PROPOSITION DE STAGE / INTERNSHIP PROPOSAL

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Measurement of a transmission matrix in laser ultrasound

Elastic guided waves are often used to evaluate the mechanical properties of a medium in a non-destructive regime. Non-contact laser ultrasonic techniques offer a unique tool to observe these guided waves in elongated structures. As the propagation acts as a linear system, these modes can be identified through the measurement of a transmission matrix [1-3]. This matrix contains the medium's responses to all possible excitations. The acquisition of this matrix requires multiple excitations in order to span the whole space of possible excitations. In conventional ultrasonic imaging, such matrices are typically acquired with transducer arrays that offer the possibility to shape a large diversity of acoustic emissions. This allows the acquisition of the transmission matrix in different bases, adapted to specific cases. With laser ultrasonic techniques, it is more difficult to arbitrarily shape the laser source, and the transmission matrix acquisition is not yet fully exploited. To this day, only measurements made by scanning point source basis have been achieved, which is limiting the deposited energy (Fig 1, [2]).

The aim of this internship is to tackle this limitation by a wavefront shaping of the laser source. Tailoring the laser shape will allow the generation of a wide variety of elastic waves to form different bases and measure the sample's transmission matrix. This shaping will be carried out using a spatial-light-modulator (SLM) [4]. The applicant will first need to get accustomed to the experimental setup including the cw-laser source, the interferometer, and the SLM. Preliminary measurements will aim at shaping the laser source, typically in an annular shape of a given size, to excite a particular acoustic mode. Then, various source shapes such as line source arrays or Hadamard patterns will be created to form a basis and measure the sample transmission matrix [3]. In parallel, some theory will be built to estimate the transmission matrix dimensions necessary to characterize the sample and optimal bases that should be used to measure this matrix.

The method will be tested on known materials first (e.g., aluminium), and then, if time allows, on more complex ones such as porous silicon [5].

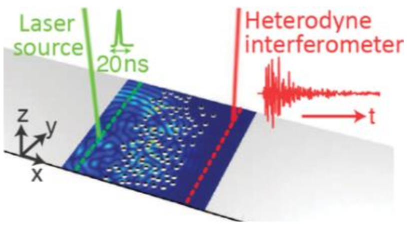

Fig. 1: Elastic transmission matrix acquisition in laser ultrasonics with a point source basis. From [2].

Some references (accessible by clicking on them):

[1] Aubry and Derode, Phys. Rev. Lett., **102**, 084301 (2009)
[2] Gérardin *et al.*, Phys. Rev. Lett., **113**, 173901 (2014)
[3] Lopez Villaverde *et al.*, IEEE Trans. UFFC **64**, 9 (2017)
[4] Mezil *et al.*, Appl. Phys. Lett., **111**, 144103 (2017)
[5] Thelen *et al.*, Nat. Commun., **12**, 3597 (2021)

- **Possibility of a PhD?** Yes, funding has been secured through the ANR project 'NEWCOMER'.
- **Internship duration:** 5-6 months (M2 internship)
- **Qualifications:** The internship will have good wave propagation knowledge in optics and acoustics and an important appetite for experiments.