PhD position (2022-2025)

Subwavelength focusing of the acoustic energy emitted from an ultrasonic transducer for near-field imaging applications

Keywords

Metamaterials, ultrasonics, elastic wave focusing, transducer, imaging, experiments, simulations, finite-elements

Resume

To increase the quality of acoustic images, the spatial resolution of the imaging system should be reduced. Improving the spatial resolution will lead to new opportunities for diagnosis in medical field (in particular for skin, gum, or eyes) and non-destructive testing in industrial field (e.g. elastic properties monitoring or sub-surface cavity detection). To improve the resolution of acoustic images, the normal course of action is to increase the operation frequency to decrease the focused spot size (e.g., harmonic imaging, acoustic microscopy). However, the size of the spot is constrained by the diffraction limit.

In the frame of the ANR BEAT project (Broadband Extraordinary Acoustic Transmission), we propose to use the principle of sub-wavelength focusing of the acoustic energy to reduce the focal sport under the diffraction limit [1]. This approach is based on the concept of extraordinary acoustic transmission (EAT) which allows to concentrate, into a spot with subwavelength size, more energy than expected by the geometrical considerations.

The main objective of this work is to design and to prototype an efficient EAT-based architecture for ultrasonic transducers working at the MHz frequency regime. By means of numerical simulations, the geometrical parameters of the architecture will be tuned to optimize the acoustic energy focusing. This PhD thesis will be based on preliminary results obtained at the GHz scale [2].

The successive tasks for this work will be as follows:

- Bibliography study of topics related to the contribution of elastic metamaterial to imaging,
- Realization of a numerical model (based on the finite element method) to design an EAT-based architecture for commercial ultrasonic transducers working at the MHz frequency regime (see Fig.1),

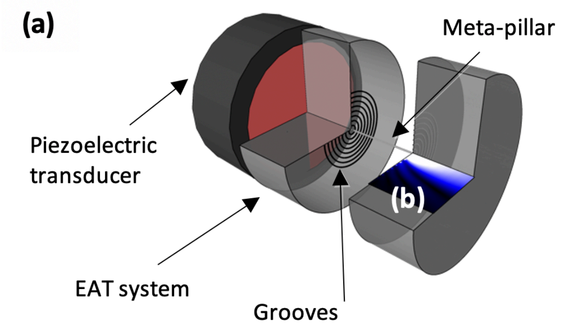

Figure 1: Schematic diagram of the EAT device **(a)** By coupling an ultrasonic transducer to an architecture made with meta-pillar and grooves **(b)** a collimation of the elastic waves at the sub-wavelength scale is expected. [2].

- Transfer of the numerical model to an experimental set-up: study of the acoustic properties of the prototype,

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- Extension of the concept to a broadband EAT system (required for ultrasound scanning) by means of numerical simulations and experiments,
- Exploitation and comparison of the imaging capabilities of the prototypes with a commercial imaging solution using image reconstruction algorithms (Fig. 2).

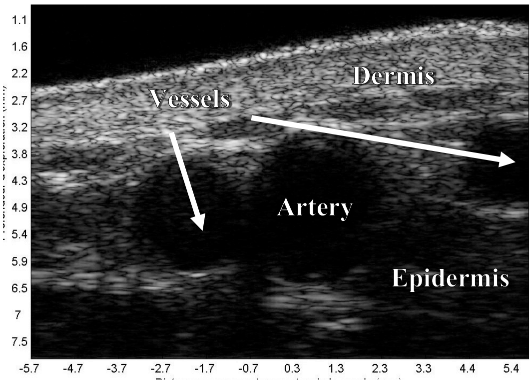

Figure 2: Acoustic image done at GREMAN laboratory with a programmable imaging platform [3].

[1] A. A. Maznev, O. B. Wright, Upholding the diffraction limit in the focusing of light and sound, Wave Motion 68, 182–189 (2017).
[2] T. Devaux, H. Tozawa, P. H. Otsuka, S. Mezil, M. Tomoda, O. Matsuda, E. Bok, S. H. Lee, O. B. Wright, Giant extraordinary transmission of acoustic waves through a nanowire, Science Advances 6, 8507 (2020).
[3] C. Bantignies et *a*l., Lead-free high-frequency linear-array transducer (30 MHz) for in vivo skin imaging, IEEE International Ultrasonics Symposium, 785-788 (2013).

Applicant's profile

This PhD work is addressed to 3rd year graduate engineering degree or Master 2 research, motivated and curious in experimental research, with skills in one or many in the following fields: ultrasonics, instrumentation, finite element software, metamaterials. The candidate will have to make evidence of its autonomy and creativity in the development of devices.

Working conditions

This PhD work will take place within the GREMAN laboratorory (UMR CNRS 7347) at INSA Centre Val de Loire (Blois). Part of the work will takes place on the site of ST Microelectronics, in Tours, of GREMAN. Laboratory website: http://greman.univ-tours.fr/
Recruitment from September 2022 for 36 months with a remuneration of 1975€/month (gross).

Supervisors and contacts

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