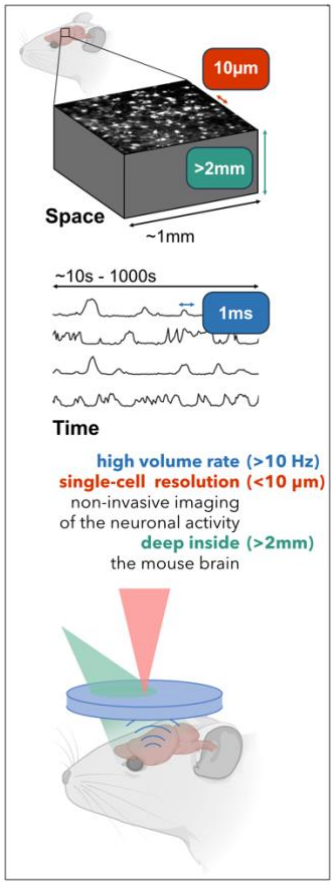
Internship/PhD position - Compressed all-optical photoacoustic imaging of neuronal activity in mice

Motivation

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).



Graphical abstract. Typical scales involved: (Space) 10 µm-diameter neurons lying several millimeters deep inside the brain (Time) exchange information by sending 1ms long electrical pulses, or action potentials. The goal of this project is to image this activity at high frame rate, single-cell resolution, at large depth. This will be achieved by using all-optical photoacoustic imaging.

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.

Research program

You 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.

Collaborations

The candidate will build upon both the existing equipment as well as the combined expertise of the PIs involved in the project, regarding photoacoustic imaging, thin-film deposition and signal processing. This project will also be carried out in close collaboration with neurobiology labs from Marseille (Inmed, INT).

Why you should apply

By joining our research group at the Fresnel Institute in Marseille, you will gain hands-on experience in cutting-edge optical imaging. We are seeking enthusiastic and motivated students to participate in groundbreaking research.

This is a unique opportunity to gain experience in a wide range of skills, from numerical simulations and clean room fabrication to optical and electrical instrumentation, along with image reconstruction and processing.

You will work closely with our team of experts, learn how to use state-of-the-art equipment, and develop programming skills (Matlab or Python). In addition to technical skills, you will also gain a strong understanding of the biology and neuroscience behind our research. Our team of over 30 international researchers is working at the crossroads of physics and biology, and we welcome students from a variety of backgrounds to join us.

On top of a thrilling research environment, the city of Marseille offers a high quality of life, with limited living costs and a unique combination of a culture and nature.

Left: the Fresnel Institute (30 minutes by bike or public transportation from the city center); Middle: the city center and old harbour, heart of Marseille; Right: the calanques, less than an hour by public transportation from the city center

Requirements

To be considered for this internship, you should have a strong background in physics, optics, electrical engineering, neuroscience (with some experience in optical imaging) or any related field. Basic programming skills are essential (Matlab or Python), as well as a certain taste for tinkering. As you will be evolving in an international environment, you must be fluent in English (at least C1), and exhibit excellent communications capabilities (written and spoken).

Application

Please send a detailed CV, a cover letter describing your interests and past achievements, (max. 1 page), a copy of your university transcripts, as well as names, affiliations, and email addresses of two references to thomas.chaigne@fresnel.fr with the subject line "[Application]". The project can lead to a full PhD in the group.

We look forward to hearing from you!

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, Available: https://opg.optica.org/oe/abstract.cfm?uri=oe-31-7-11164.

[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. Available: http://ieeexplore.ieee.org/document/4472240/.

[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. Available: https://www.spiedigitallibrary.org/journals/journal-of-biomedical-optics/volume-24/issue-12/121907/Single-pixel-camera-photoacoustic-tomography/10.1117/1.JBO.24.12.121907.full.

[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. Available: https://www-nature-com.insis.bib.cnrs.fr/articles/s41566-018-0300-7.