Synchrotron X-ray imaging for brains

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The high-brightness x-rays provided by the new facilities such as synchrotrons and x-ray free electron laser opens the door for x-ray microscopy to an unprecedented level of performance. The technology to focus hard-x-rays photons has made great progress in the past decade. However, practically achieving nanometer scale resolution remains a formidable technology challenge. The development of nanotechnology to fabricate nanostructured device impacted x-ray microscopy by providing finally the long-sought optics required to achieve high resolution and high contrast tomography.

The progress was particularly spectacular for Fresnel zone plate (FZP) optics. FZPs are widely used as focusing and magnifying devices in almost the entire electromagnetic spectrum. It offers particularly the highest imaging resolution and low aberration for the x-ray full-field imaging and makes it the device of choice for X-ray full-field imaging. This evolution is the result of a painstaking optimization of many different aspects and the sub-20 nm spatial resolution we achieved opening up entirely new domains of application, with particular impact to the materials characterization and the biomedical research.

The new capability of high spatial and temporal resolution by the integration of micro- and nano-tomography is best for neurobiology. The complexity of the complete neural networks is beyond the current technology to describe, analyze and understand and comprehensive mapping of neural networks in the brain is therefore a formidable but very exciting challenge. It is now a consensus that the first step towards understanding brain functions is to construct a basic map – a connectome – showing the neural network at the level of single neurons and connections.

Could x-ray techniques be the tool of choice to challenge the animal brain connectome mapping? Is the overall performance adequate, however? Our positive results show that there are two additional directions need to be further improved: an even better spatial resolution and higher probe depth, both are relevant to the high brightness synchrotron radiation and new nanofabrication facilities. As one of the six “high priority challenges” in the US BRAIN Initiative: “Maps at multiple scales: Generate circuit diagrams that vary in resolution from synapses to the whole brain”, we believe our approach will transform this vision into reality with these improvements.