Thesis subject

Laboratory: Institut Fresnel

Thesis supervisor: Thomas Chaigne

Title of the thesis subject: Compressed all-optical photoacoustic imaging of neuronal activity in mice

Description of the thesis subject:

The **study of large scale neuronal circuits throughout the brain** is currently *one of the biggest challenge in neurobiology.* Non-invasive imaging of neuronal activity with single cell resolution is however limited to shallow depths, due to prominent light scattering beyond one millimeter. **Photoacoustic imaging**, a fascinating technique relying on *ultrasound generation upon the absorption of a light pulse*, has been developed to overcome this issue, enabling to **probe optical absorption contrast at large depths in biological tissue**.

To achieve cellular resolution, the detected ultrasound bandwidth must be as large as 100 MHz, which is beyond the reach of conventional piezo-electric based sensors. We therefore developed **optical sensors of ultrasound** to overcome this issue [1]. This however requires an interrogation beam to be raster-scanned across the sensor, thus preventing to reach the required frame rate for our application (>1 Hz). **The goal of this PhD is to develop a fast interrogation technique of the sensor based on compressive sensing** [2], [3]. Inspired by single-pixel camera approaches [4], this system will reduce by at least two orders of magnitude the number of acquisitions and provide high frame rate to image neuronal activity deep inside tissue.

The candidate will develop a wide-field interrogation system of the optical ultrasound sensors, as well as implement data acquisition and image reconstruction approaches based on compressive sensing. By harnessing the spatio-temporal sparsity and known statistical properties of neurons and their electrical activity, this will speed up the final volume rate by at least two orders of magnitude. These techniques will first be tested in controlled phantom samples, and then be applied to perform calcium imaging in mice.

References :

[1] J. Saucourt, A. Moreau, J. Lumeau, H. Rigneault, and T. Chaigne, “Fast interrogation wavelength tuning for all-optical photoacoustic imaging,” *Opt. Express, OE*, vol. 31, no. 7, pp. 11164–11172, Mar. 2023

[2] E. J. Candes and M. B. Wakin, “An Introduction To Compressive Sampling,” *IEEE Signal Process. Mag.*, vol. 25, no. 2, pp. 21–30, Mar. 2008, doi: 10.1109/MSP.2007.914731.

[3] N. Huynh *et al.*, “Single-pixel camera photoacoustic tomography,” *Journal of Biomedical Optics*, vol. 24, no. 12, p. 1, Sep. 2019, doi: 10.1117/1.JBO.24.12.121907.

[4] M. P. Edgar, G. M. Gibson, and M. J. Padgett, “Principles and prospects for single-pixel imaging,” *Nature Photonics*, vol. 13, no. 1, p. 13, Jan. 2019, doi: 10.1038/s41566-018-0300-7.