Towards a dynamic map of neuronal circuits

Alipasha Vaziri*†1

1Research Institute of Molecular Pathology (IMP) – University of Vienna, Austria

Abstract

Knowledge on structural connectivity in neuronal circuits is necessary for understanding information representation and processing in local circuits. However, as some examples of well-characterized neuronal architectures illustrate, structural connectivity alone it is not sufficient to predict how input stimuli are mapped onto activity patterns of neuronal populations and how the collective dynamics of all neurons in the network leads to behavior. Addressing this challenge has been hampered by lack of appropriate tools and methods that allow parallel and spatiotemporally specific application of excitation patterns onto neuronal populations while capturing the dynamic activity of the entire network at high spatial and temporal resolution. The combination of new optical excitation techniques, optogenetics and high speed functional imaging are providing new opportunities to address this question and move towards a dynamic map of neuronal circuits.

I will address a number advances in that respect that we have recently implemented in our lab using two different technologies. One approach relies on "sculpting" the excitation volumes in biological samples using non linear optics and the other relies on light field imaging, a tomography type approach for simultaneous readout of neuronal activity in 3D. Using these techniques we have recently shown brain-wide functional imaging of entire nervous systems at single cell resolution [1]. Further, we demonstrate intrinsically simultaneous volumetric Ca-imaging in the entire brain of larval zebrafish during sensory stimulation [2]. We are able to track the activity of 5000 neurons distributed throughout the brain at 20Hz volume rate. The simplicity of this technique and the possibility of the integration into conventional microscopes make it an attractive tool for high-speed volumetric functional-imaging. These tools combined with high speed optogenetic control of neuronal circuits [3, 4], advanced statistics tools and mathematical modeling and will be crucial to move from an anatomical wiring map towards a dynamic map of neuronal circuits.

References:

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*Speaker

†Corresponding author: alipasha.vaziri@univie.ac.at