Advanced phase contrast imaging using a grating interferometer

X-ray tomographic microscopy is a powerful technique for fast, non-destructive, high-resolution, quantitative 3-D investigations of objects and is now used in a wide variety of disciplines ranging from life sciences through materials science to environmental and earth sciences. The use of conventional absorption based X-ray microtomography, where contrast is generated by the difference in X-ray attenuation between the different features contained within the sample, can become limited for objects showing only very weak attenuation contrast at high energies. The X-ray absorption coefficient is roughly proportional to the fourth power of the atomic number Z and, therefore, materials consisting of low-Z elements such as soft tissue samples or organic and polymer materials produce very little image contrast. However, a wide range of samples studied in biology and materials science can produce significant phase shifts of the X-ray beam. The interaction cross-section of the X-ray phase shift can be as much as three orders of magnitude larger than that of absorption and thus phase contrast X-ray imaging can provide substantially increased contrast sensitivity. This enables the structure of soft tissue samples, for example, to be investigated without the need for tissue alteration/modification for contrast enhancement. An added advantage is that phase signals can be produced with much lower dose deposition than absorption, which can be very important when radiation damage becomes an issue.

A Differential Phase Contrast (DPC) imaging facility, based on grating interferometry, has been installed at the TOMCAT beamline, with the aim of having a high-throughput of samples in terms of fast data acquisition and post-processing. The technique is complementary to the Modified Transport of Intensity phase contrast method also used at the beamline. This propagation-based phase contrast method is particularly suited for small specimens when high resolution (around 1 μm) is required. The DPC method is characterised by a higher sensitivity to low spatial frequencies and by moderate resolution with larger samples. With the present work, published in *Journal of Synchrotron Radiation*, we report on the DPC imaging technique with regards to the latest hardware and software advancements, including an illustration of different imaging methods such as region-of-interest and widefield DPC tomography and darkfield imaging. In the latter the image contrast is formed through the mechanism of small-angle scattering, thus providing complementary information about a sample at the micron and the sub-micron length scales. The method simultaneously provides differential phase contrast, darkfield and transmission signals, thus providing maximum information about a sample.

Figure 1, the front cover illustration for the July edition of *Journal of Synchrotron Radiation*, shows a DPC tomographic reconstruction of the anatomy of a rat brain, obtained with X-ray grating interferometry at the TOMCAT beamline of the Swiss Light Source. With a sensitivity in the order of 1 mg/cm^3 at an isotropic voxel size of 7.4 μm, this method allows to visualize regions of the brain such as hippocampus and cerebellum (with white and grey matter) with a contrast impossible to reach for conventional absorption-based imaging.

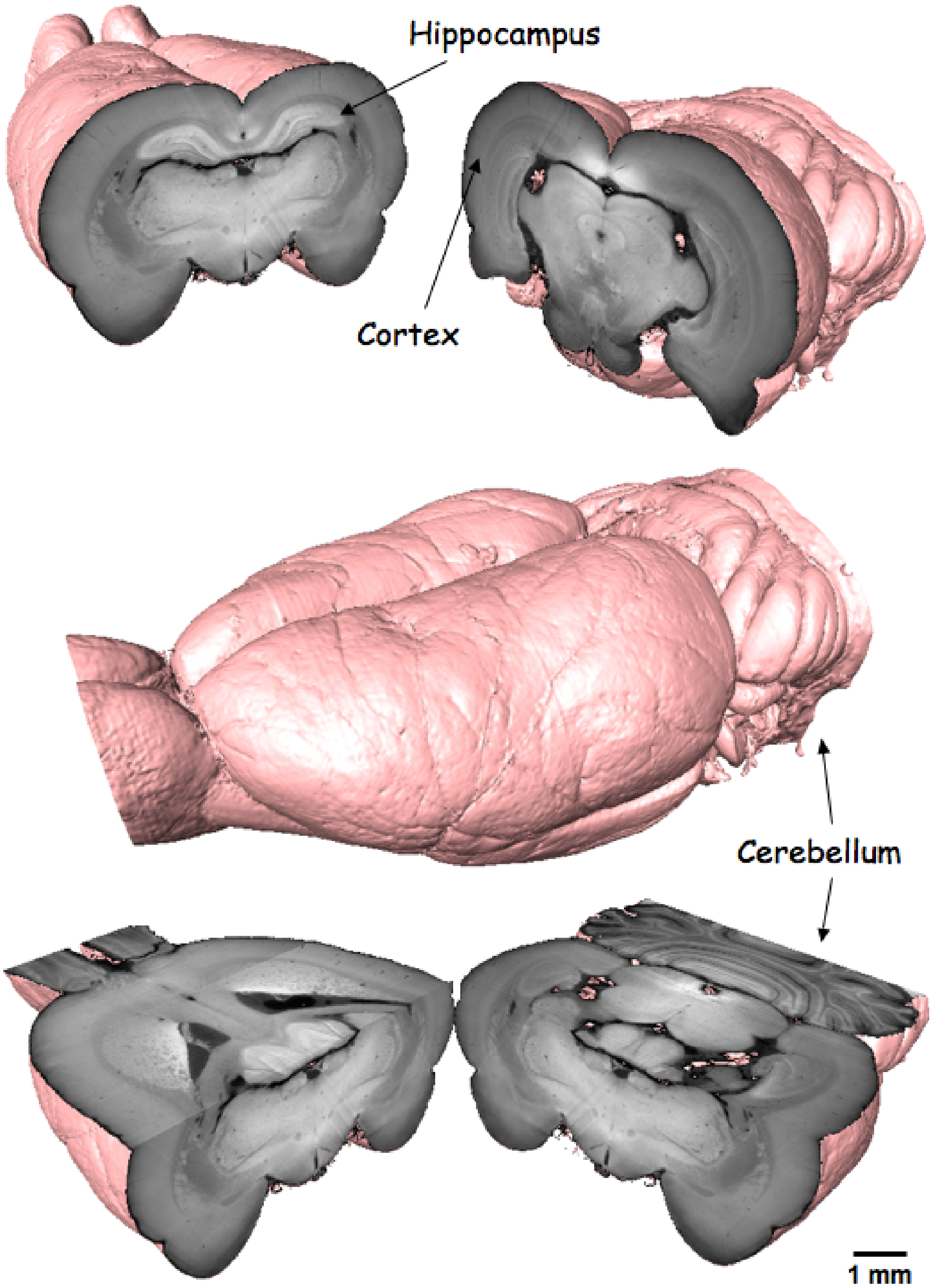

Figure 1. 3D tomographic volume of a rat brain scanned using differential phase contrast and reconstructed with a pixel size of 7.4 µm.

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