Two-photon holographic manipulation of neuronal circuits

Valentina Emiliani
Vision Institute, Sorbonne University/ CNRS UMR 7210/ INSERM UMR S968/
17, rue Moreau 75012 Paris, France

Abstract:

The genetic targeting of neuronal cells with activity reporters, such as calcium or voltage indicators, has driven a paradigmatic shift in neuroscience, where photons have replaced electrons in reading large-scale brain activities at cellular resolution. Simultaneously, optogenetics has shown that targeting neuronal cells with photosensitive microbial opsins enables the transduction of photons into electrical currents of opposing polarities. This allows for the activation or inhibition of neuronal signals in a minimally invasive manner.

These advances have, in turn, spurred the development of sophisticated wavefront-shaping techniques to enable "all-optical" interrogation of deep brain circuits with high spatial and temporal resolution across large volumes[1].

In this presentation, we will discuss the most recent approaches that we have recently proposed to enhance the capacity for patterned all-optical circuit manipulation. These approaches enable efficient in vivo two-photon multitarget optogenetic photostimulation[2] and voltage imaging[3] in both head-fixed and freely moving mice[4]. As an example of patterned optogenetics, we will present a recent experiment demonstrating high-throughput connectivity mapping in the mouse visual cortex[5].

1. V. Emiliani et al. *Optogenetics for light control of biological systems*.
Nature Rev Methods Prime. (2022)
2. G.Faini*, D.Tanese*, et al.
Ultrafast Light Targeting for High-Throughput Precise Control of Neuronal Networks
Nature Comm, 14, 1888 (2023)
3. R. R. Sims*, I. Bendifallah*, et al. *Scannes volage imaging*
Nature Comm, 15, 5095 (2024)
4. N. Accanto*, F. Blot *, A. Lorca* et al. *A flexible two-photon fiberscope for fast activity imaging and precise optogenetic photostimulation of neurons in freely moving mice*
Neuron, Jan 18;111(2):176-189.e6 (2023)
5. I-W. Chen*, C. Y. Chan*, et al. *High-throughput synaptic connectivity mapping using two-photon holographic optogenetics and compressive sensing in vivo*
Research Square 2023, Biorxiv (2023)