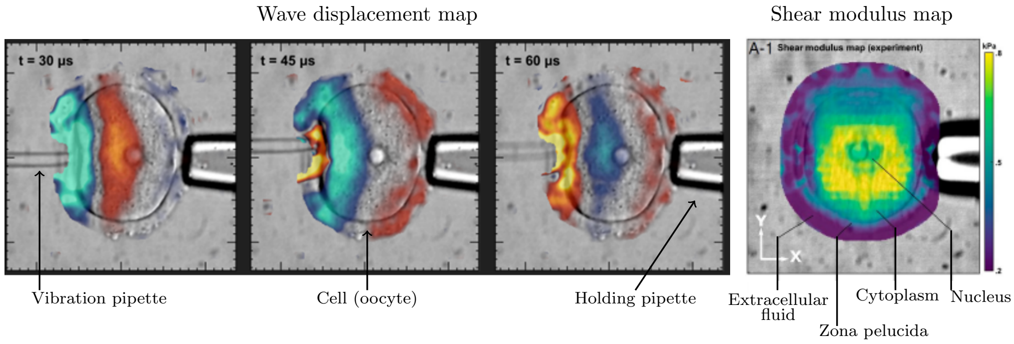
Bubble-induced contactless microelastography of biological cells

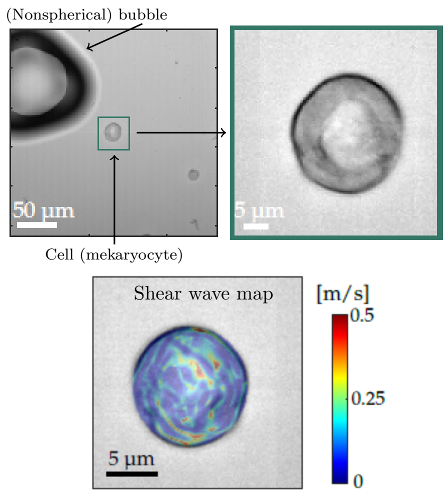
M2 internship proposal in Acoustics, Spring 2026

Context and preliminary work

In wave physics, uncorrelated vibrations could be exploited using noise correlation tools to reconstruct images of a medium. By using a high-frequency vibration, a high-speed tracking device, and a reconstruction technique based on temporal correlations of travelling waves, it is possible to map the elasticity of tissues or organs. Measuring the elasticiy of tissues is primordial in the aim of assessing the pathological state of an organ for instance, by probing the change of stiffness in comparison to a healthy sample. Coupling optical microscopy to the elastography technique allowed in 2018 to perform a significant scale change by detecting the propagation of shear waves into a single biological cell [1]. The measurement of the cell elasticity at the micrometer scale, called microelastography, allows mapping internal cell structures, and thus represents a tractable option for interrogating biomechanical properties of diverse cell types.



The cell microelastography technique has been performed using oocytes ($\sim 100\mu$m diameter) attached to a micropipette and excited by another one on the opposite side. Such a contacting excitation disturbs the behavior of the cell membrane and make complex the automatization of the process. These drawbacks have been recently raised by using a unique oscillating bubble that shakes a single biological cell of smaller size ($\sim 30\mu$m diameter). This bubble can oscillate spherically or non-spherically depending on the driving pressure amplitude [2]. Coupling sensitive optical microscopy to elastography technique revealed that shear waves propagate in the cell allowing the mapping of its elasticity for micrometric cell size [3].



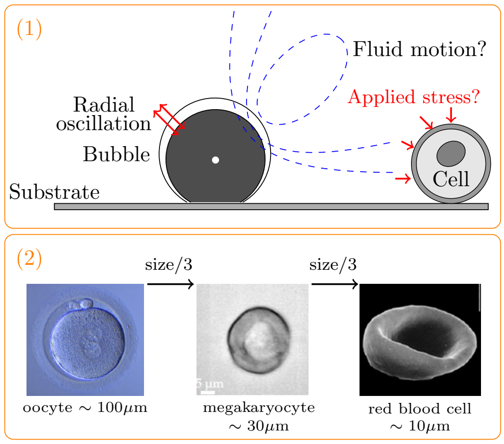
Problematics

While the proof-of-concept of the microelastography technique has been performed, the mechanisms underlying the bubble-mediated wave generation within the cells are still unknown, and the cell size needs to be decreased to the common size of cancerous cells.

Work program

The objective of the M2 internship project is to advance in the understanding of the mechanisms leading to shear wave propagation within micrometric single biological cells using a contactless vibrating body : the acoustic bubble. One of the challenge is to fasten the acquisition process of the cell elastography technique, in order to make reproducible and to broaden the application of this technique to smaller cells, to various cell lines and to differentiate cancerous cells versus intact ones. These investigations will be performed in a twofold program :

1. The interaction between a single oscillating bubble and a single micrometric cell will be determined at the acoustic timescale, quantifying cell deformation, the surrounding fluid motion, the scattered pressure field from the bubble that can oscillate spherically or along shape oscillations.
2. The second challenge consists in decreasing the size of the investigated cells : after oocyte (100μm diameter) and megakaryocyte ($30 - 40\mu$m), optimization of the optical setup must be handled in order to investigate cancerous cells, with a characteristic size of 10μm.



Laboratory

The work program will be performed at the Laboratory of Therapeutic Applications of Ultrasound (LabTAU, Lyon, France). LabTAU possesses an expertise in the study and optimization of innovative ultrasound strategies, cavitation physics and wave elastography.

Supervision

— Claude INSERRA, LabTAU, Associate Professor (HdR), claude.inserra@inserm.fr
— Stefan Catheline, LabTAU, INSERM Research Director (HdR), stefan.catheline@inserm.fr

Intern profile and Application

The candidate should have academic knowledge in one or several disciplinary fields related to the project : acoustics, applied physics, fluid mechanics, microfluidics.

Bibliography

1. P. Grasland-Mongrain, A. Zorgani, S. Nakagawa, S. Bernard, L. Gomes Pain, G. Fitzharris, S. Catheline, G. Cloutier. *Ultrafast imaging of cell elasticity with optical microelastography.* PNAS, **115**(5), 861-866, 2018.
2. M. Fauconnier, C. Mauger, J.C. Bera, C. Inserra. *Nonspherical dynamics and microstreaming of a wall-attached microbubble.* J. Fluid Mech., **935**, A22, 2022.
3. G. Laloy-Borgna, M. Fauconnier, C. Inserra, S. Catheline. *Contactless, bubble-mediated microelastography of a single biological cell*, in preparation.