PhD position proposal 2020-2023

Real time remotely structurable acoustic reflector using the acoustic radiation force

Key-words

Programmable reflector, interface deformation, acoustic radiation force, finite elements, ultrasonic wave propagation, meta-surface

Context of the study

An interface between two elastic media can be deformed by the force of acoustic radiation [1,2] (see: Figure 1). When this non-linear effect is controlled and optimized, it is possible to develop complex devices for wave control, such as an acoustic diode or an acoustic transistor [3]. Recent scientific advances have made possible to create metasurfaces that allow exotic control of acoustic wave propagation. These new materials pave the way for new functionalities such as frequency converters [4] or wavefront modulators [5].

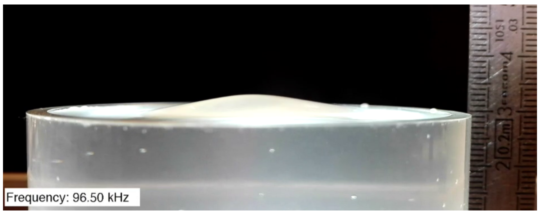

FIG1: Shape change of a water/air interface by the acoustic radiation force.

Objectives of the study

The aim of the PhD work is to propose a new programmable surface architecture based on non-contact deformation of a physical interface induced by the acoustic radiation force. The reflection of an elastic wave on the interface can be controlled using a second acoustic wave (see Figure 2). The advantage of this concept is the real time reconfigurability, making it possible to implement the different functionalities mentioned above from the same system. The "single-source" principle described in Figure 2 will be extended in 2D with multiple sources using an array of control transducers, hence allowing the tunability of deformation distribution of the interface, based on a meta-surface model.

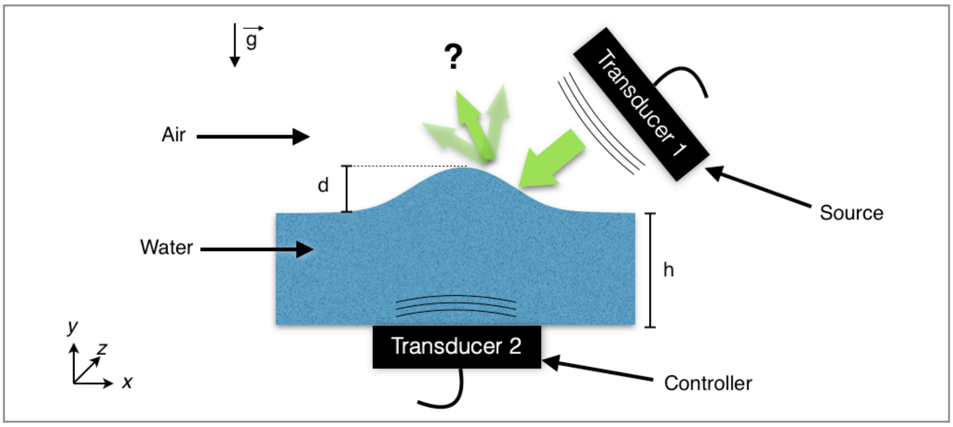

FIG2: Sketch of the reconfigurable acoustic reflector. Depending on the field emitted by the piezoelectric transducer 2 (controller), the water-air interface shape is changed as a result of the acoustic radiation pressure. This deformation will modify the reflection of the wave emitted by sensor 1 (source).

Work plan

The successive tasks for this work will be as follows:

- Numerical study based on the finite element method to identify key parameters for tailoring deformation: size and frequency of the control transducer elements, acoustic excitation waveform, medium properties, etc;
- Realization of a device for the measurement of the deformation of the interface;
- Dimensioning of an experimental prototype of a programmable surface introducing a single acoustic source;
- Realization and study of the experimental prototype, comparison with the simulations;
- 2D extension of the prototype using a matrix of acoustic sources (controllers);
- Optimization of choice of ultrasonic excitations according to the desired surface deformation, and of the functionalities achievable with the 2D programmable reflector.

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[3] T. Devaux, A. Cebrecos, O. Richoux, V. Pagneux, V. Tournat, Acoustic radiation pressure for nonreciprocal transmission and switch effects, Nature Communications 10, 3292 (2019)

[4] X. Guo, V. E. Gusev, V. Tournat, B. Deng, and K. Bertoldi. Frequency-doubling effect in acoustic reflection by a nonlinear, architected rotating-square metasurface. Physical Review E, 99(5):052209, 2019.

[5] Y. Xie, W. Wang, H. Chen, A. Konneker, B.-I. Popa, and S. A. Cummer. Wavefront modulation and subwavelength diffractive acoustics with an acoustic metasurface. Nature communications, 5:5553, 2014.

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 of 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 place

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