2026-2027

# Master thesis proposal

**Title**: Generation of High-Frequency Transverse Acoustic Waves Using Picosecond Ultrasonics

**Keywords**: optical pump probe experiment, picosecond ultrasonics, sound attenuation, phonons, disordered materials, glasses, silica

**Scientific description**: Phenomena responsible for sound attenuation in disordered amorphous materials (glasses) are still a matter of research. Indeed, despite the lack of periodicity, collective vibrations reminiscent of phonons in crystals occur in glass but specific features arise when their wavelength becomes comparable to the disorder length scale, at frequencies of a few THz. There are two major obstacles to the progress of experimental research in this field. Primarily, there is a lack of techniques capable of accessing the appropriate range of phonon wave vector, q or frequency, $\nu$. This range lies between the upper limit of optical Brillouin spectroscopy using ultraviolet (UV) incident radiation, and the lower limit of inelastic thermal neutron or x-ray scattering (IXS) spectroscopies. This corresponds roughly to the 0.1 – 1 THz frequency range, little explored. Significant efforts have been made over time to develop tools that can bridge this gap. In particular, the development of novel setups in picosecond ultrasonics experiments has enabled us to gain access to this crucial (q, $\nu$) region of values, allowing a study of the longitudinal acoustic (LA) modes in an amorphous silica layer [1]. Another emerging technique uses a transient grating method induced by pulses of extreme UV light from the new free-electron laser sources. It primarily probes surface waves. The second issue is that, due to some instrumental limitations, IXS studies are restricted to the investigation of the LA modes, while the density of acoustic vibration modes is largely dominated by transverse modes (TA). Our project, therefore, is to develop **specific configurations of our picosecond acoustics setup dedicated to the generation of high frequency TA waves** that would allow, for the first time, access to the dynamics of both LA and TA branches (sound dispersion and attenuation) in the sub-THz range for a selected group of structural glasses, including silica.

Picosecond acoustics is an optical pump-probe technique that allows the excitation and detection of acoustic pulses. A thin metallic film, deposited on the surface of the sample, acts as an opto-acoustic transducer: it is responsible, after absorption of the "pump" laser pulse, for the generation of an acoustic pulse that will propagate in the sample. This acoustic wave returns to the surface after reflection on different interfaces of the sample, modifying the optical properties of the film. The "probe" laser pulse, delayed in time, will detect reflectivity changes. By these means, it is possible to study the time-of flight and decay of a picosecond acoustic pulse propagating through thin films, and access to sound propagation characteristics.

In thin film deposition, some specific techniques enable the fabrication of anisotropic structures. The GLancing Angle Deposition (GLAD) is among the most attractive approaches for producing original surface morphologies, especially to tune the surface anisotropy. Figure 1 shows an example of GLAD tungsten films, grown by Nicolas Martin (FEMTO ST, Besançon), consisting of oriented columnar microstructures. It has recently been demonstrated that such tilted thin metal films can be used as transducers to excite both longitudinal and transverse hypersonic waves [3].

This research project will focus on **the study of the transverse waves generated by various GLAD films deposited on $SiO_2$ layers on silicon**, in collaboration with Nicolas Martin and Marie Foret (L2C, Montpellier). Several aspects will be addressed, including the optimization of the experimental conditions, film thickness and deposition angle.

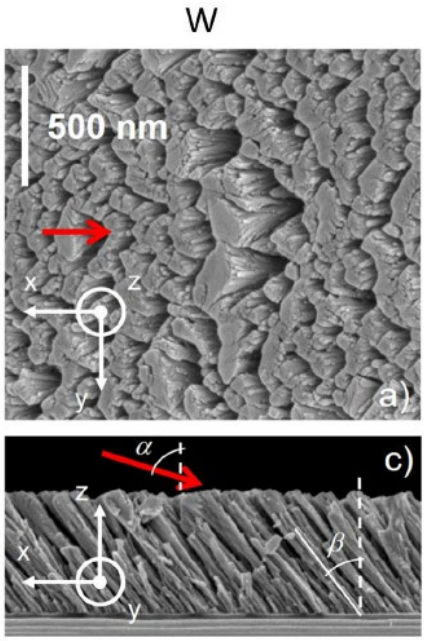


Fig. 1. SEM observations of surfaces (a) and cross-sections (c) of 500 nm thick W thin films sputter-deposited by DC magnetron sputtering with a normal incidence of the particle flux (α=0°). The scale bar is the same for all pictures. [2]


[1] P.-J. Wang *et al*., Quartic scaling of sound attenuation with frequency in vitreous silica, Phys. Rev. Lett. **134**, 196101 (2025)

[2] Raya El Beainou *et al*., Electrical resistivity and elastic wave propagation anisotropy in glancing angle deposited tungsten and gold thin films, Surface Science **475**, 606–614 (2019)

[3] A. Chargui *et al*., Tilted columnar metal film as transducer of transverse coherent acoustic phonons in picosecond acoustics, Appl. Phys. Lett. **125**, 192202 (2024)


**Techniques/methods in use**: optical pump probe experiment, cryogenic

**Applicant skills**: A strong interest in experimental physics is necessary with knowledge of optical experimental methods. Dynamism, autonomy, high work capacity as well as good written / oral and synthesis skills are also expected. Basic knowledge of solid states.

**Industrial partnership**: no


**Internship supervisor**(s) : Agnès Huynh, agnes.huynh@sorbonne-universite.fr

**Internship location**: INSP, campus Jussieu, Sorbonne University


**Possibility for a Doctoral thesis**: Yes (already financed)