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Airborne and ultrasonic characterisation of acoustic surface waves on structured plates

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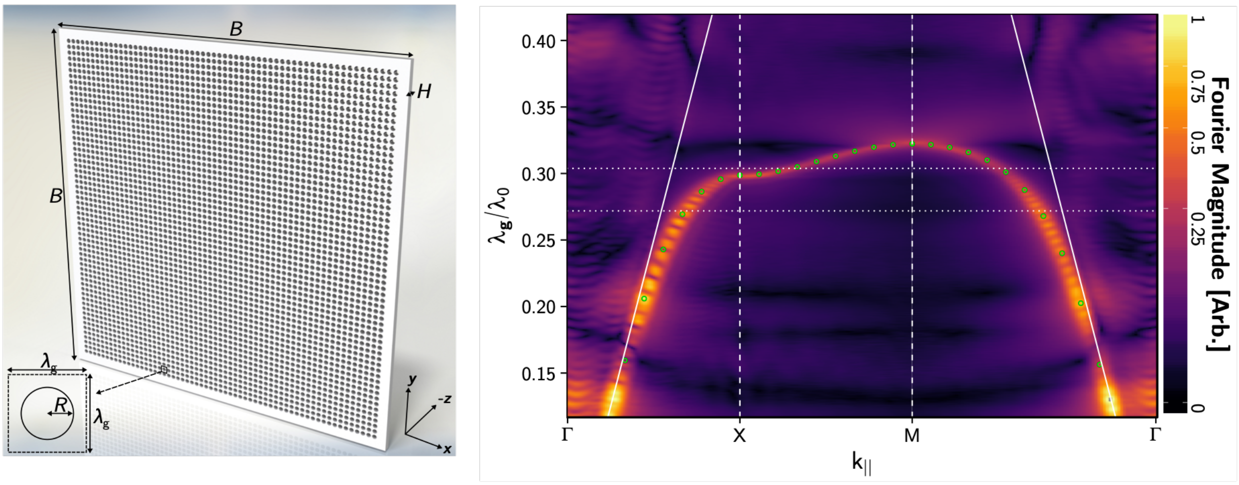
Abstract
We present the experimental and numerical characterisation of resonant-cavity-based structured surfaces for the control of sound in air and underwater. Aluminium plate samples are drilled with hole arrays and experimentally characterised by spatially-mapping the acoustic near field of the sample surface following excitation from a point-like source. Experimental results show that bound acoustic modes are supported on these surfaces, and can exhibit acoustic beaming and zero-group velocity. Airborne ASW characterisation of the dispersion relation show good agreement with Finite Element Method (FEM) simulations when the sample surface is considered acoustically rigid. Underwater characterisation shows good agreement only when the samples elastic properties are accounted for. Having demonstrated these bound acoustic modes experimentally, we show some new ideas towards coupling them to turbulent flow.

Keywords: Acoustic Surface Wave, Metamaterial, Beaming

The past 20 years have seen a wealth of research into sculpted surfaces to control waves using length scales that are on order of, or less than, their wavelength. Following the seminal work on extraordinary optical transmission [1] through a structured metal film, Pendry realised that a simple holey metallic plate could support a surface localised plasmon-like resonance (or 'spoof-surface-plasmon') even when the metal is perfectly conducting [2]. This realisation arguably spearheaded the great interest into designer metamaterials across the physical sciences disciplines. Acoustic metamaterials have since become an active area in contemporary acoustics since they offer, a route to control, guide, or otherwise manipulate the propagation of acoustic energy that might address a range of real-world problems, not easily overcome by conventional acoustic engineering approaches [3, 4].

An appropriately structured surface can support a bound acoustic surface wave in a similar way to Pendry's spoof-surface-plasmon. These acoustic surface waves (ASWs) have pushed extensive development in areas such as Enhanced Acoustic Transmission (EAT) [5, 6, 7], and subwavelength imaging [8, 9]. Despite this, some of the simplest patterned structures that support surface-localised acoustic waves have received little attention.

In this paper, we will show the characterisation of resonant-cavity-based structured surfaces for the control of sound in air and underwater. Samples are made from plates that are drilled with different hole-array geometries, and experimentally characterised by near acoustic field mapping. The measured results show that bound acoustic modes are supported by these surfaces, and can exhibit acoustic beaming and zero-group velocity. These samples are studied in air for audiable frequencies, and underwater in the 50 to 100 kHz frequency range. Characterisation of the dispersion relation for airborne surface modes show good agreement with FEM simulations when the sample surface is considered acoustically rigid; underwater characterisation shows good agreement only when the samples elastic properties are accounted for.



(a) (b)

Figure 1. Schematic and mode dispersion of square hole array: (a) acrylic plate schematic, the sample has side lengths B = 560.00 mm, hole depth $H = 9.60 \pm 0.23$ mm, hole radius $R = 3.25 \pm 0.05$ mm, with an x/y grating pitch λ_g = 8 mm. (b) measured dispersion of the hole array sample between points of high lattice symmetry, obtained from the spatial Fourier transforms of the pressure fields of the acoustic mode propagating on the surface.

Figure 1 shows results for airborne acoustic surface modes supported by a square array of $\lambda/2$ cavity resonators. We will further discuss results from different 2D lattices of resonators, and modes supported in 1D.

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