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Orientation Map of Nerve Fibres in Thin Brain Sections by Small Angle X-ray Scattering

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The brain is the most complex organ in the body that serves as the center of the nervous system and consists of billions of neurons [1]. The structure and function of the brain is intricately linked to the structural connectome i.e the neurons and neural connections. To better understand function, dys-function and neurodegenerative disease of the brain, it is essential to have a map of the connectome.
The standard method for connectome mapping is Diffusion Magnetic Resonance Imaging (dMRI), which is limited to a spatial resolution of ~500 µm (post mortem) or 2 mm (in vivo), respectively. More recently, 3D polarized light imaging (3D-PLI) has been developed into a powerful tool to determine the nerve fiber (i.e., myelinated axon) orientations and their distribution (FOD) across a thin (60µm), unstained histological brain sections by transmitting polarized light through them and quantifying the resultant birefringence [2].
However, the addressable voxel size is largely anisotropic, which often leads to partial volume effects in voxels comprising fibers running in multiple directions. This means that the average birefringence signal is close zero and FOD cannot be determined reliably. To overcome this, we have started using small angle x-ray scattering (SAXS) to determine the FOD and the structural details of the myelin sheath around the axon [3].
Here, we will demonstrate our recent SAXS results from the thin, unstained histological brain sections. We have carried out 2D scans of several full brain sections of mouse (sectioned along sagittal-cut and coronal-cut direction) and human (few complex ROI) using transmission SAXS at a synchrotron as well as a laboratory x-ray source. We were able to prepare a complete 2D orientational map of nerve fibers from the azimuthal distribution of the scattering peak/arc/rings out of thousands SAXS patterns, collected at a spatial resolution of 100-200µm. We will also present the 3D-PLI results of the corresponding brain sections to obtain a complete picture of the connectome map [4]. Recently Giorgidias et. al. have shown that by measuring a brain slice at different tilt angles the FOD in 3D can be obtained. The underlying principle of their work and our plans in terms of experiments and more detailed analysis of the scattering from nerve fibers are outlined.

[1] C. S. von Bartheld et al, J. Comparat. Neurology, 524, 3865 (2016). [2] M. Axer et al Front. Neuroinform., 5, 34 (2011). [3] M. De Felici et al., Phys. Med. Biol. 53, 5675 (2008). [4] S. Maiti, M. Dulle, M. Axer and S. Förster (in preparation) [5] M. Georgiadis et al, Neuroimage 204, 116214 (2020),

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