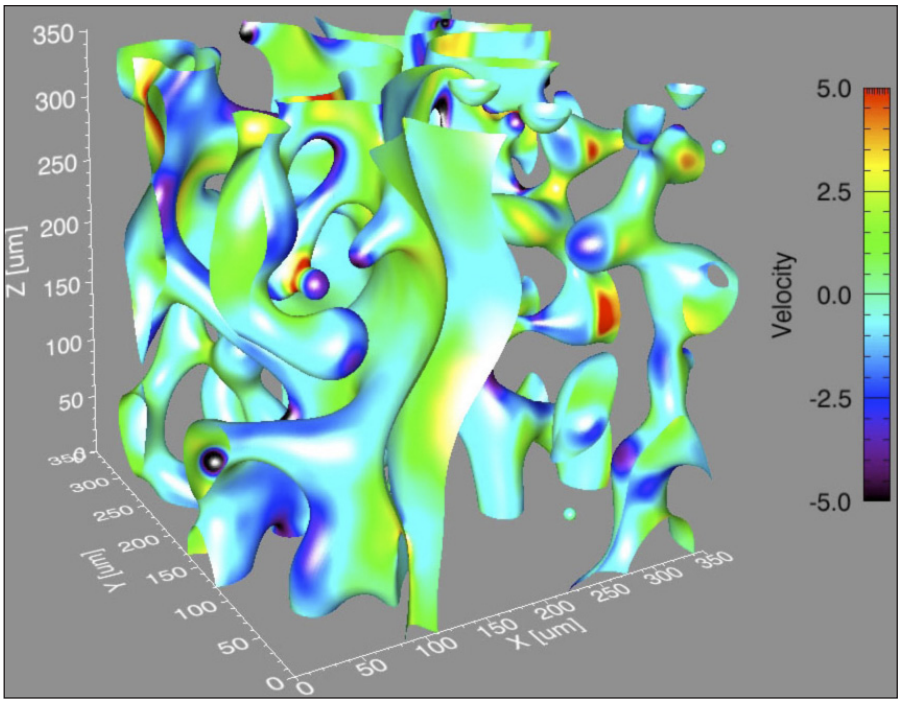

Figure 3: **Solid-liquid interface of a binary Aluminum-Copper microstructure (74% solid volume) captured during in-situ coarsening colored by the experimentally-determined characteristic velocity (used with the permission of Prof. Dr. Peter W. Voorhees, Northwestern University, USA).**

For similar samples, automation and high throughput is achieved by using an automated sample exchanger.

Applications

Fields of application of this method are:
- Materials sciences
- Food and pharmaceutical sciences
- Biological and medical sciences
- Earth and environmental sciences

Samples as diverse as:
- Wood, polymers, fibers, composites, ceramics
- Solid (Al, Si, CeO) or liquid foams
- Al-, Zn-, and Cu- alloys
- Granules and tablets
- Fuel cells
- Rocks and fossils
- Biomedical biopsies

can be investigated to extract, in addition to details on the 3D internal structure, qualitative and quantitative information on:
- Pore and crack spatial distribution
- Pore connectivity and pore size distribution
- Liquid distribution in porous material
- Particle shape and orientation
- Vessel thickness, density and spacing in microvasculature networks
- Number of vessel junctions and segments in microvasculature networks
- Cortical and trabecular bone thickness
- Bone mineralization

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SYN-F17-D-10, 10.2010