

## PSD Mini Symposium

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### Diffraction, Imaging and Optics

Tuesday, March 12, 2019

10:00 to 12:15, WBGB 019

**10:00 Strain field in deformed InSb revealed by in-situ X-ray Laue micro diffraction and post-mortem ptychographic topography**

*Verezhak Mariana, Sadat T., Renault P-O, Jacques V., Godard P., Wakonig K., Thilly L., Van Petegem S., and Diaz A.*

**10:30 Analysis methods for terabyte-scale volume images: application to brain microvasculature**

*Miettinen Arttu*

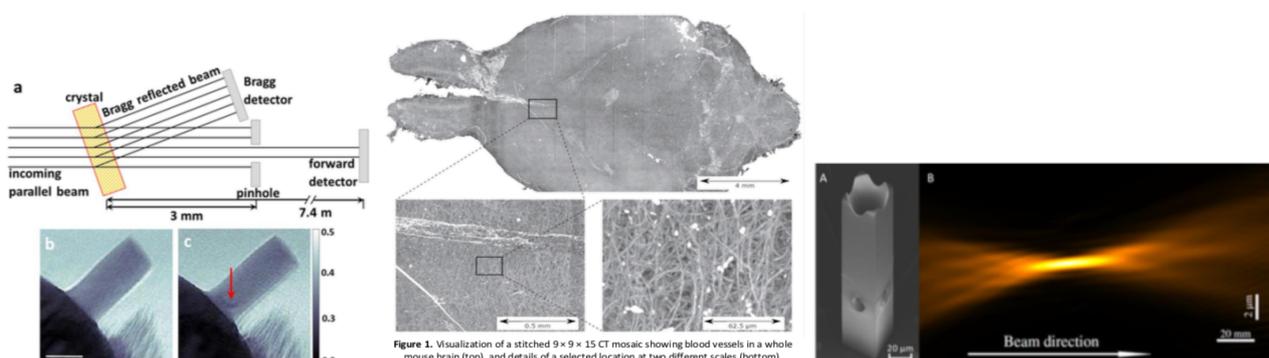
**11:00 Coffee break**

**11:15 Large volume tomography of biological tissues at TOMCAT**

*Borisova Elena, Lovric G., Miettinen A., Fardin L., Stampanoni M., Schittny J-C and Schlepütz C.M.*

**11:45 Free-form refractive X-ray optical elements made by Two-Photon Lithograph**

*Koch Frieder, Lyubomirskiy M., Roth T., Seiboth F., Schroer C.G. and David C.*



# Strain field in deformed InSb revealed by in-situ X-ray Laue micro diffraction and post-mortem ptychographic topography

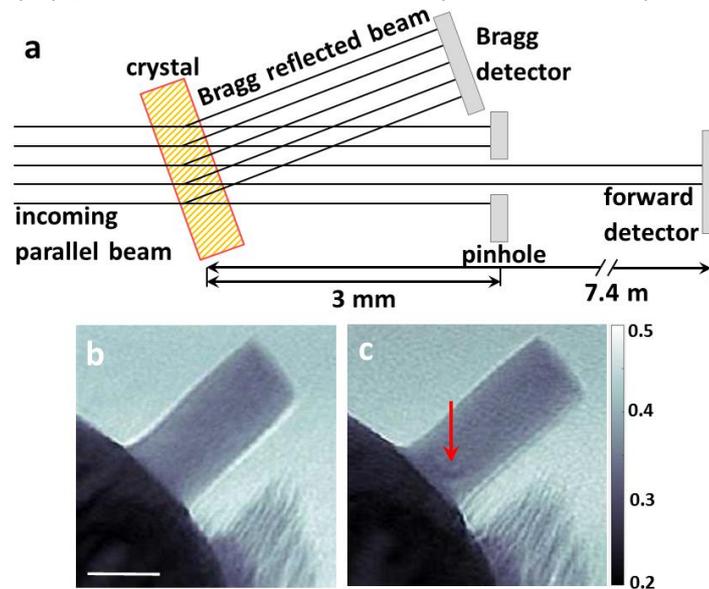
Verezhak Mariana<sup>1</sup>, Sadat Tarik<sup>2</sup>, Renault Pierre-Olivier<sup>2</sup>, Jacques Vincent<sup>3</sup>, Godard Pierre<sup>2</sup>, Wakonig Klaus<sup>1</sup>, Thilly Ludovic<sup>1</sup>, Van Petegem Steven<sup>1</sup>, and Diaz Ana<sup>1</sup>

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Non-invasive strain fields and defects characterization is a challenging task that finds a broad use in materials properties characterization, fabrication and design. InSb semiconductor is an interesting model for validation of strain characterization approaches. InSb in the form of micro-objects deforms differently from its bulk version in similar conditions: at room temperature and pressure, pillars with a diameter of a few microns exhibit ductile behaviour, although in such experimental conditions the macroscopic samples are brittle. In addition, it exhibits a single slip dislocation mechanism upon compression along a specific crystallographic axis [1]. We used a combination of in-situ X-ray Laue micro diffraction and ptychographic topography [2] to characterise strain fields present in this crystal.



**Figure 1.** a) Scheme of ptychographic topography setup; ptychographic amplitude images of the pillar that is out (b) and in (c) Bragg condition. Lattice distortion is observed (red arrow) when the sample is close to Bragg condition [2]. Scale bar: 2  $\mu\text{m}$ .

With in-situ X-ray Laue micro diffraction, we observed the beginning of plastic deformation and post-mortem ptychographic topography revealed the presence of lattice distortions with a resolution of 100 nm, as shown in Fig. 1. While Laue micro diffraction provides strain characterization with resolution limited by the beam size, ptychographic topography allows direct visualization of lattice defects with higher resolution.

[1] J. M. Wheeler et al., *Acta Materialia*, (2016).

[2] M. Verezhak et al., *Microsc. Microanal.* 24 (Suppl 2), (2018).

# Analysis methods for terabyte-scale volume images: application to brain microvasculature

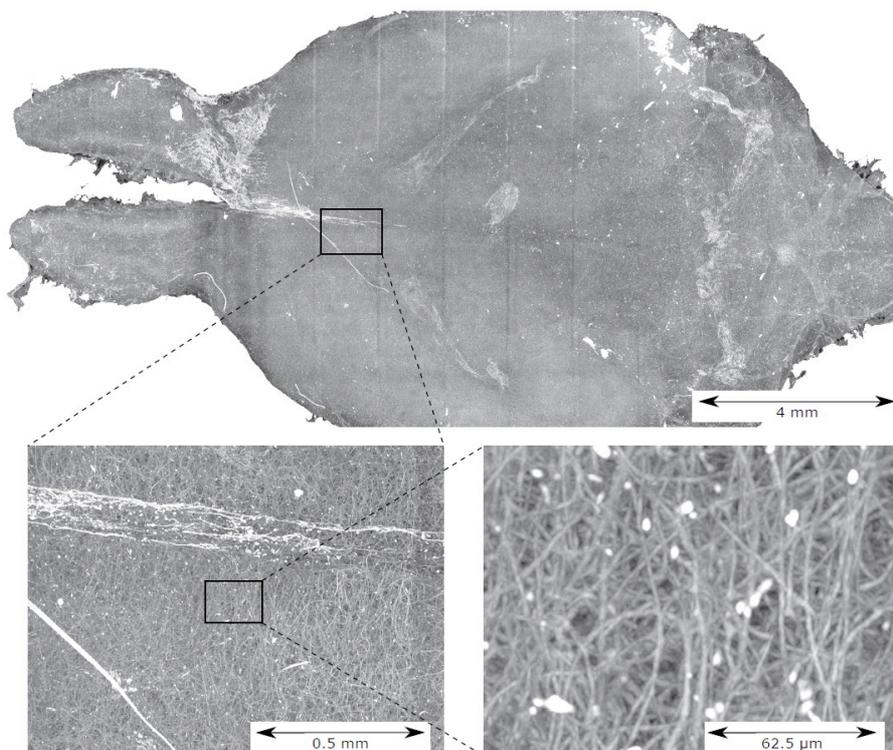
Miettinen Arttu<sup>1,2</sup>

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Recent developments in various imaging techniques, such as X-ray tomography, have enabled acquisition of volume images whose size is in the terabyte scale. Analysis of such large datasets often requires use of computing clusters and high-performance computing techniques not readily available in existing software packages. In this presentation we show a recently developed image analysis system that enables processing and analysis of volume images of practically any size. The system divides large analysis tasks automatically to smaller sub-tasks that can be completed either using the local computer or compute nodes if they are available. All the work distribution is done automatically so the same analysis script can be run on a small or a large image, making the system very user-friendly. Multiple user interfaces (e.g. Python) are supported.

As an example of the use of the software we apply it to construction and analysis of a tomographic image of full mouse brain with  $0.65\ \mu\text{m}$  pixel size, acquired at the TOMCAT beamline. We show that it is possible to use the developed system to make a segmentation of microvasculature in the brain and perform quantitative analysis on it. The possibility to perform such large-scale analysis may open new directions both in biomedical and materials sciences.



**Figure 1.** Visualization of a stitched  $9 \times 9 \times 15$  CT mosaic showing blood vessels in a whole mouse brain (top), and details of a selected location at two different scales (bottom).

# Large volume tomography of biological tissues at TOMCAT

Elena Borisova<sup>1</sup>, Goran Lovric<sup>1,2</sup>, Arttu Miettinen<sup>1</sup>, Luca Fardin<sup>3</sup>, Marco Stampanoni<sup>1,4</sup>, Johannes C. Schittny<sup>2</sup> and Christian M. Schlepütz<sup>1</sup>

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When performing X-Ray tomography on biological tissue, the goal is to capture it in its original state before ageing or beam-induced alterations of the structure occur. For large tissue samples with small sized structures, a single high-resolution tomographic scan cannot cover the whole volume of interest with a single acquisition. As the tissue is undergoing irreversible changes with time, acquiring a mosaic of tomographic scans on such samples is valid only if taken in a sufficiently short period of time such that changes in the tissue structure are minimized. This puts strict constraints on the speed of the acquisition system and how fast the motors can move the sample in the field of view to capture its different parts. In this talk, an example of a large volume biological tomographic experiment at TOMCAT will be presented. Limitations of the imaging system as well as ways of handling such types of data will be discussed.

[1] Borisova, Lovric et al., in prep., (2019).

# Free-form refractive X-ray optical elements made by Two-Photon Lithography

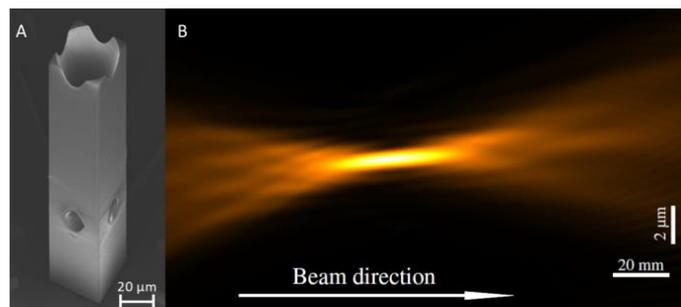
Frieder Koch<sup>1</sup>, Mikhail Lyubomirskiy<sup>2</sup>, Thomas Roth<sup>3</sup>, Frank Seiboth<sup>2</sup>, C.G. Schroer<sup>2</sup> and Christian David<sup>1</sup>

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Refractive X-ray optical elements are used in many synchrotron radiation applications, e.g. as objectives for full-field microscopy or for the creation of nanoscale beams for scanning techniques. The low refractive power of all lens materials introduces the need for very small radii of curvature, which complicates fabrication. Refractive lenses made from Silicon, Beryllium, Aluminum or SU-8 have been reported, all with their individual advantages. Recently additive manufacturing has been introduced as a way to fabricate X-ray optical components that offers high quality and greatly enhanced flexibility in optics design compared to established techniques. The talk will present results on refractive lenses and corrective phase plates fabricated with two-photon polymerization as examples to highlight the capabilities of the technique for X-ray optics fabrication.



**Figure 1.** A SEM picture of an additive manufacturing CRL B beam caustic of this lens calculated from a ptychographic scan at 8.2 keV.

An example of a refractive lens made by two-photon polymerization is shown in Fig. 1 [1]. The lens has a focal length of 240 mm at 8.2 keV. The beam caustic is calculated from the illumination function determined by a ptychographic scan and shows small sidelobe intensity. Propagation of the wavefront to the exit of the lens confirms aberrations to be significantly smaller than typically found e.g. in Be lenses. Large apertures can also be realized by switching to a kinoform lens layout. Used as corrective phase plates, these polymeric structures show a similar performance as previous structures made by laser ablation of SiO<sub>2</sub>, while significantly increasing the transmission[2].

Two-photon polymerization offers an easy way to fabricate high quality, free form refractive X-ray optical elements, both for polymeric compound refractive lenses as well as corrective elements for other lens types. Additionally, it offers new degrees of freedom in design of optical elements such as lens arrays or freestanding optics for difficult sample environments.

[1] M. Lyubomirskiy, F.Koch *et al.*, "Ptychographic characterization of polymer compound refractive lenses manufactured by additive technology," *Press*.

[2] F. Seiboth *et al.*, "Perfect X-ray focusing via fitting corrective glasses to aberrated optics," *Nat. Commun.*, vol. 8, p. 14623, Mar. 2017.