UNIVERSITÉ DE FRANCHE-COMTÉ

UBFC UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ

école doctorale **sciences pour l'ingénieur et microtechniques** SPIM

Titre de la thèse/Thesis title :

Characterization by micro-Brillouin analysis of nanostructured materials and biological objects

Laboratoire d'accueil / Host Laboratory : FEMTO-ST, MN2S department

Spécialité du doctorat préparé/Speciality : Engineering sciences

Mots-clefs / Keywords : Brillouin light scattering, opto-acoustics, material science

Descriptif détaillé de la thèse / Job description

It is proposed to work on microscopy techniques based on inelastic light scattering (**Brillouin light scattering**). Such techniques allow one to obtain acoustic velocities inside matter, with many applications in material science but also in biology. Instrumental developments will be complemented by the development of computer programs aiming at simplifying and guiding measurements. Samples considered include functional materials fabricated at the FEMTO-ST institute or obtained through collaborations, but also biological objects present in blood, e.g. cells or vesicles.

Specific goals include setting up the micro-Brillouin experiment on an existing **multi-pass Fabry-Perot interferometer** (The Table Stable LTD), including translation tables to obtain Brillouin maps of small samples; writing computer code for experiment/theory comparison; considering piezoelectric and glancing-angle deposition thin-films elaborated on-site; setting up a virtual laboratory experiment for public demonstrations; characterizing biological samples and comparing with atomic force microscopy results in terms of mechanical elasticity; characterizing active and functional samples obtained within an international collaboration.

The PhD student will be in charge of instrumental developments together with an optical research engineer, will write codes together with a theorist of light and sound interactions, and will examine biological objects under the supervision of a biologist. Team work is expected.

We plan to consider different types of samples, as follows.

1. **Crystals and optically transparent homogeneous media**. Based on already available models that give the Brillouin response as a function of experimental parameters [1,2], the goal will be to compare in almost real-time to experimental measurements. Furthermore, the inverse problem will be solved, in which a set of optimal experimental configurations (sample orientation and material cut) will be identified to obtain a faithful estimation of material tensors [3]. The technique will be applied for instance to lithium niobate ($LiNbO_3$), sapphire, and tellurium dioxide (TeO_2).

2. **Piezoelectric thin films and nanocomposites** (available locally). In complement to the above steps, micro-Brillouin measurements will be performed to obtain local variations of the structural properties of samples.

3. **Active and functional materials** (national and international collaborations). We have access to polymer samples containing for instance liquid crystals with controlled orientation. Such smart materials are sensitive to external stimuli, either thermal or optical, and are used for 4D additive micro-structures [4].

4. **Biological objects and media** (available locally). The goal is to measure locally the elastic properties and provide information useful to discriminate between sub-populations. Of interest is the elastic characterization of cell membranes under diverse situations, including separation from or fusion with extracellular vesicles [5]. Comparison will be made with atomic force microscopy in liquids that provides a quasi-static measurement of elasticity at the nanometer scale.

Références bibliographiques / Bibliography

[1] V. Laude and J.-C. Beugnot, "Lagrangian description of Brillouin scattering and electrostriction in nanoscale optical waveguides," New J. Phys. 17, 125003 (2015). http://dx.doi.org/10.1088/1367-2630/17/12/125003

[2] Vincent Laude, Jean-Charles Beugnot, Thibaut Sylvestre, "Special Issue on Brillouin Scattering and Optomechanics," Applied Sciences 9, 3745 (2019). https://doi.org/10.3390/app9183745.

[3] Vincent Laude, Julio Andres Iglesias Martinez, Yan-Feng Wang, Muamer Kadic, ``Effective anisotropy of periodic acoustic and elastic composites,'' Journal of Applied Physics 129 (21), 215106 (2021). https://doi.org/10.1063/5.0045827.

[4] Qingxiang Ji, Johnny Moughames, Xueyan Chen, Guodong Fang, Juan J. Huaroto, Vincent Laude, Julio Andrés Iglesias Martínez, Gwenn Ulliac, Cédric Clévy, Philippe Lutz, Kanty Rabenorosoa, Valerian Guelpa, Arnaud Spangenberg, Jun Liang, Alexis Mosset, and Muamer Kadic, ``4D Thermomechanical metamaterials for soft microrobotics,'' Communications Materials 2 (1), 1-6 (2021). https://doi.org/10.1038/s43246-021-00189-0.

[5] Silva, Amanda KA, et al. "Development of extracellular vesicle-based medicinal products: A position paper of the group “Extracellular Vesicle translatiOn to clinicaL perspectiVEs–EVOLVE France”." Advanced Drug Delivery Reviews 179 (2021): 114001.

Profil demandé / Applicant profile

The candidate should hold a master degree in optics, acoustics, applied physics, wave physics, or instrumental techniques, or equivalent. Understanding of reference frames and tensors describing material properties will be useful. Interest in fundamental aspects of physics and instrumentation will be appreciated. Brillouin experiments require care, self-organization, and commitment to control precisely all experimental aspects. The depth of numerical simulations will be adapted to the candidate’s profile and interest.

Preferred selection criteria:
- Master in optics, wave physics, instrumentation, or applied physics
- Fluent English

Personal characteristics:
- Committment to write scientific publications
- Rigor
- Communication skills
- Computer programming and instrumentation

Financement : UBFC (contrat doctoral)

Dossier à envoyer pour le **20 mai 2022**
Début du contrat : 1er Octobre 2022

Direction de la thèse:/ **Thesis Supervision**
Dr Hab. Vincent Laude (thesis director), vincent.laude@femto-st.fr

Encadrement de la thèse : **co-directeur(s) et co-encadrant(s)**
Dr Alexis Mosset (co-supervisor), alexis.mosset@femto-st.fr
Dr Hab. Céline Elie-Caille (co-supervisor), celine.caille@femto-st.fr

Applicants are invited to submit their application to the PhD supervisors.
Application must contain the following documents:
- CV
- Cover letter
- At least 1 reference letter