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The Study of Acoustic Metamaterials

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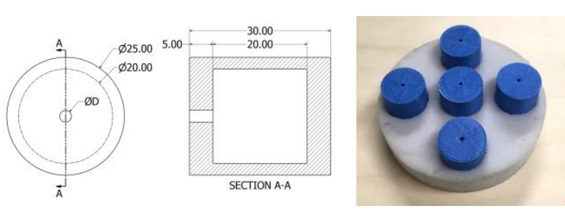
1. Introduction

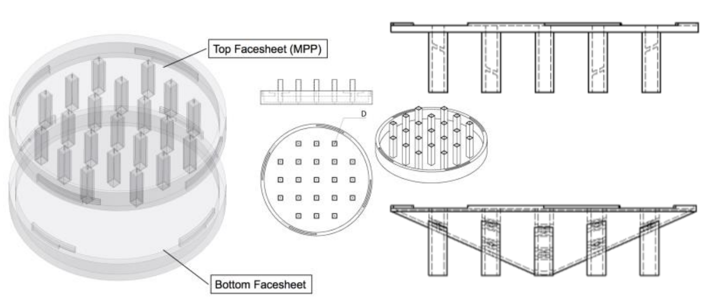
Acoustic metamaterials are materials that have the ability to control and manipulate sound waves in ways that cannot be found in conventional materials. Properties such as extraordinary absorption, broadband dispersion and negative refractive index can be obtained.

2. Heterogeneous & Hybrid Metamaterials

Helmholtz resonator and hybrid based heterogeneous (HG) metamaterials have been used to **absorb a targeted frequency of sound**. A broad range and high peak absorption was achieved through the parametric experimentation of geometric parameters.



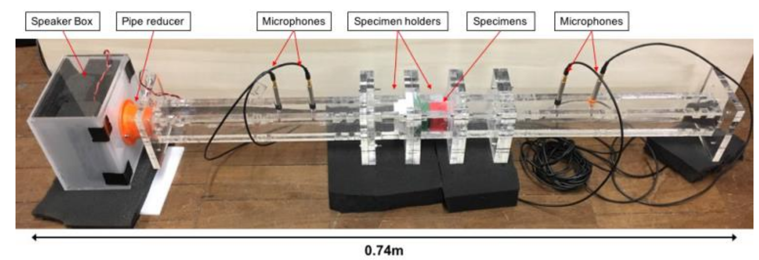
Helmholtz (left) and HG (right) resonators



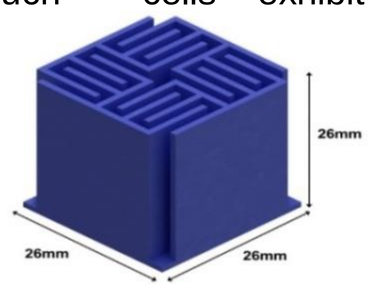
Hybrid perforated honeycomb-corrugation (above)

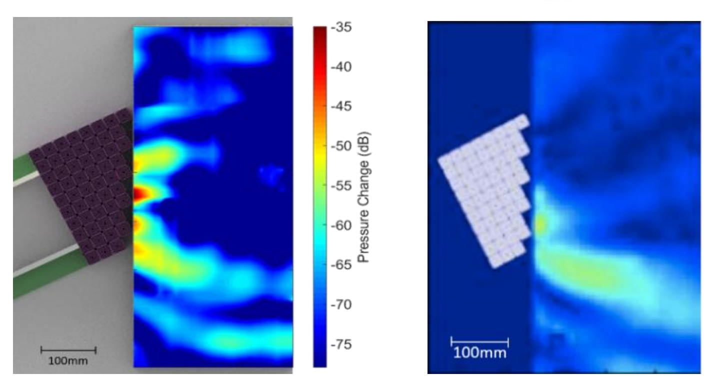
3. Labyrinthine Metamaterials

Space-coiling designs work by forcing waves to travel in subwavelength folded channels, greatly increasing the wave path length. This macroscopically delays the propagating phase.

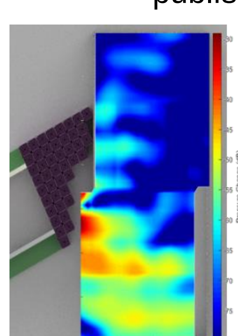


Impedance tube experiments (above) carried out to show that such cells exhibit **extraordinarily high transmission loss** with low mass**.** 2D waveguide used to demonstrate **negative refraction**.

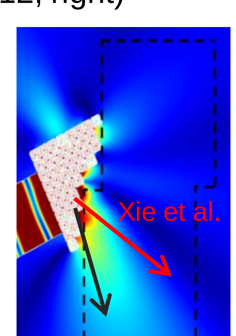




Our results (left) successfully replicate other published results (Xie et al. 2012, right)

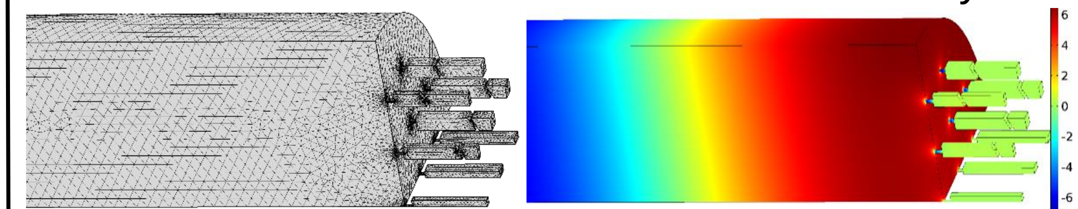


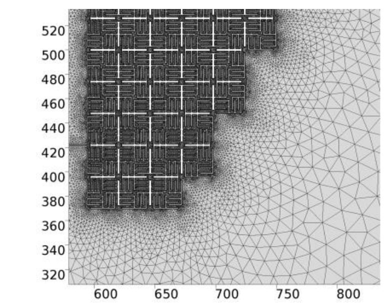
Use of numerical studies (right) to improve prism structure giving more negative refraction. Confirmed experimentally (left).



4. Numerical & Analytical Studies

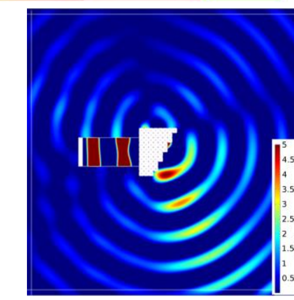
Use of COMSOL software to model 1D, 2D & 3D metamaterial units that are tested in the laboratory.

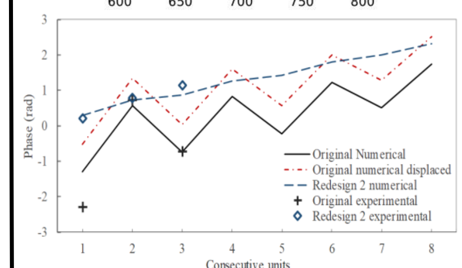


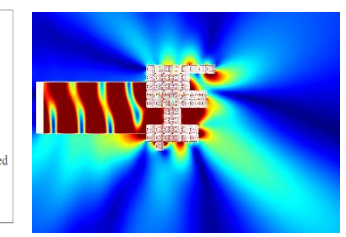


3D model of hybrid metamaterial (above).

2D model of a 50 unit labyrinth prism (left and right)

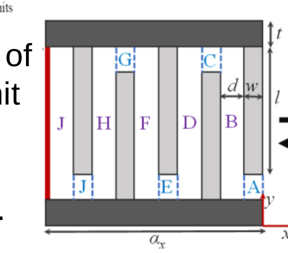


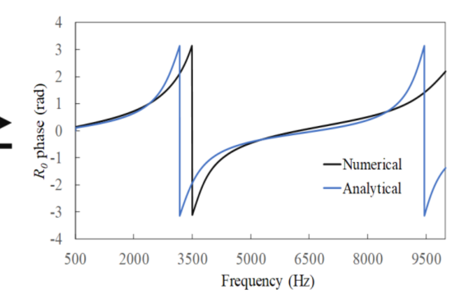




Phase delay of combined labyrinth units (left) used to design a new prism showing negative refraction (right).

Analytical model of single zig-zag unit reflection (left). Comparison with numerical (right).





5. Conclusions

- HG can be designed to exhibit high absorption at either targeted or broadband frequencies.
- Replication and improvement of the negative refraction found by PRL [1].
- Satisfactory agreement between numerical and experimental work and further understanding of labyrinth metamaterials.
- Reliable analytical modeling of labyrinth structures is feasible but requires more numerical studies for extended validation.