Centrale Méditerranée

Proposition de sujet d'alternance 1A
2024-25

Laboratoire : Institut Fresnel

Titre du sujet : All-optical photoacoustic imaging of neuronal activity

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** un co-encadrement est possible.*
*** l'encadrement devra être assuré de préférence par un permanent du laboratoire, au **minimum titulaire d'un Doctorat**.*

Descriptif du sujet et de la mission (au moins sur la 1er année) :

All-optical photoacoustic imaging of neuronal activity

We are seeking enthusiastic and talented candidates to develop innovative imaging strategies combining optics and acoustics to study neuronal activity deep inside the brain.

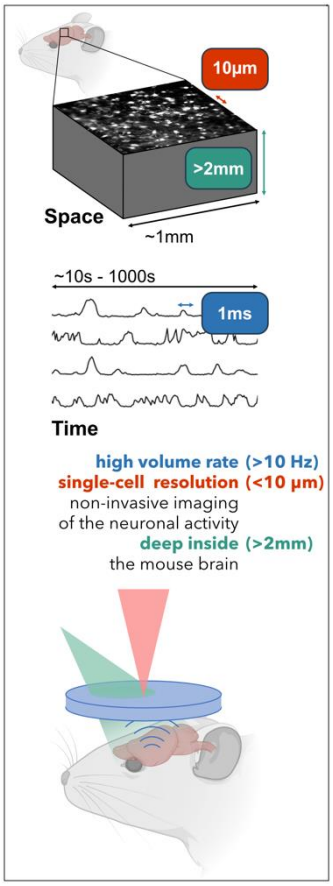
Context

The study of large-scale neuronal circuits throughout the brain is currently one of the biggest challenges in neurobiology[1]. Non-invasive imaging of neuronal activity with single-cell resolution is however limited to shallow depths, due to prominent light scattering beyond one millimeter[2]. 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[3].
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[4].

Research program

Our goal is to push forward the capabilities of this technique and reach the spatio-temporal resolution required to image the activity of neurons *in vivo.*
Several challenges must therefore be tackled at all levels:

- **Sensors:** numerical modelling, fabrication, characterization
- **Imaging:** explore various strategies to enhance sensitivity and throughput



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.

- **Image/signal processing:** exploit application specificities to efficiently extract signals of interest
- **Application:** apply our technique to various systems, from *ex vivo* brain slices to living, awake animals

Collaborations

The candidate will build upon both the existing equipment as well as the combined expertise of the PIs involved in the project within the Fresnel Institute, 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). Collaborations with KIT (Karlsruhe, Germany) can be considered.

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 candidates 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

Applicant skills

To be considered for this position, you should have a strong background in physics, optics, electrical engineering, 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, cover letter, and the contact details of two references to thomas.chaigne@fresnel.fr with the subject line "[Application]".
We look forward to hearing from you!

References

1. Yuste, R. From the neuron doctrine to neural networks. *Nature Reviews Neuroscience* **16**, 487–497 (2015).

2. Ntziachristos, V. Going deeper than microscopy: the optical imaging frontier in biology. *Nature Methods* **7**, 603–614 (2010).

3. Beard, P. Biomedical photoacoustic imaging. *Interface Focus* **1**, 602–631 (2011).

4. Saucourt, J., Moreau, A., Lumeau, J., Rigneault, H. & Chaigne, T. Fast interrogation wavelength tuning for all-optical photoacoustic imaging. *Opt. Express, OE* **31**, 11164–11172 (2023).

Validation pour mise en ligne ECM :