University of BRISTOL

Wavefront Manipulation by Fractal Space-Coiling Acoustic Metamaterials

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Abhishek Gautam
Mahdi Azarpeyvand

Outline

- Aerialist & Metamaterials
- Wavefront Manipulation
- Additional Works
- Future Works

Aerialist

AERIALIST aims at the disclosure of the potential of metamaterials to envisage innovative devices for the mitigation of the civil aviation noise

Scattering cancellation, hyper-focusing, and noise trapping techniques will be investigated to achieve virtual scarfing of intakes, suitable treatment of outflow ducts and enhancement of shielding effects

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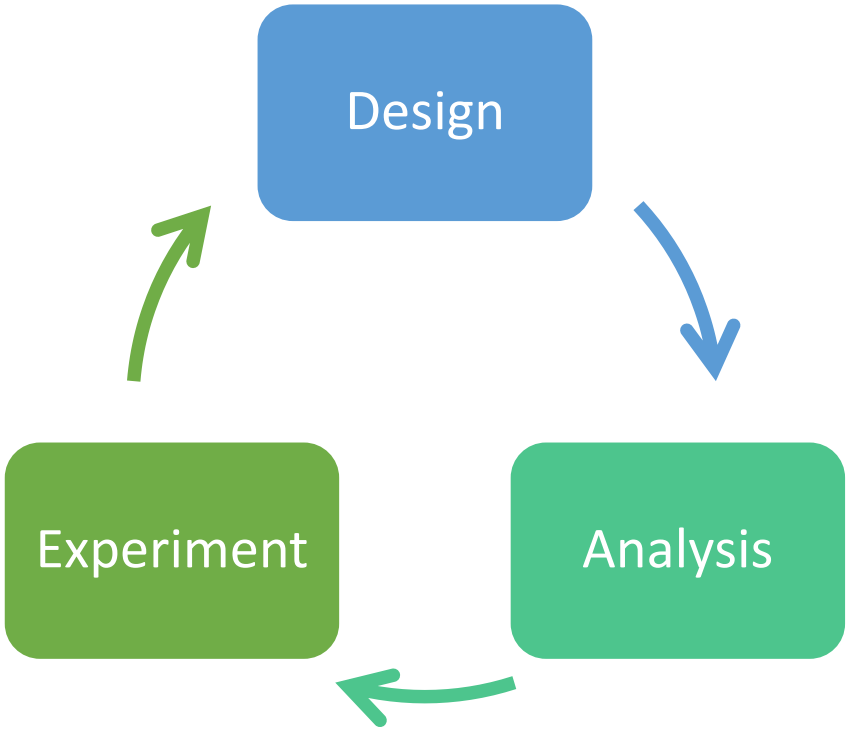
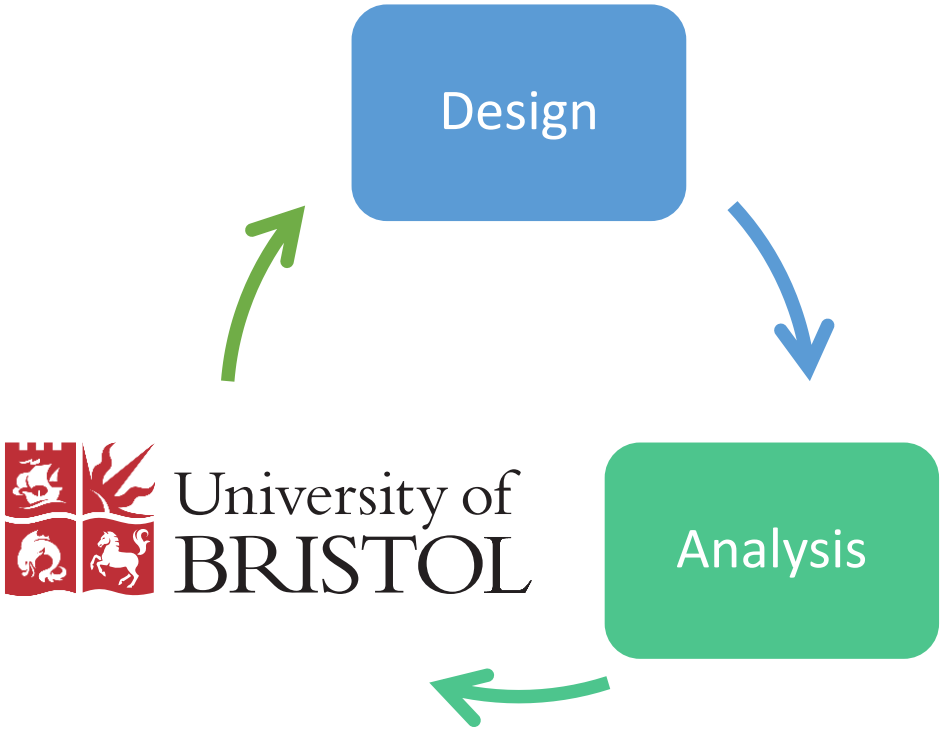
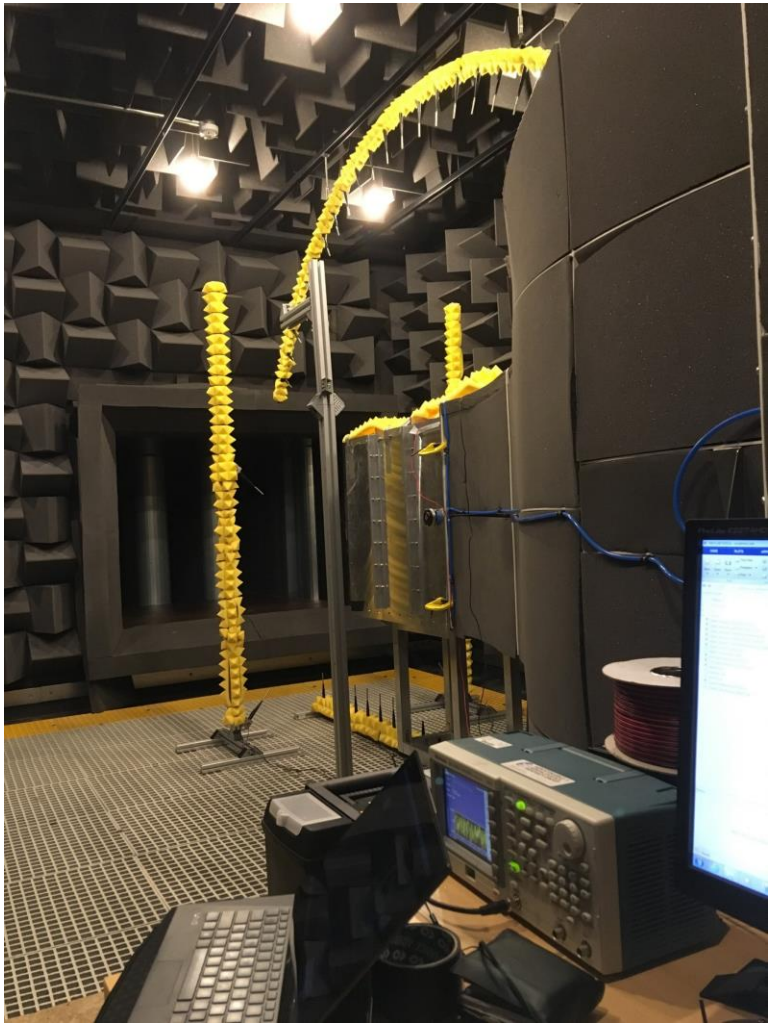
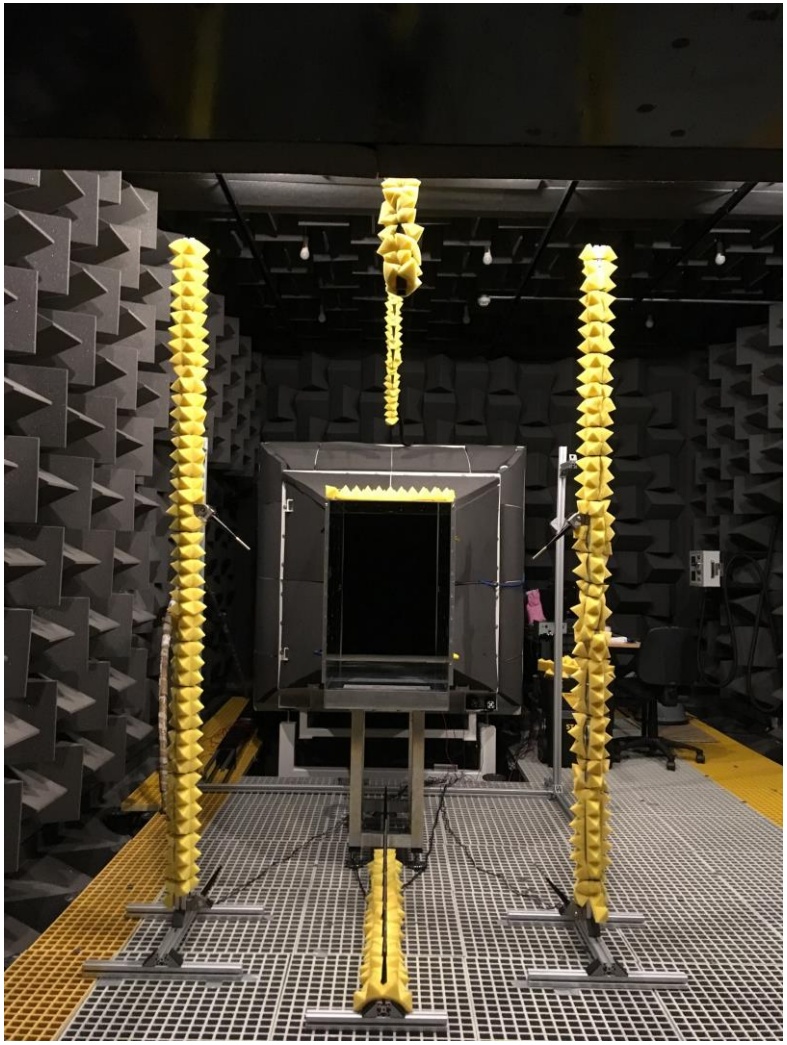
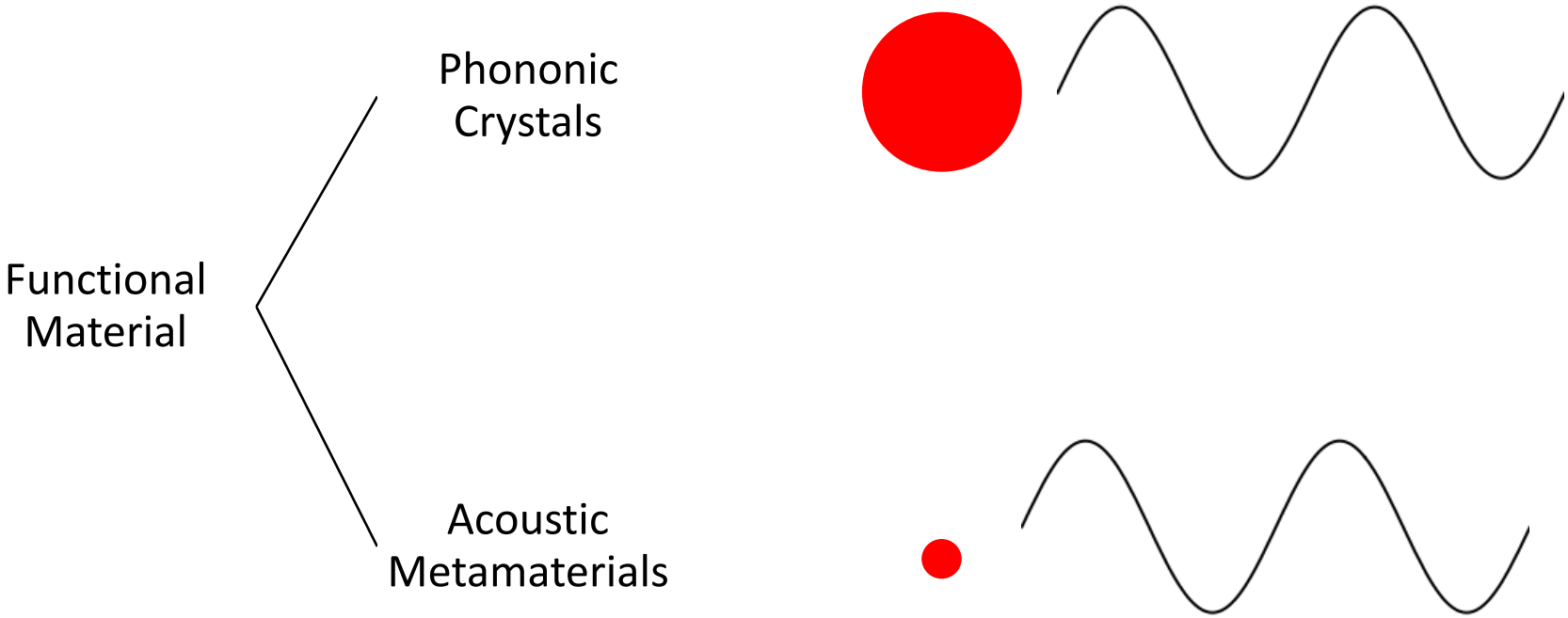


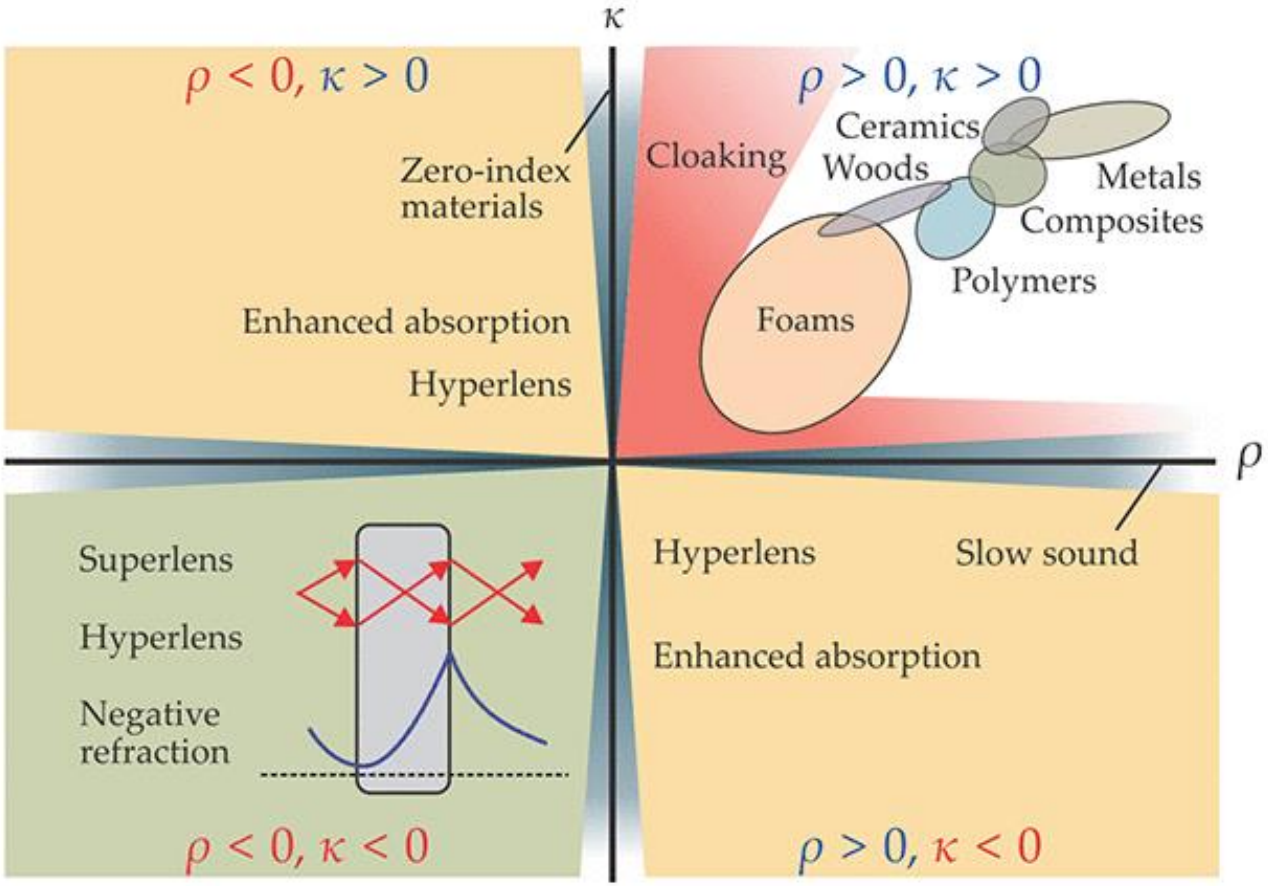






Metamaterial





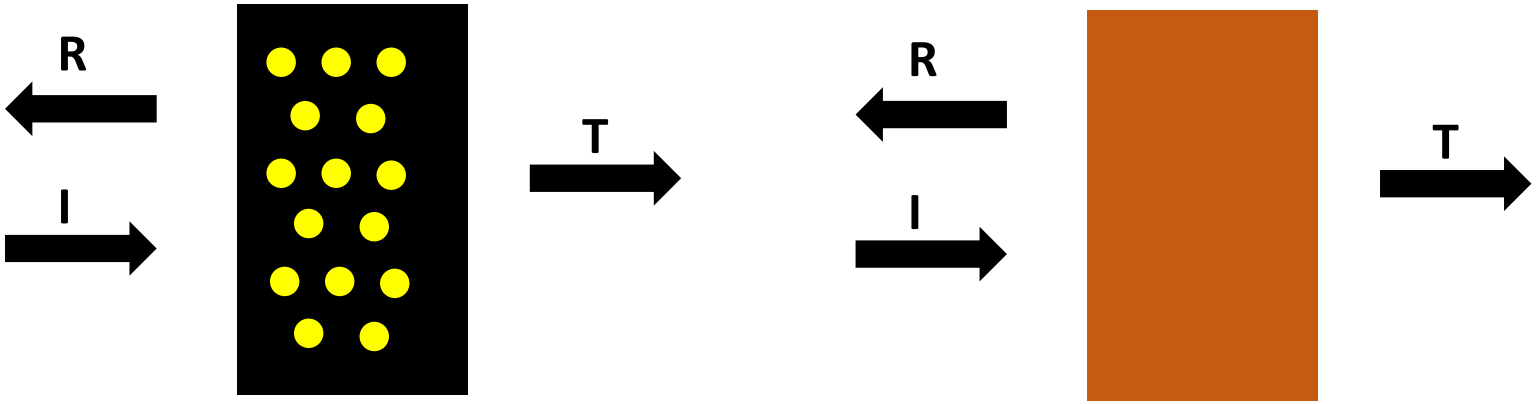
Acoustic metamaterials

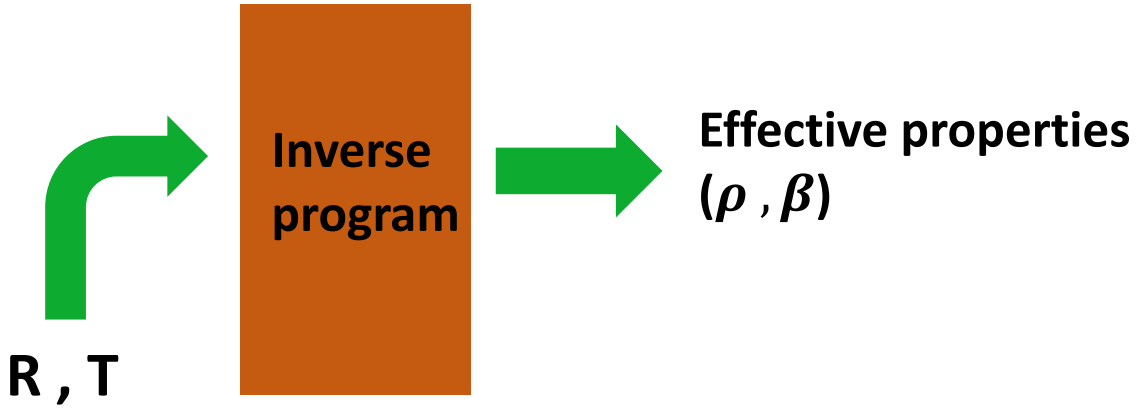
Michael R. Haberman, and Matthew D. Guild

Citation: Physics Today **69**, 6, 42 (2016); doi: 10.1063/PT.3.3198

Method for retrieving effective properties of locally resonant acoustic metamaterials

Vladimir Fokin, Muralidhar Ambati, Cheng Sun, and Xiang Zhang*

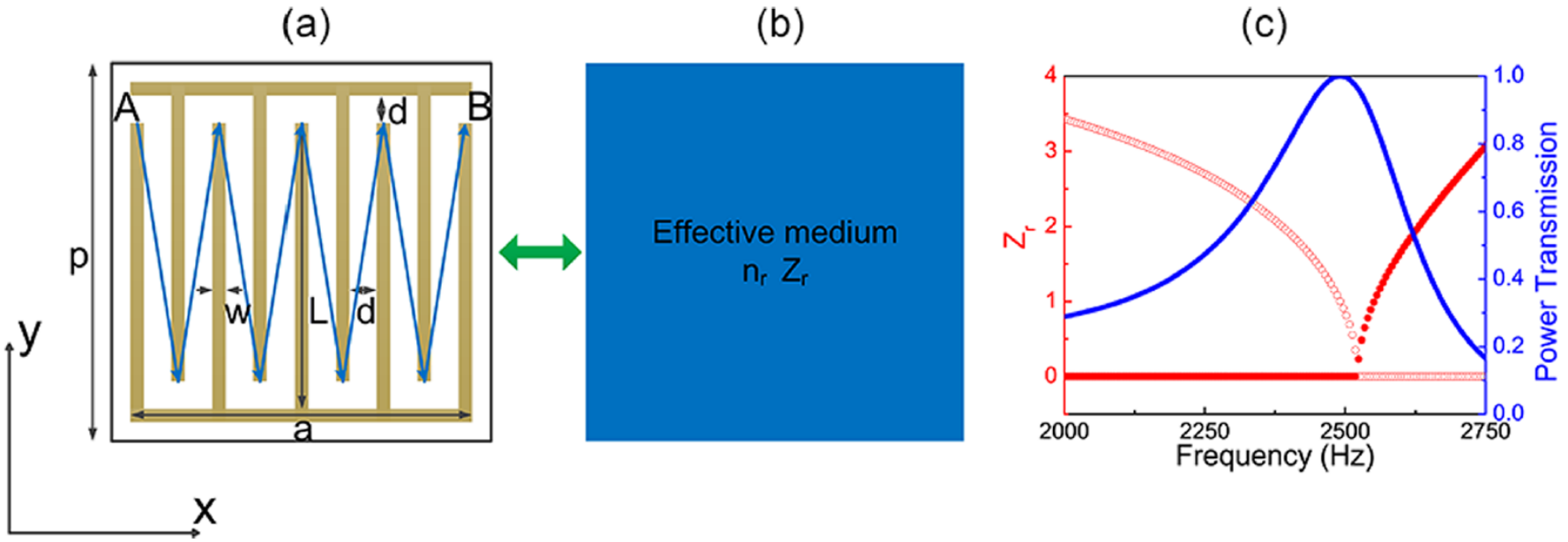




APPLIED PHYSICS LETTERS **101**, 233508 (2012)

Acoustic focusing by coiling up space

Yong Li,[1,2] Bin Liang,[1,2,a)] Xu Tao,[1] Xue-feng Zhu,[1] Xin-ye Zou,[1] and Jian-chun Cheng[1,2,a)]



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Acoustic Metamaterial With Fractal Coiling Up Space for Sound Blocking in a Deep Subwavelength Scale

Inspired by fractal photonic/phononic crystals, the self-similar fractal technique is applied to design acoustic metamaterial. By replacing the straight channel of coiling up space with a smaller coiling up space, a class of topological architectures with fractal coiling up space is developed. The significant effect of the fractal-inspired hierarchy on the band structure with fractal coiling up space is systematically investigated. Furthermore, sound wave propagation in the acoustic metamaterial with the fractal coiling up space is comprehensively highlighted. Our results show that the acoustic metamaterial with higher-order fractal coiling up space exhibits deep subwavelength bandgaps, in which the sound propagation will be well blocked. Thus, this work provides insights into the role of the fractal hierarchy in regulating the dynamic behavior of the acoustic metamaterial and provides opportunities for the design of a robust filtering device in a subwavelength scale. [DOI: 10.1115/1.4037514]

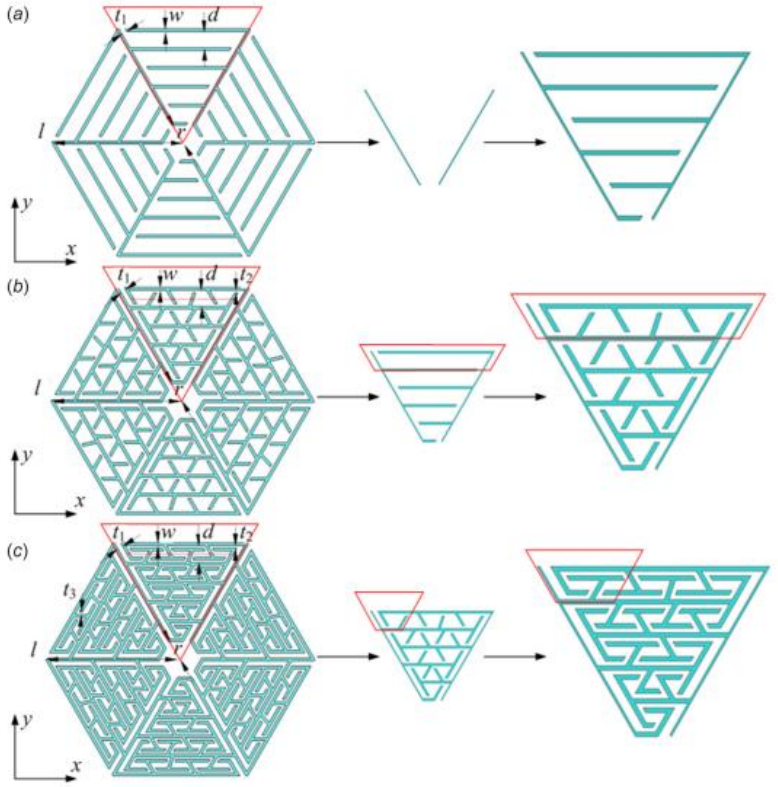
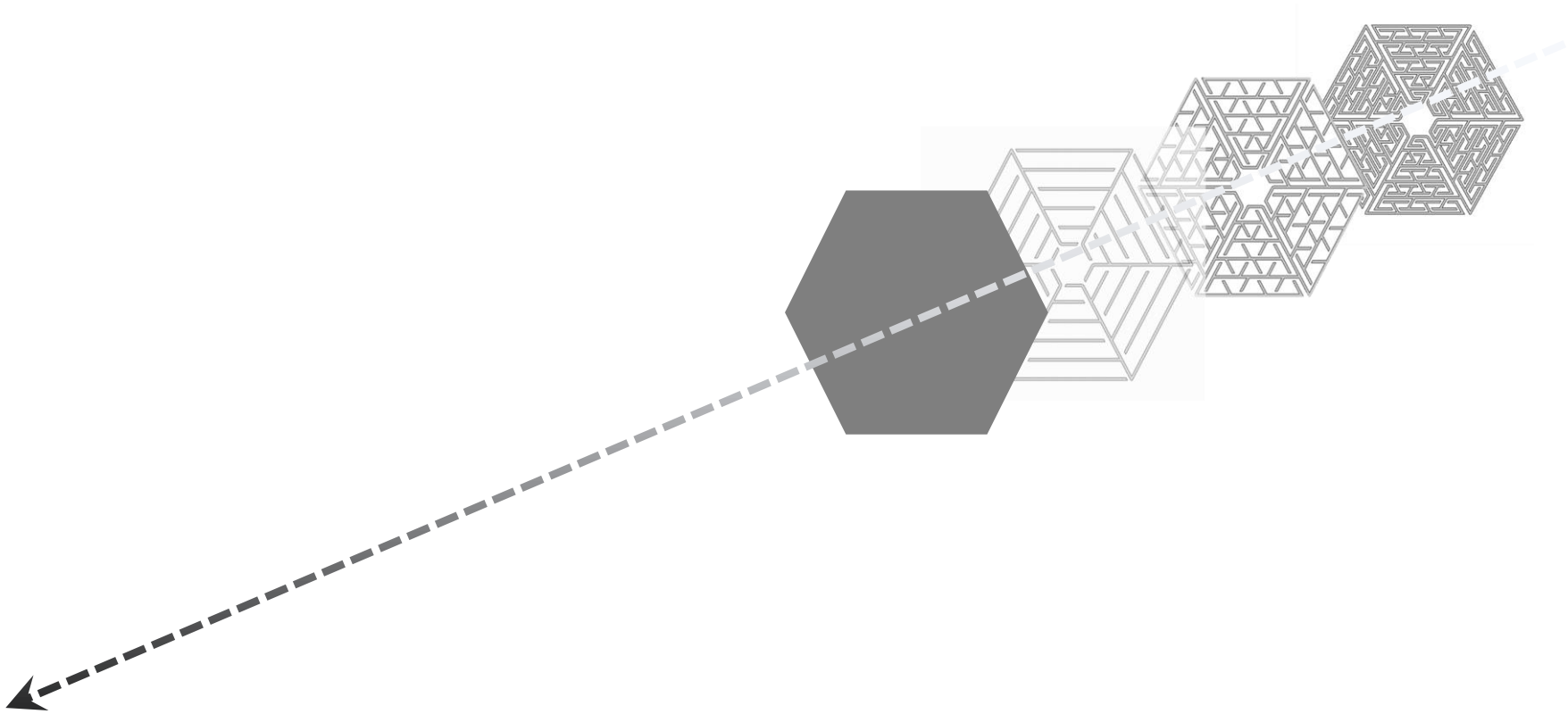
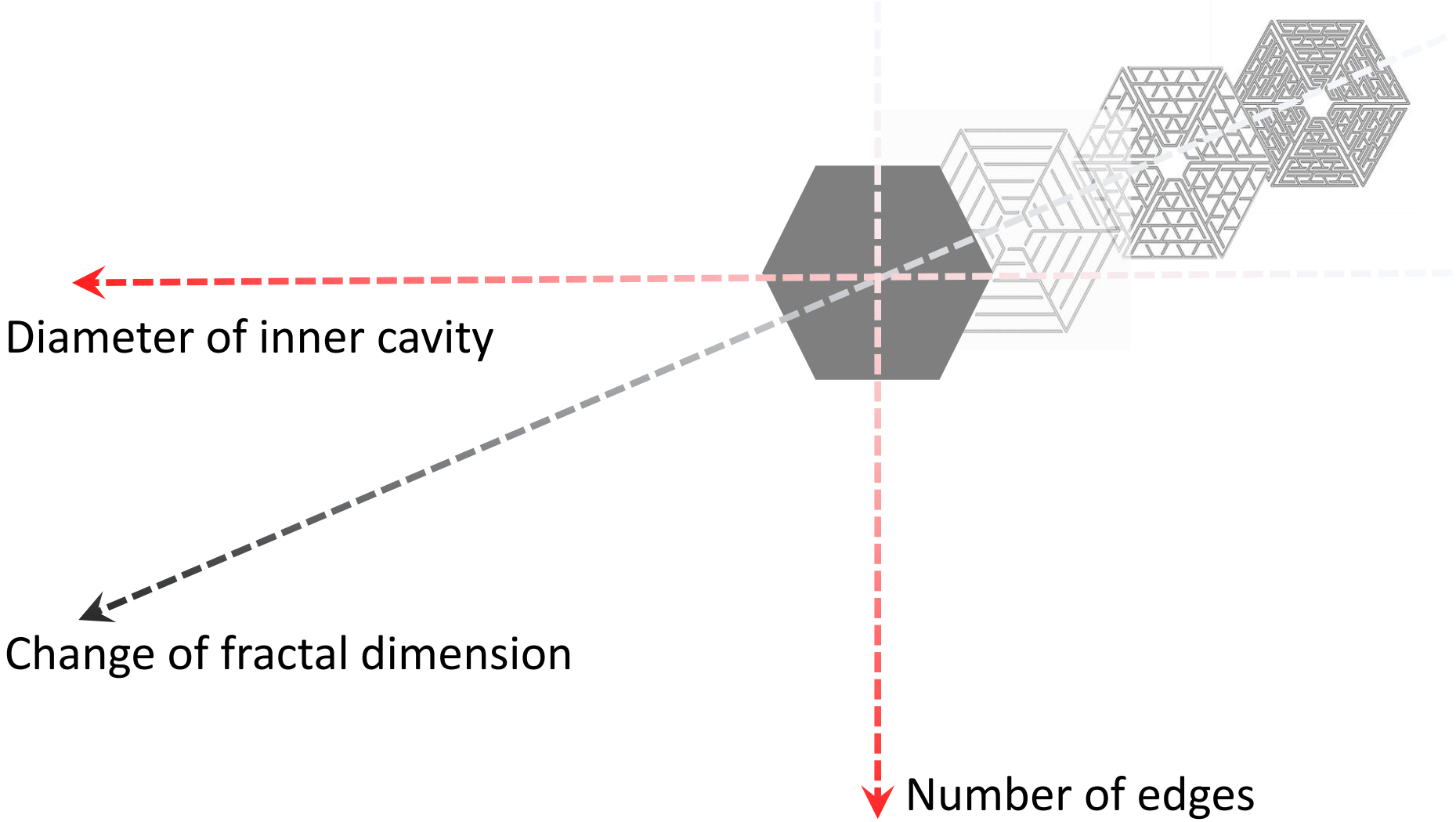
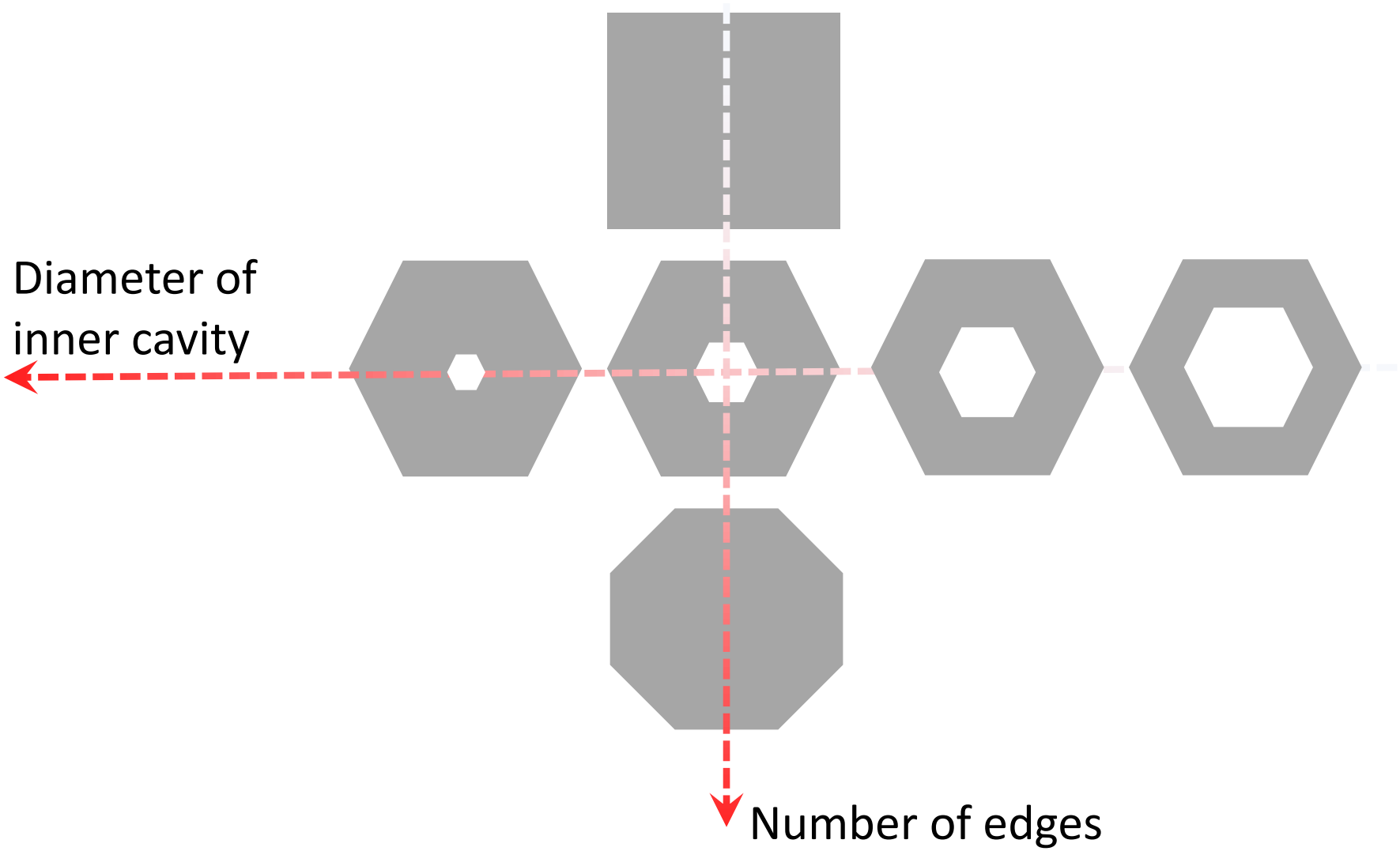


Fig. 1 Schematic cross-sectional illustrations of three types of acoustic metamaterials with coiling up spaces: (*a*) acoustic metamaterial with the first-order coiling up space, (*b*) acoustic metamaterial with the second-order coiling up space, and (*c*) acoustic metamaterial with the third-order coiling up space

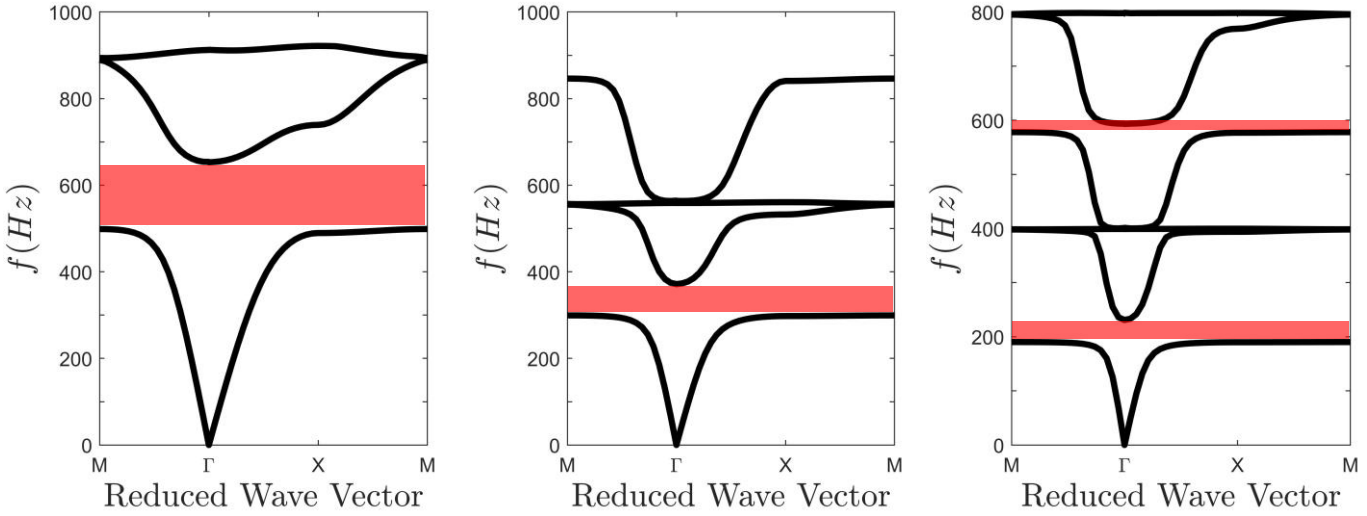


Change of fractal dimension

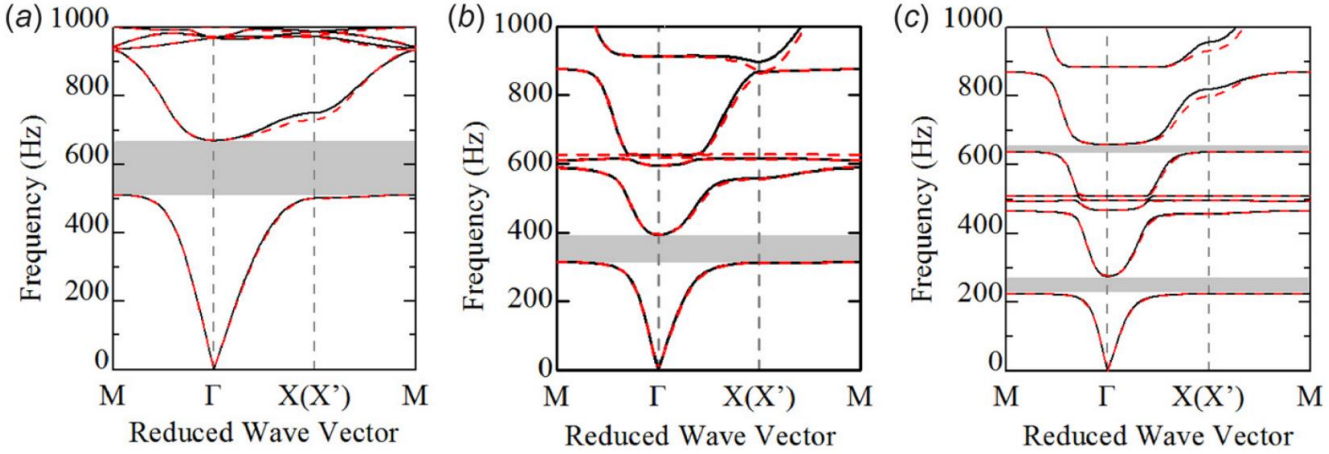

Diameter of inner cavity
Change of fractal dimension
Number of edges

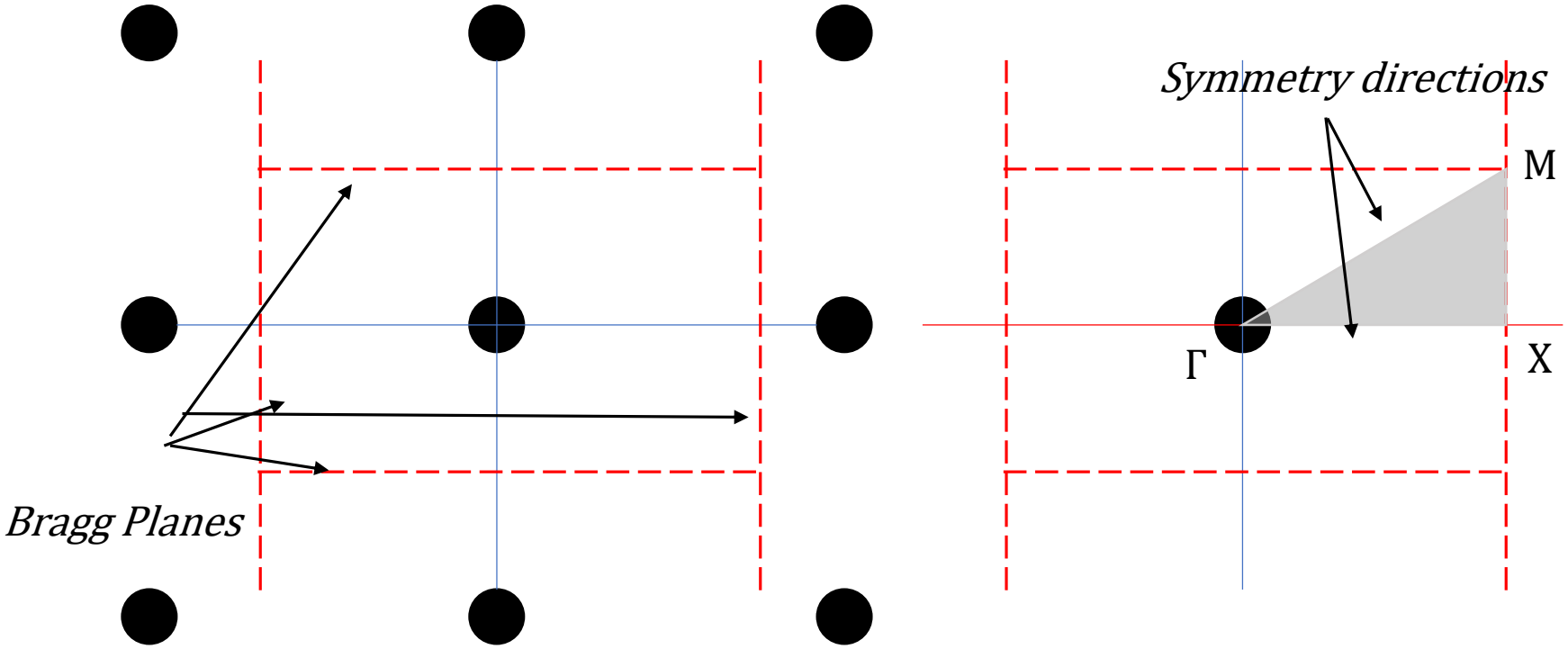


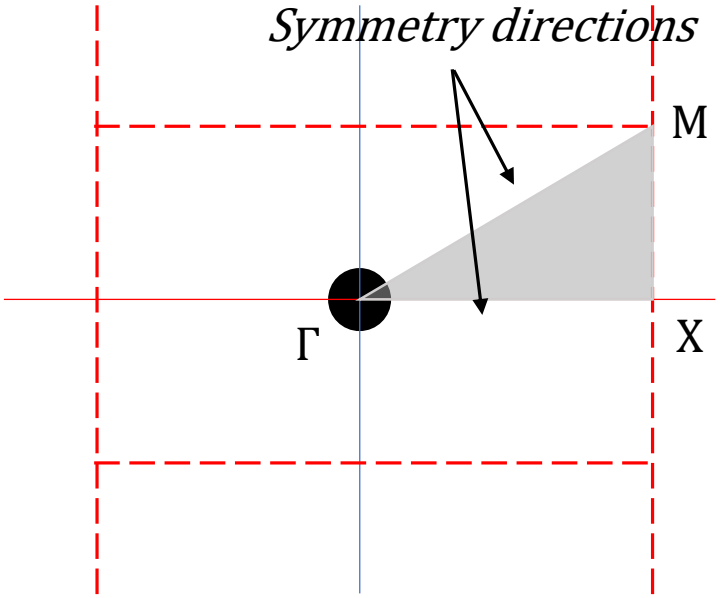
UoB

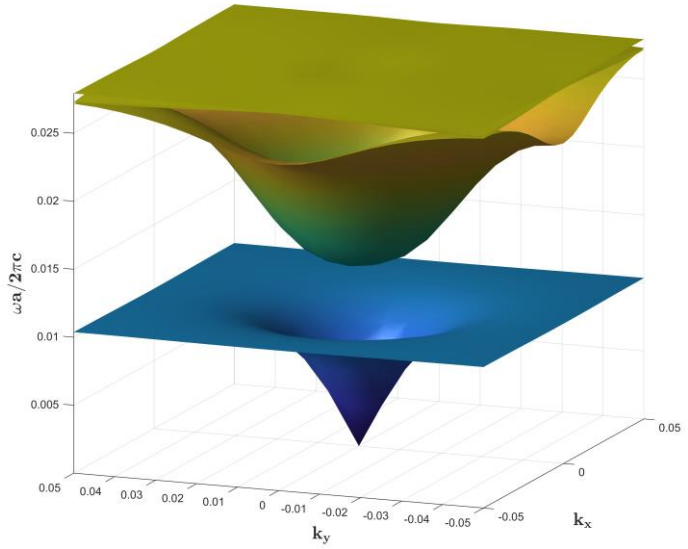


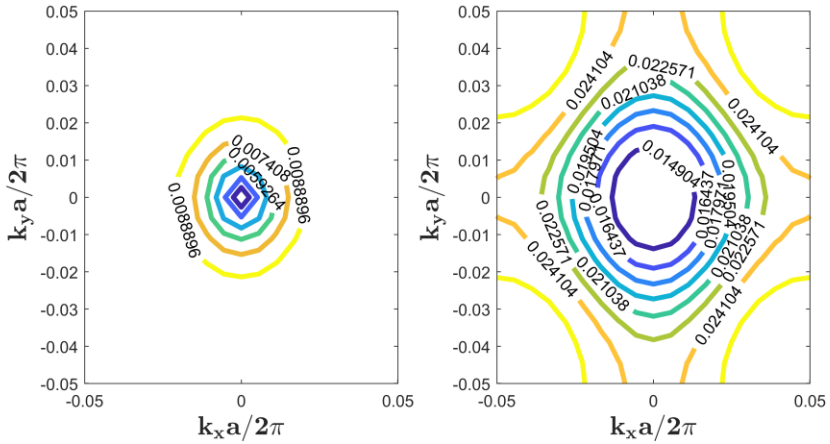
Paper



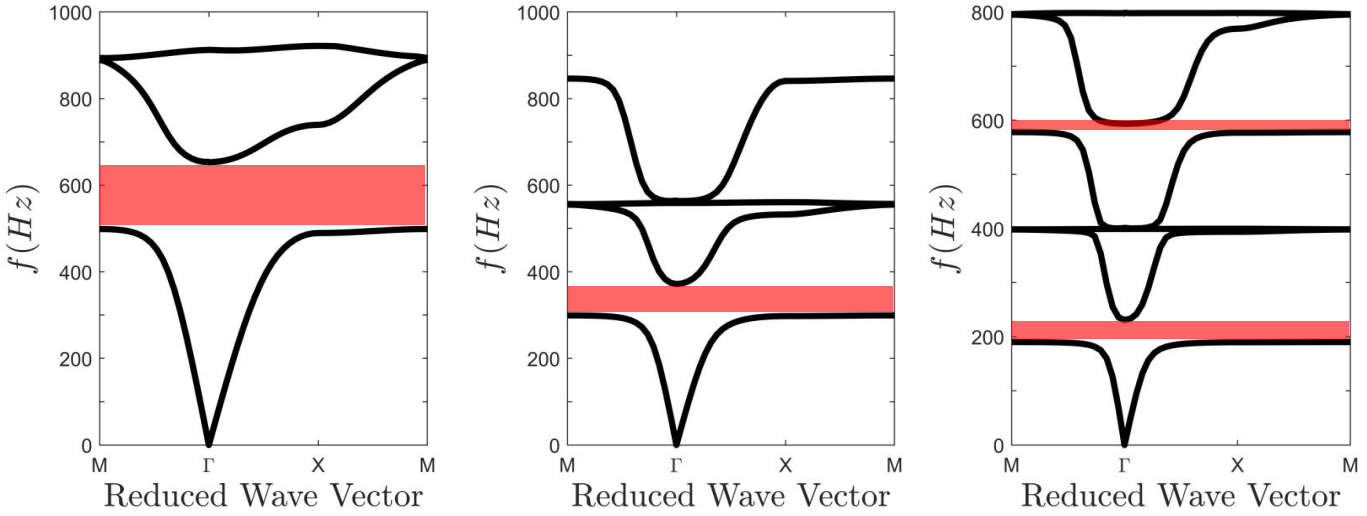

Bragg Planes
Symmetry directions
M
Γ
X


Symmetry directions
M
Γ
X

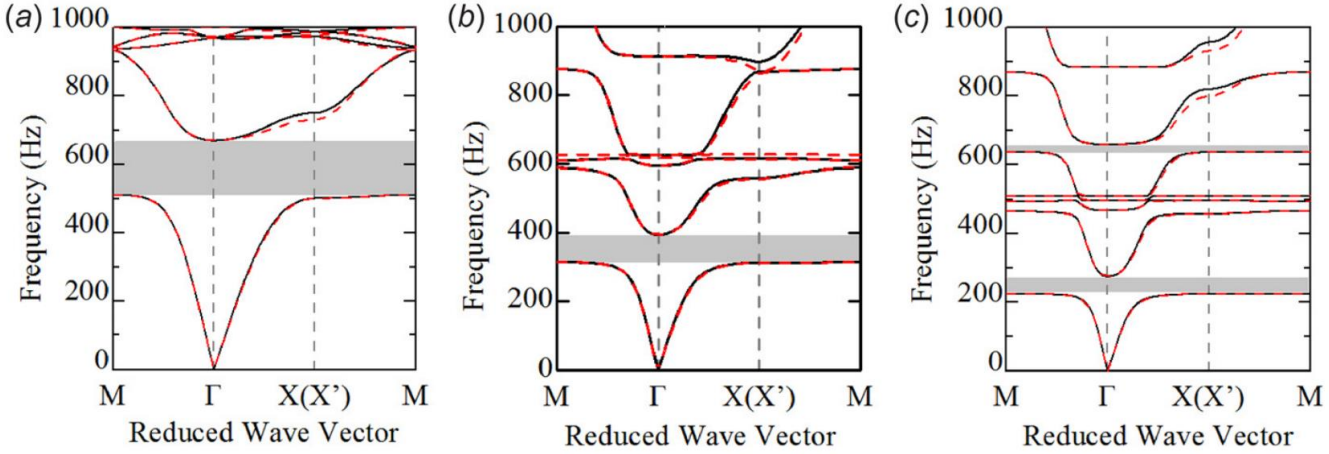

$\omega a/2\pi c$
k_y
k_x

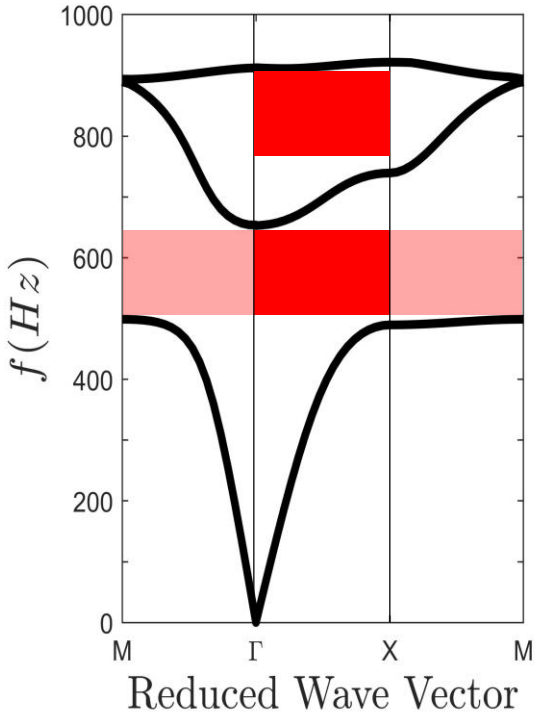

$k_y a/2\pi$
$k_x a/2\pi$
$k_y a/2\pi$
$k_x a/2\pi$

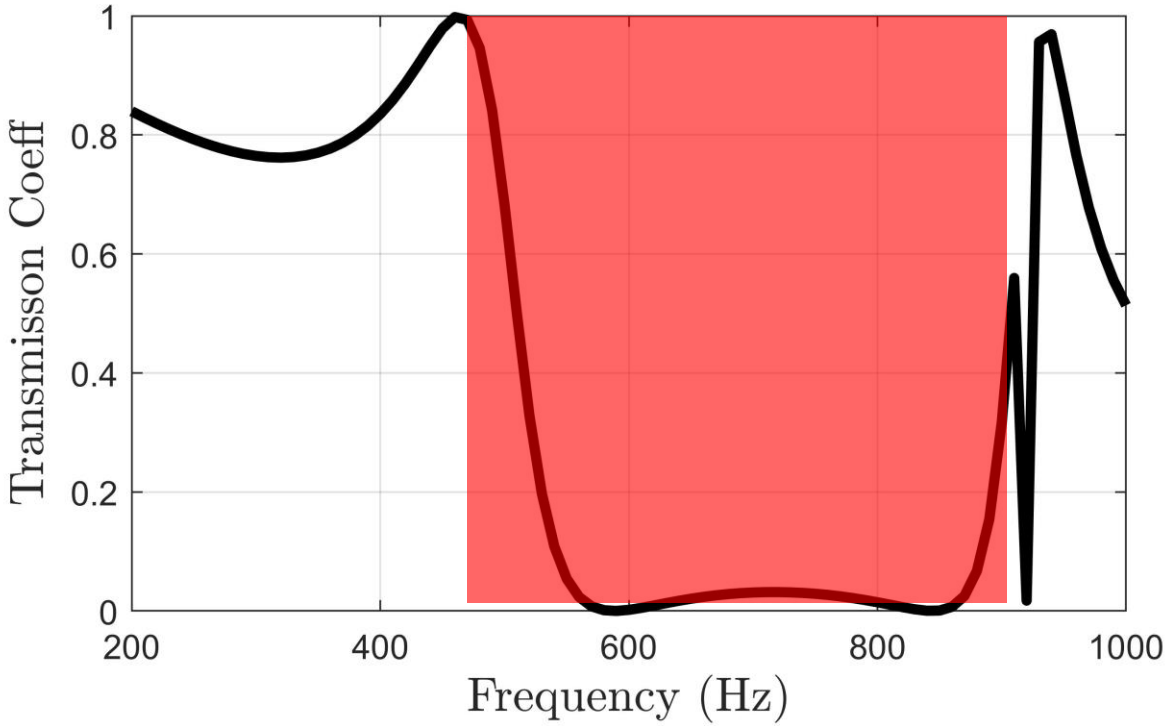
UoB

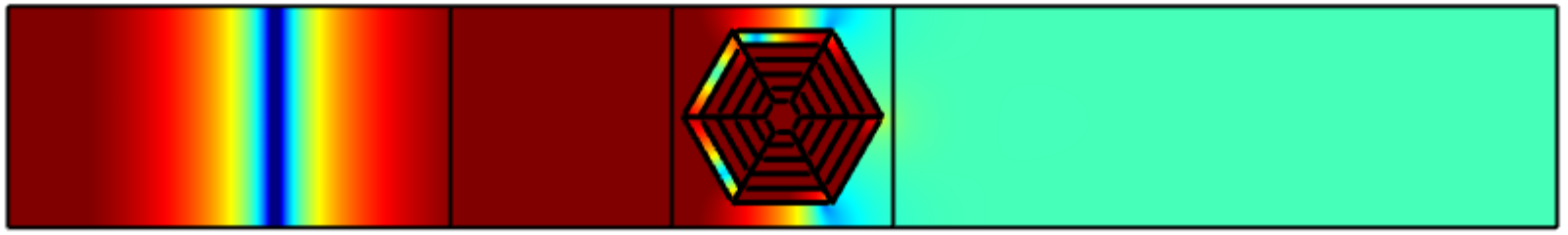


Paper

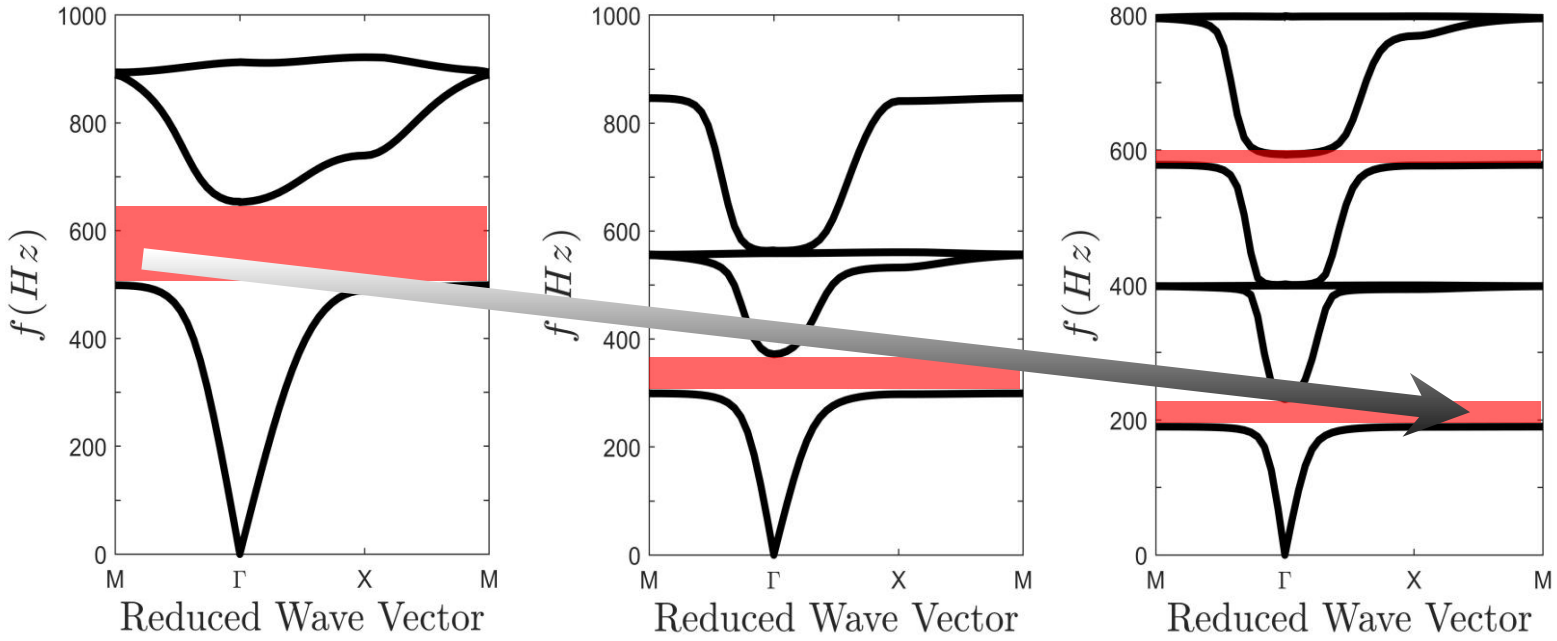


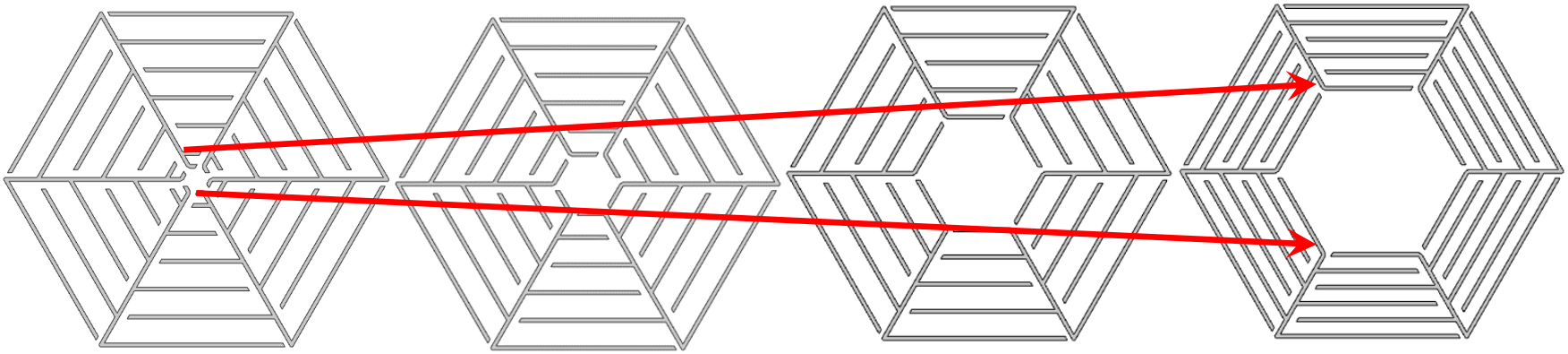

1000
800
600
400
200
0
$f(Hz)$
M
Γ
X
M
Reduced Wave Vector

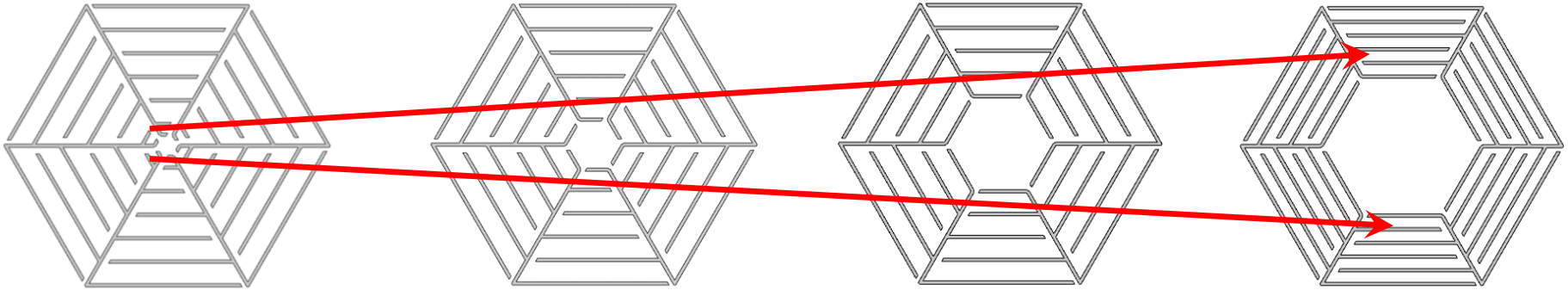

1
0.8
0.6
0.4
0.2
0
Transmisson Coeff
200
400
600
800
1000
Frequency (Hz)

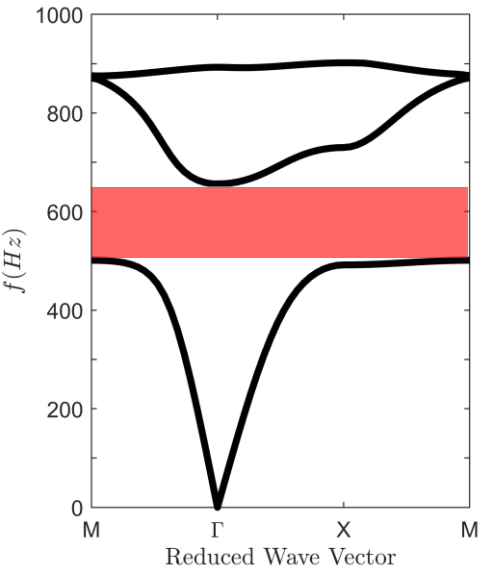


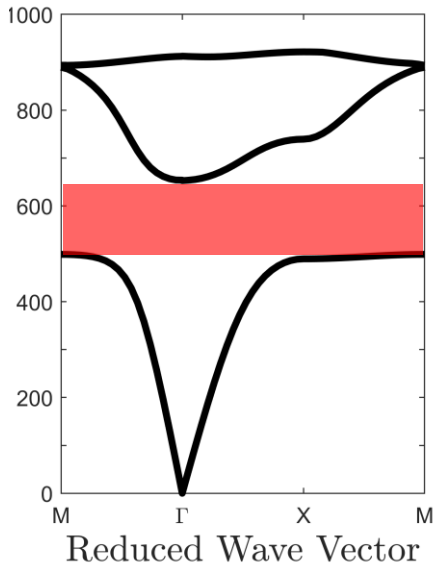
Increasing order of fractal

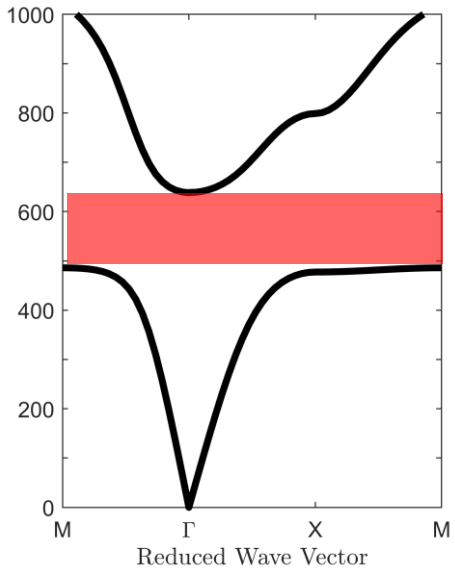


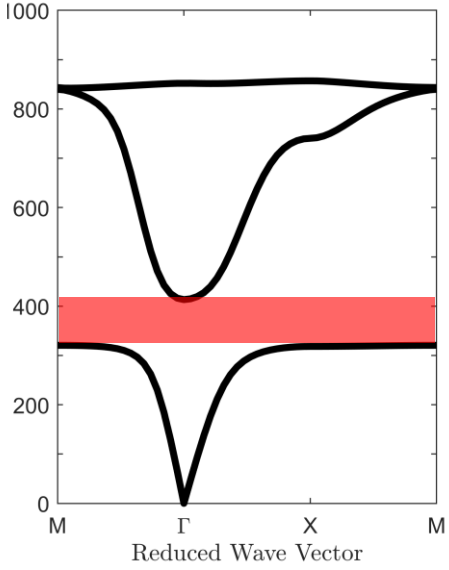


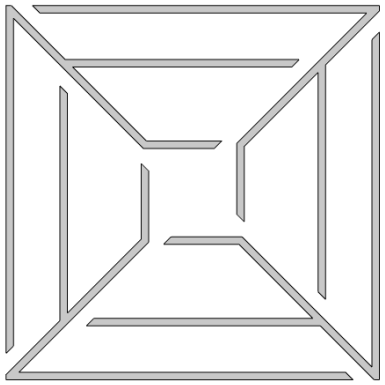


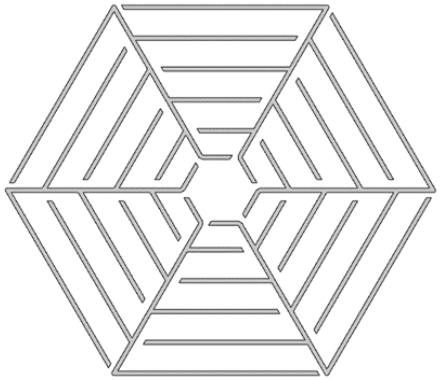

1000
800
600
400
200
0
$f(Hz)$
M
Γ
X
M
Reduced Wave Vector

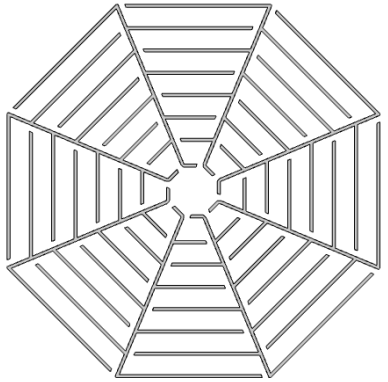

1000
800
600
400
200
0
M
Γ
X
M
Reduced Wave Vector

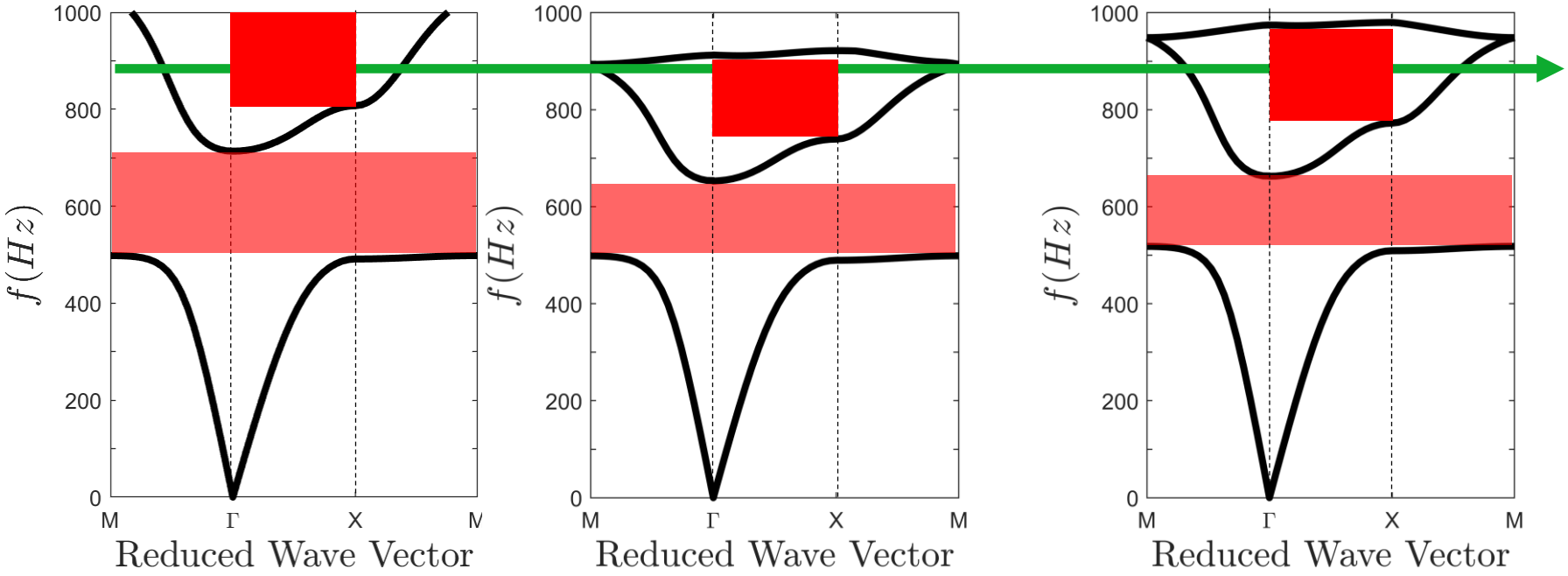

1000
800
600
400
200
0
M
Γ
X
M
Reduced Wave Vector

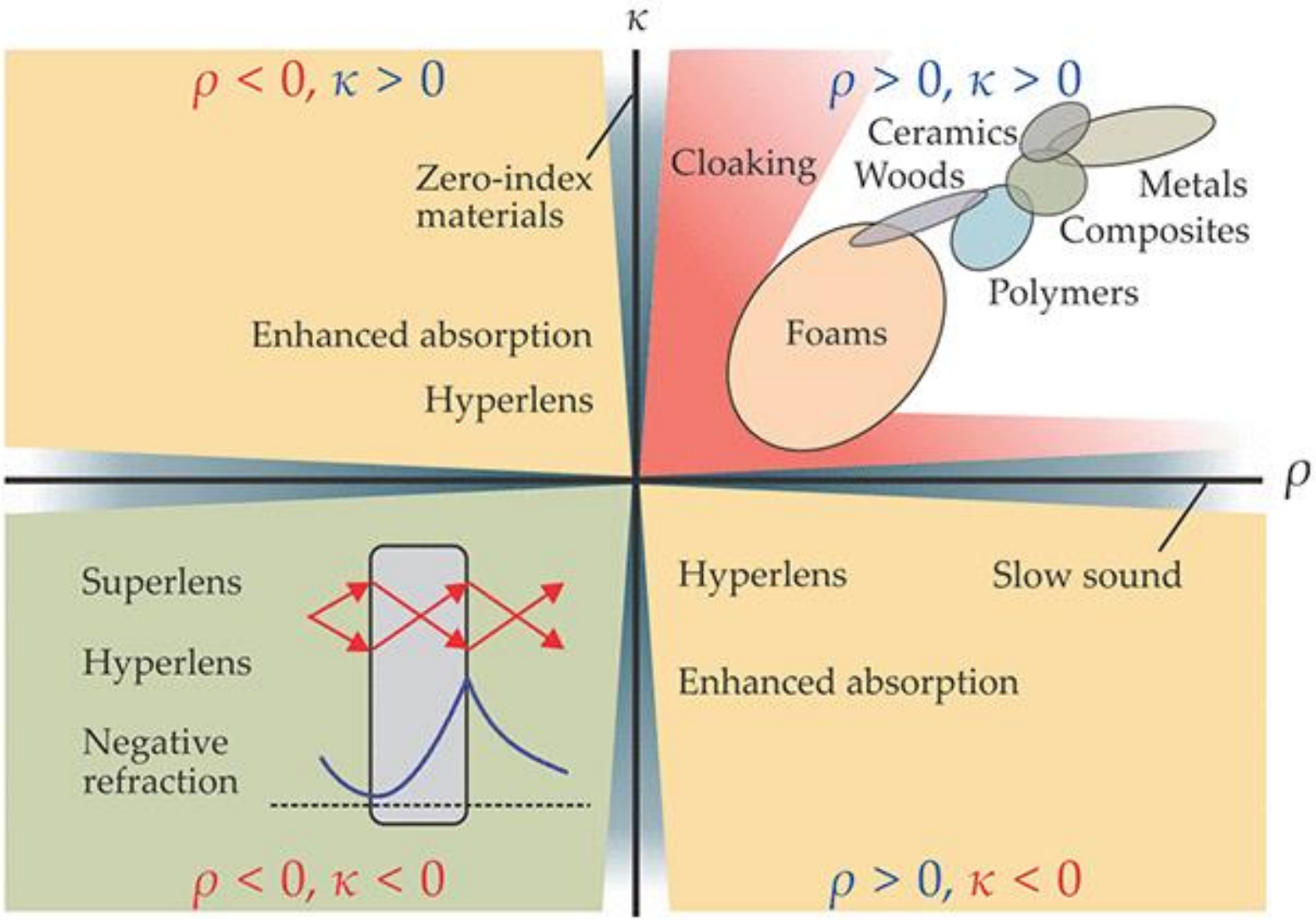

1000
800
600
400
200
0
M
Γ
X
M
Reduced Wave Vector

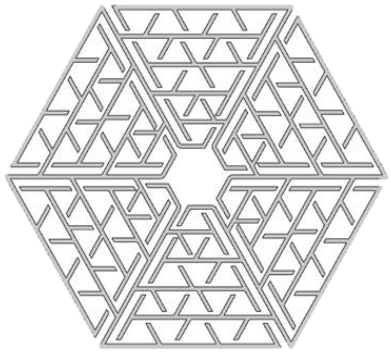


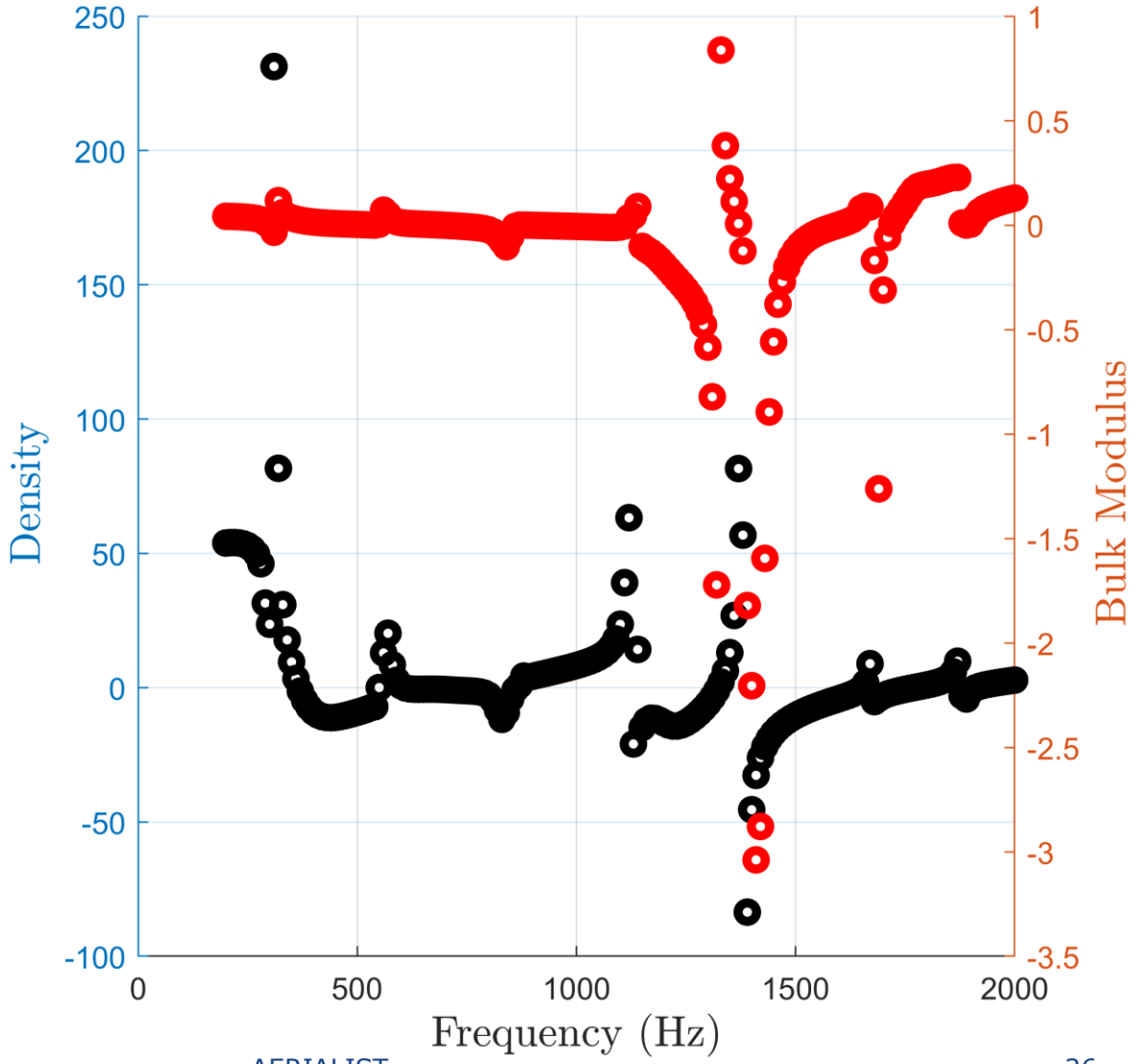







κ
ρ < 0, κ > 0
Zero-index materials
Enhanced absorption
Hyperlens
ρ > 0, κ > 0
Cloaking
Ceramics
Woods
Metals
Composites
Polymers
Foams
ρ
Superlens
Hyperlens
Negative refraction
ρ < 0, κ < 0
Hyperlens
Slow sound
Enhanced absorption
ρ > 0, κ < 0




Density
Bulk Modulus
Frequency (Hz)
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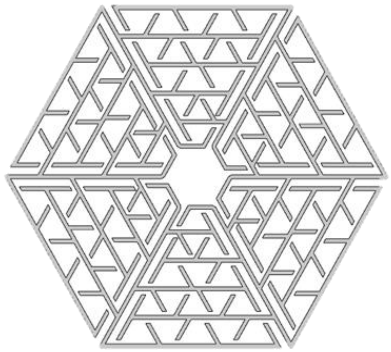
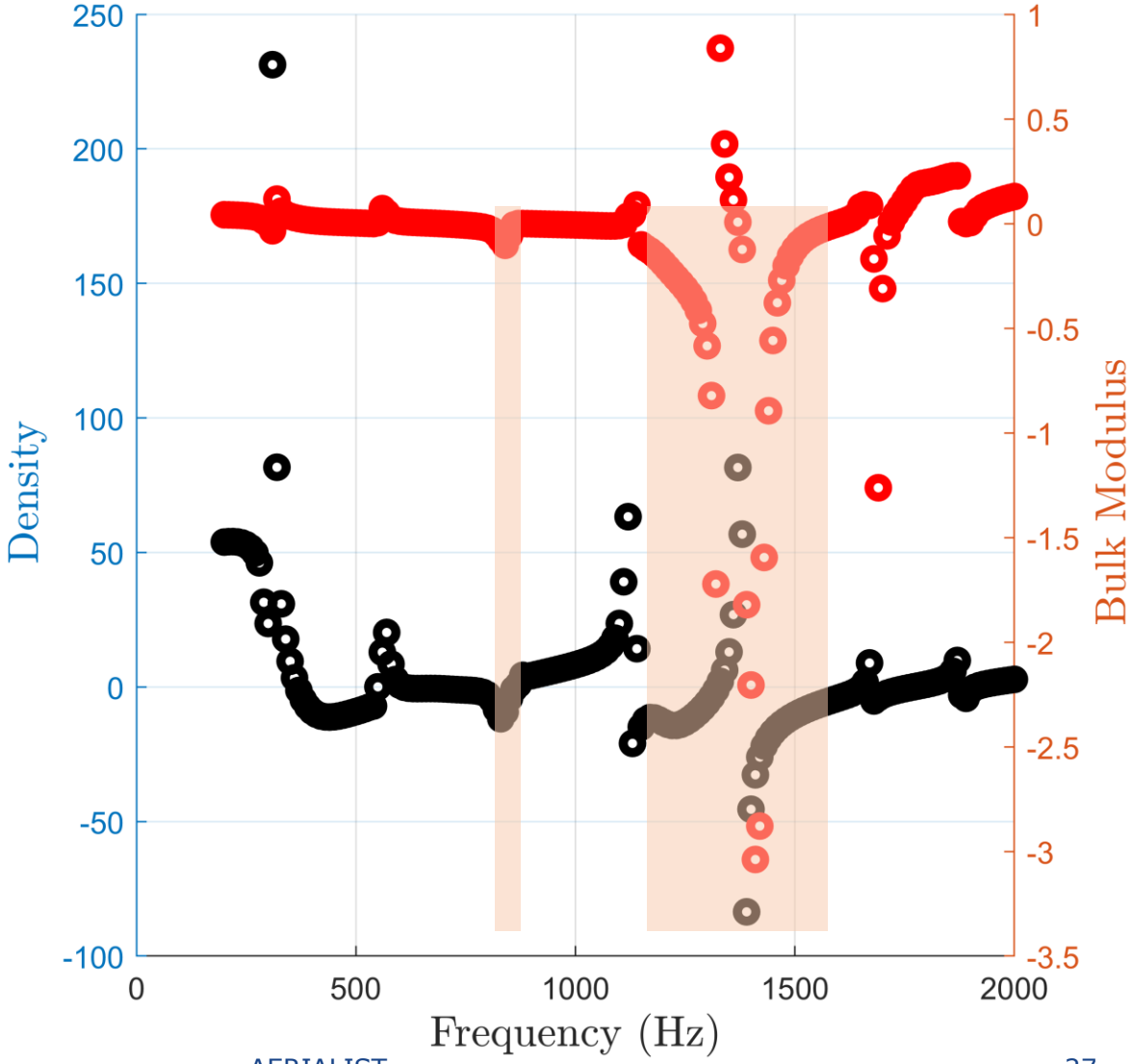
200
150
100
50
0
-50
-100
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
0
500
1000
1500
2000




Density
Bulk Modulus
Frequency (Hz)
250
200
150
100
50
0
-50
-100
1
0.5
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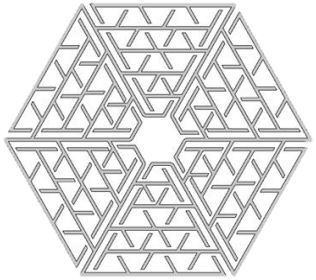
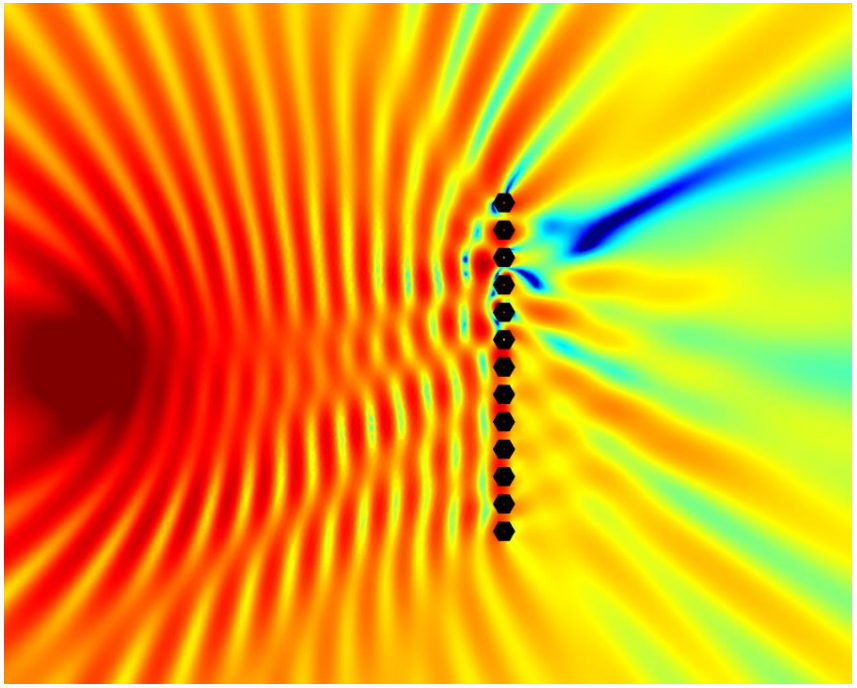
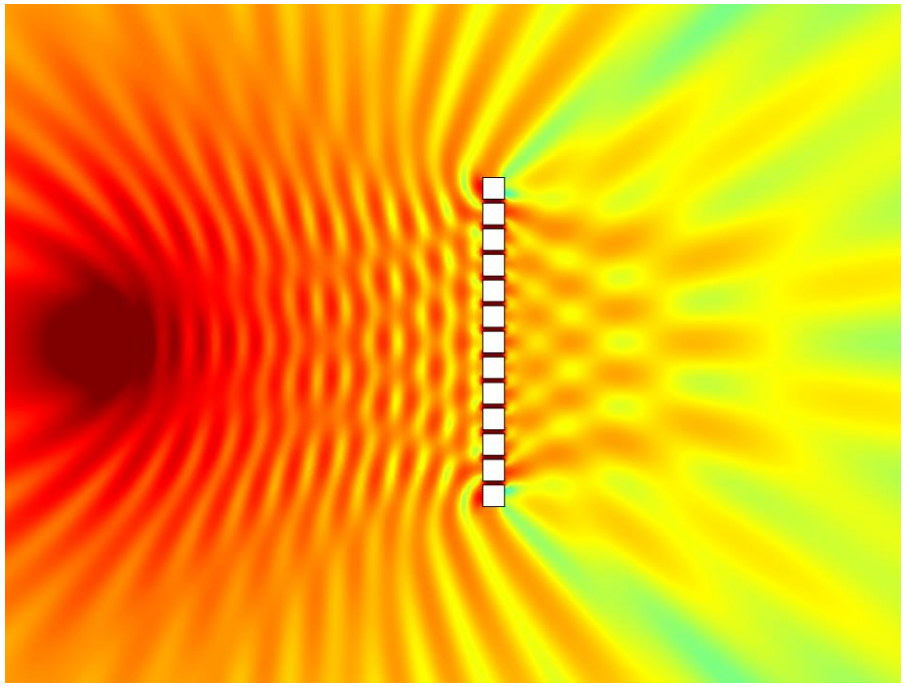
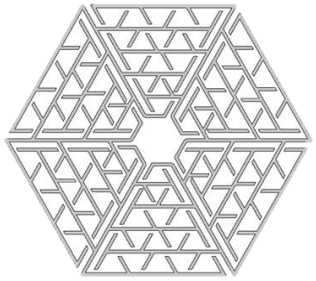
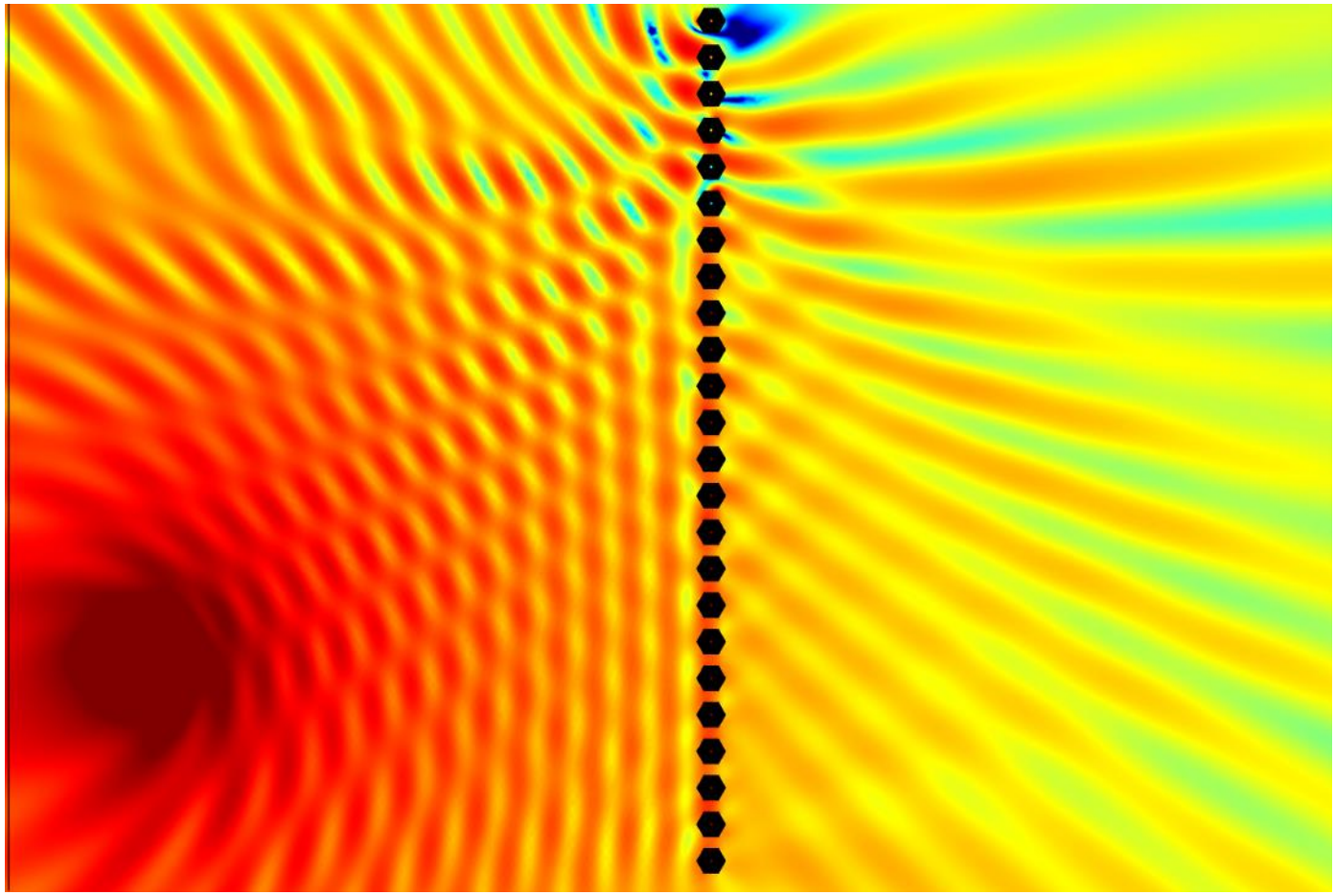
-1
-1.5
-2
-2.5
-3
-3.5
0
500
1000
1500
2000

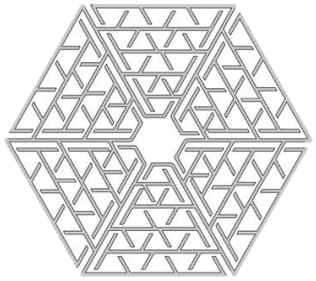


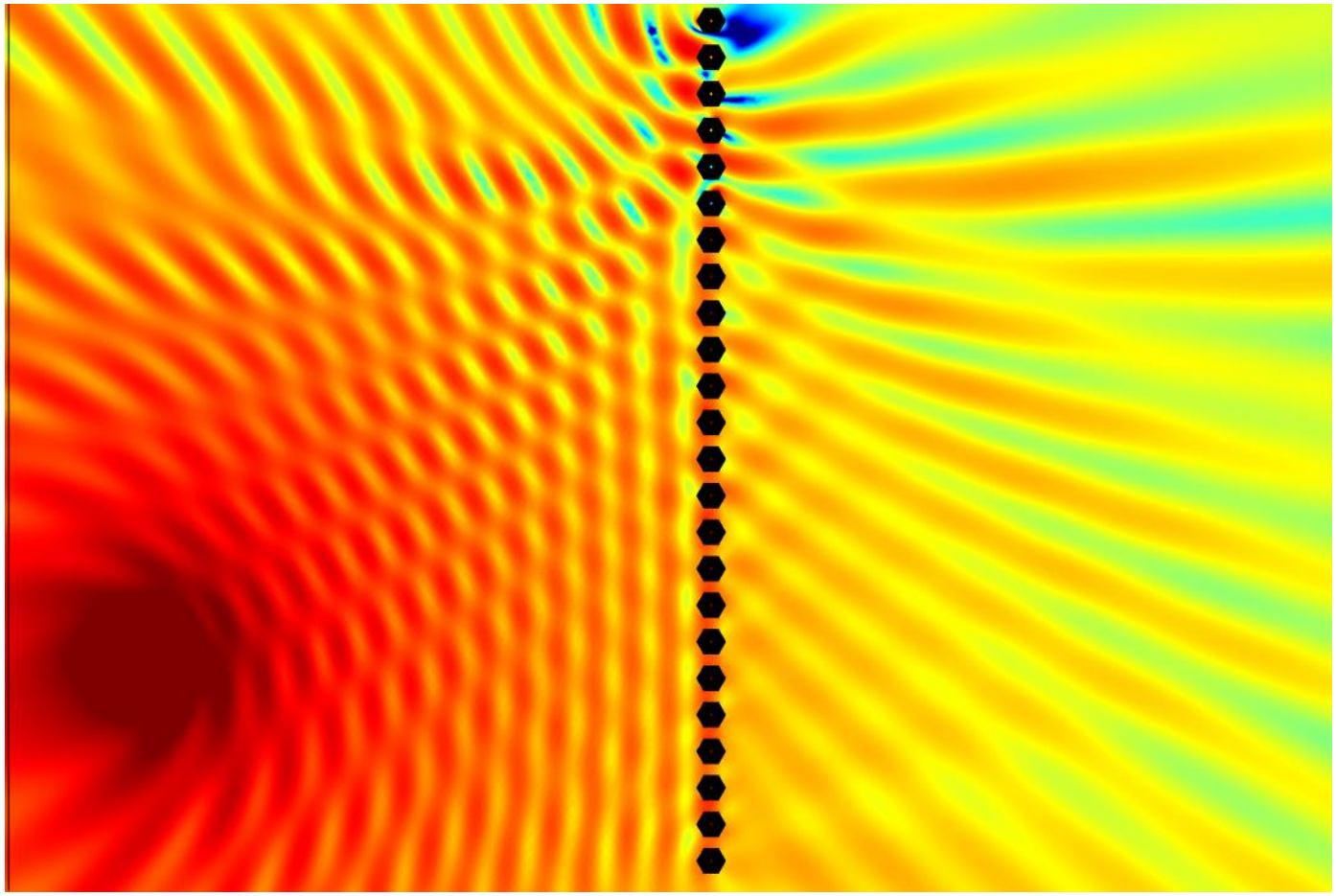




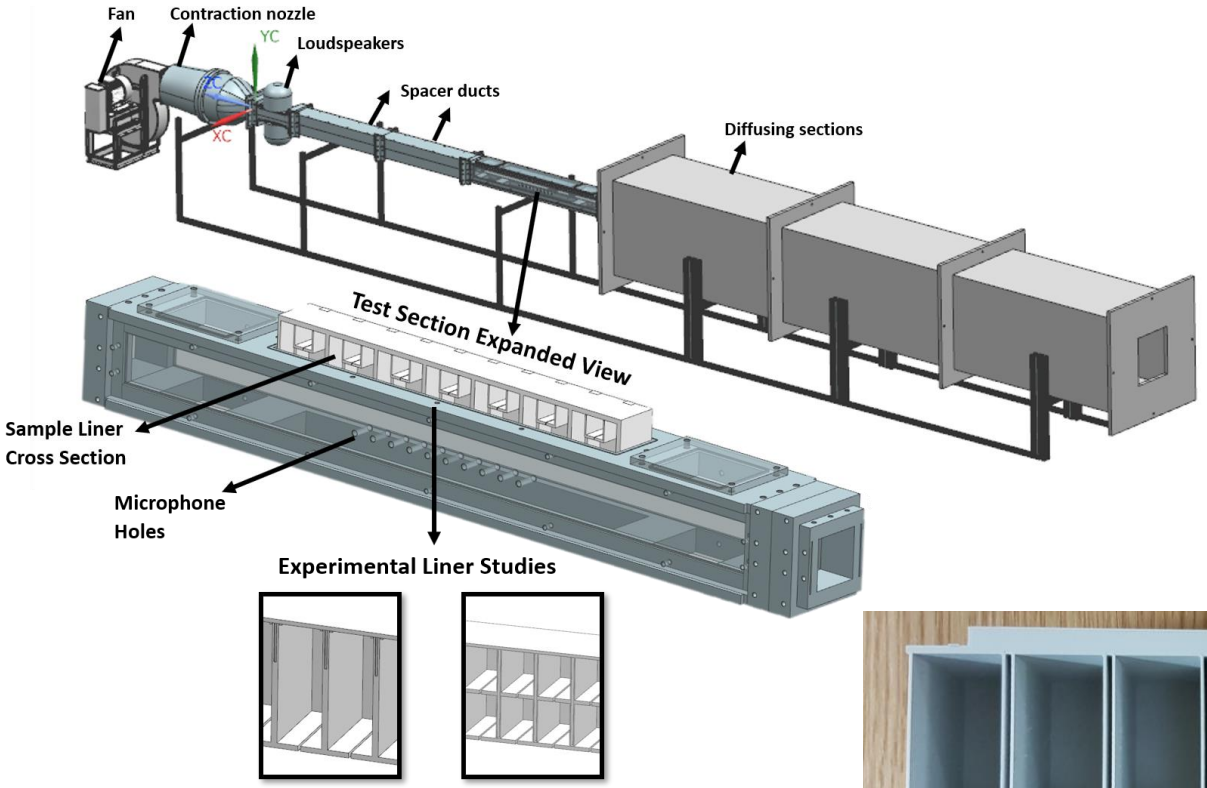


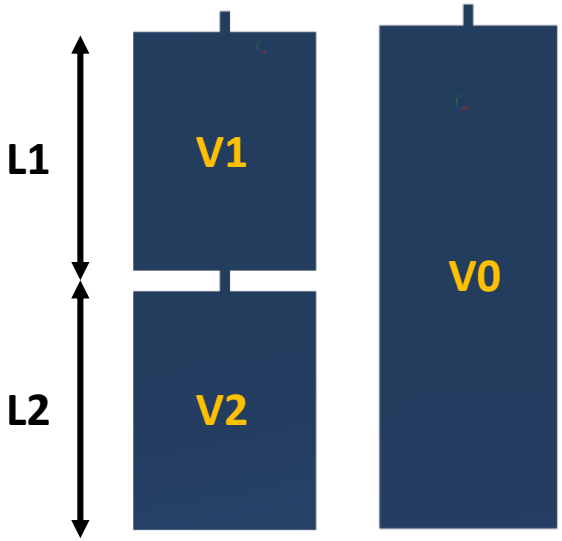


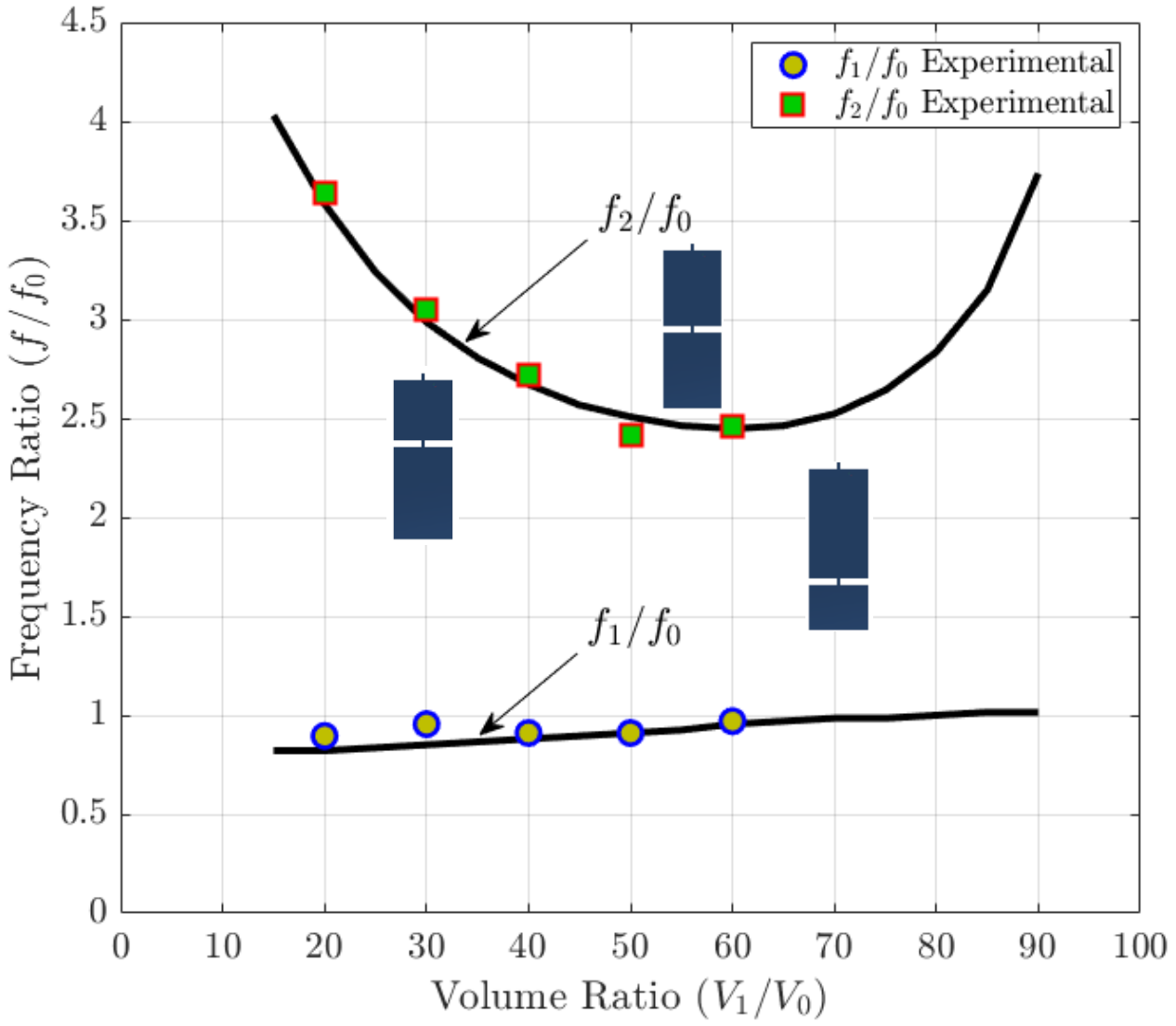


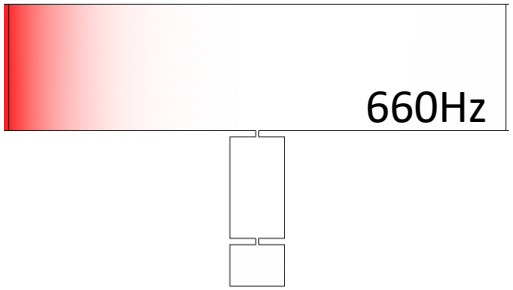


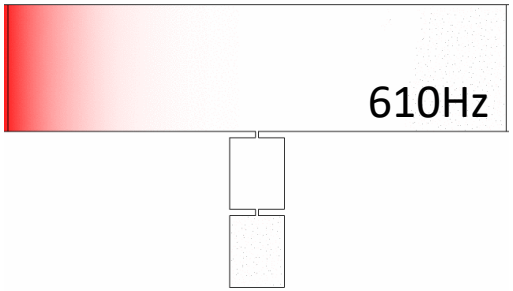
2 DoF Resonators

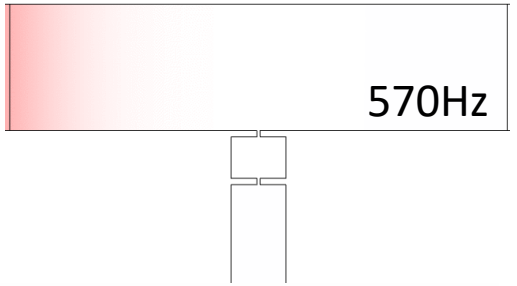


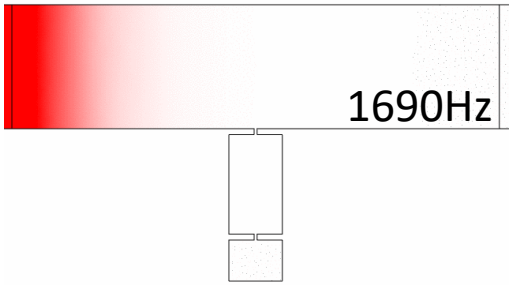


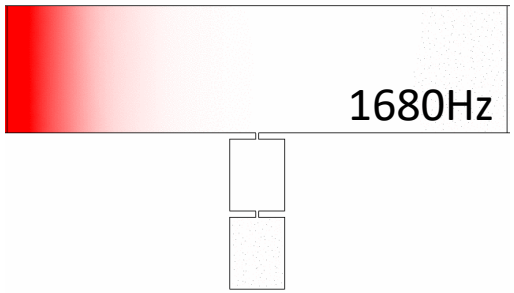

f_1/f_0 Experimental
f_2/f_0 Experimental
f_2/f_0
f_1/f_0
Frequency Ratio (f/f_0)
Volume Ratio (V_1/V_0)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
10
20
30
40
50
60
70
80
90
100

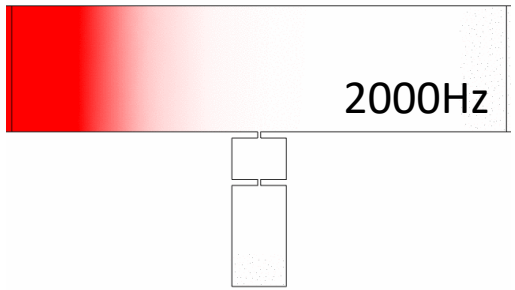

660Hz

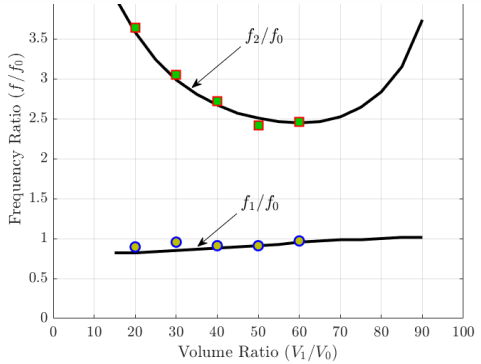

610Hz

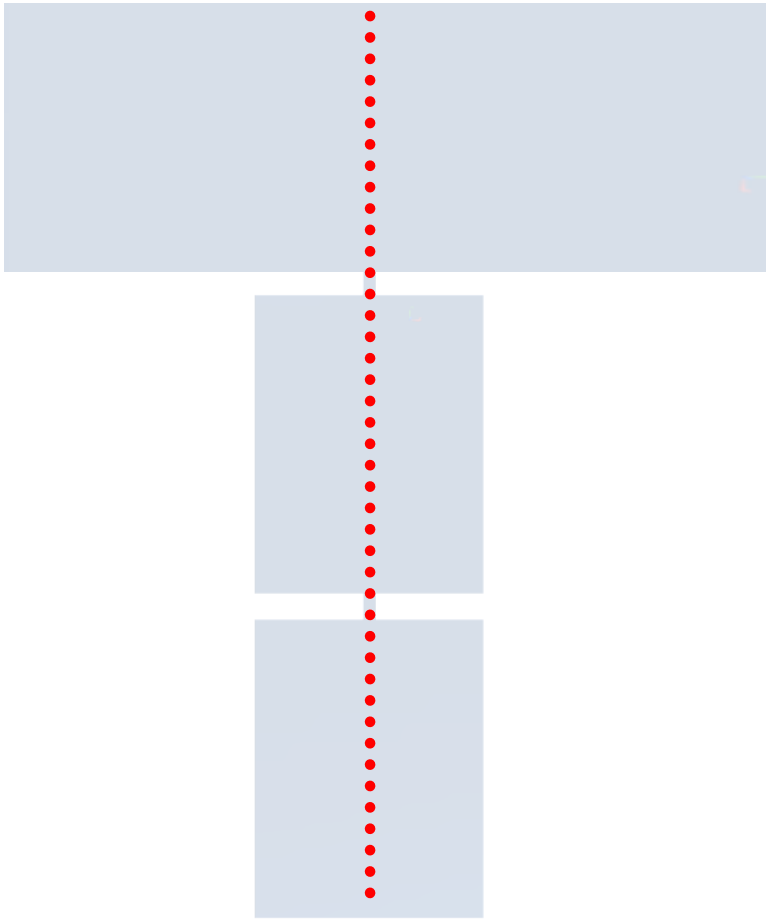

570Hz

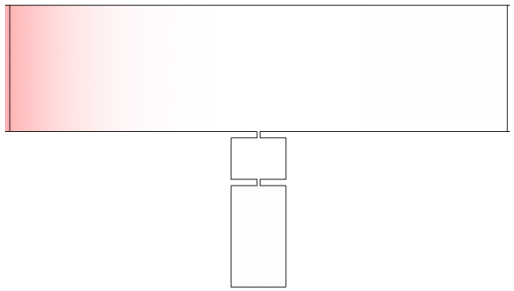

1690Hz

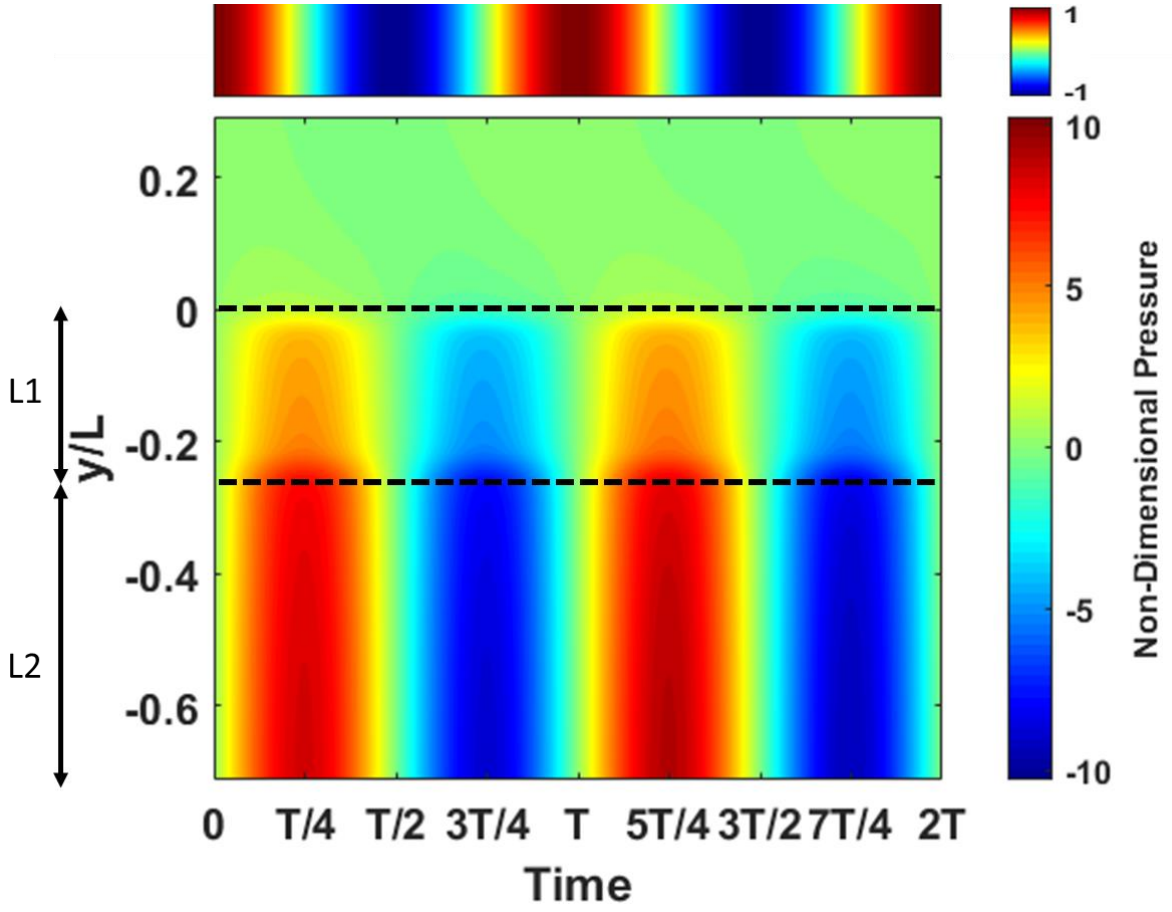

1680Hz

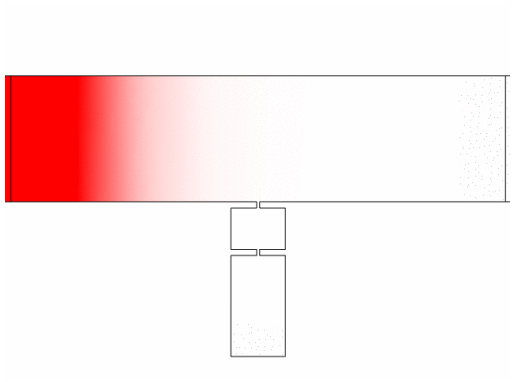

2000Hz

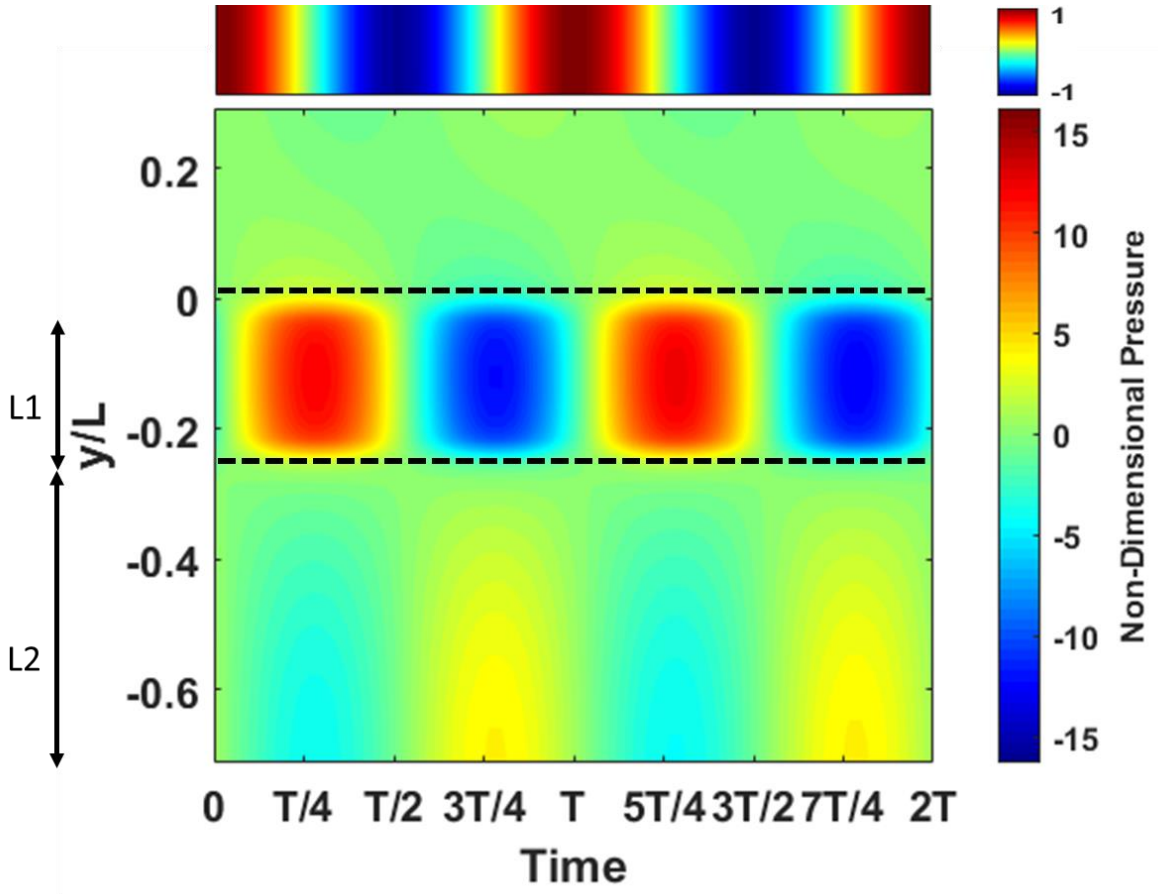

f_2/f_0
f_1/f_0
Frequency Ratio (f/f_0)
Volume Ratio (V_1/V_0)
0
0.5
1
1.5
2
2.5
3
3.5
0
10
20
30
40
50
60
70
80
90
100

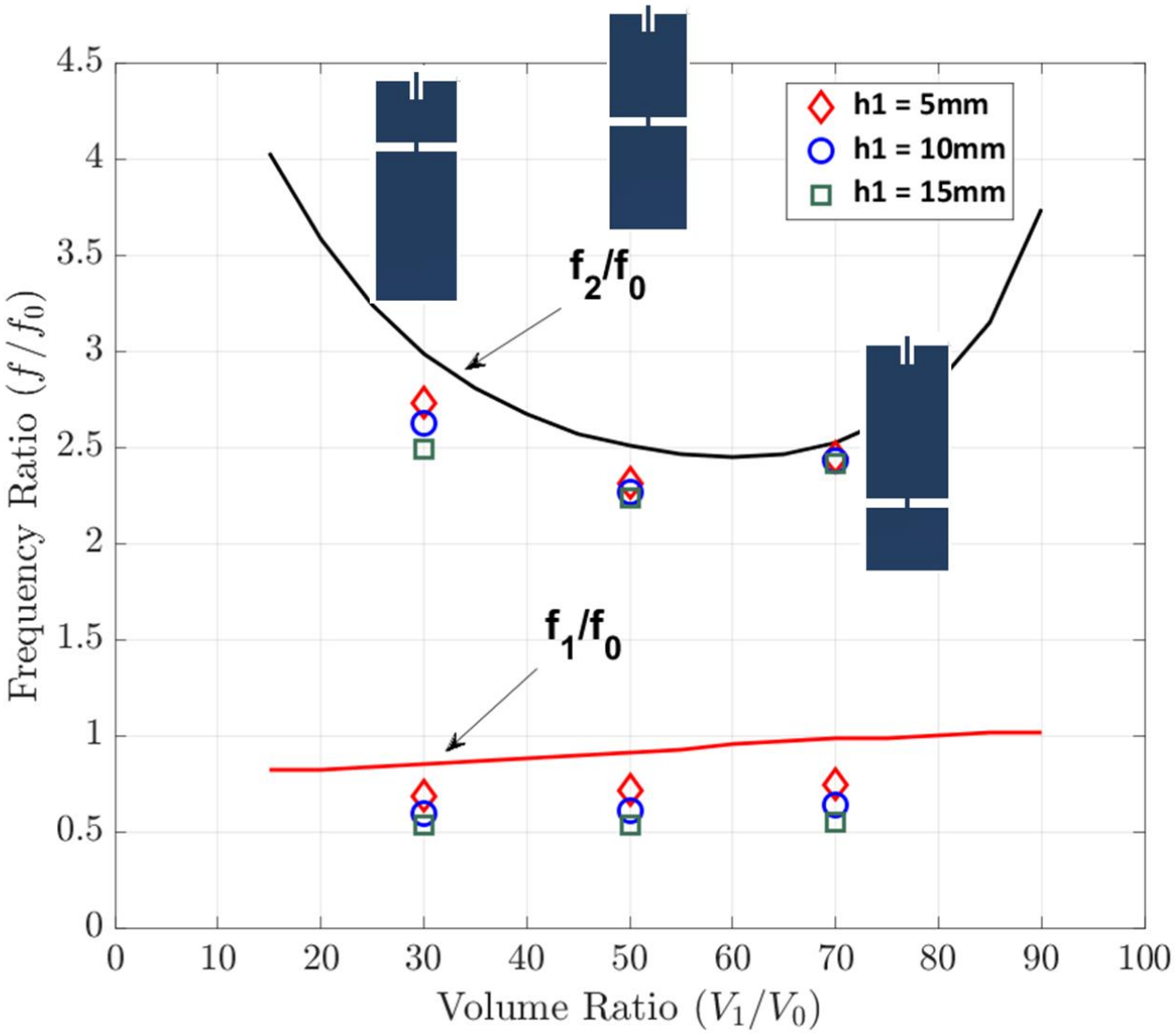


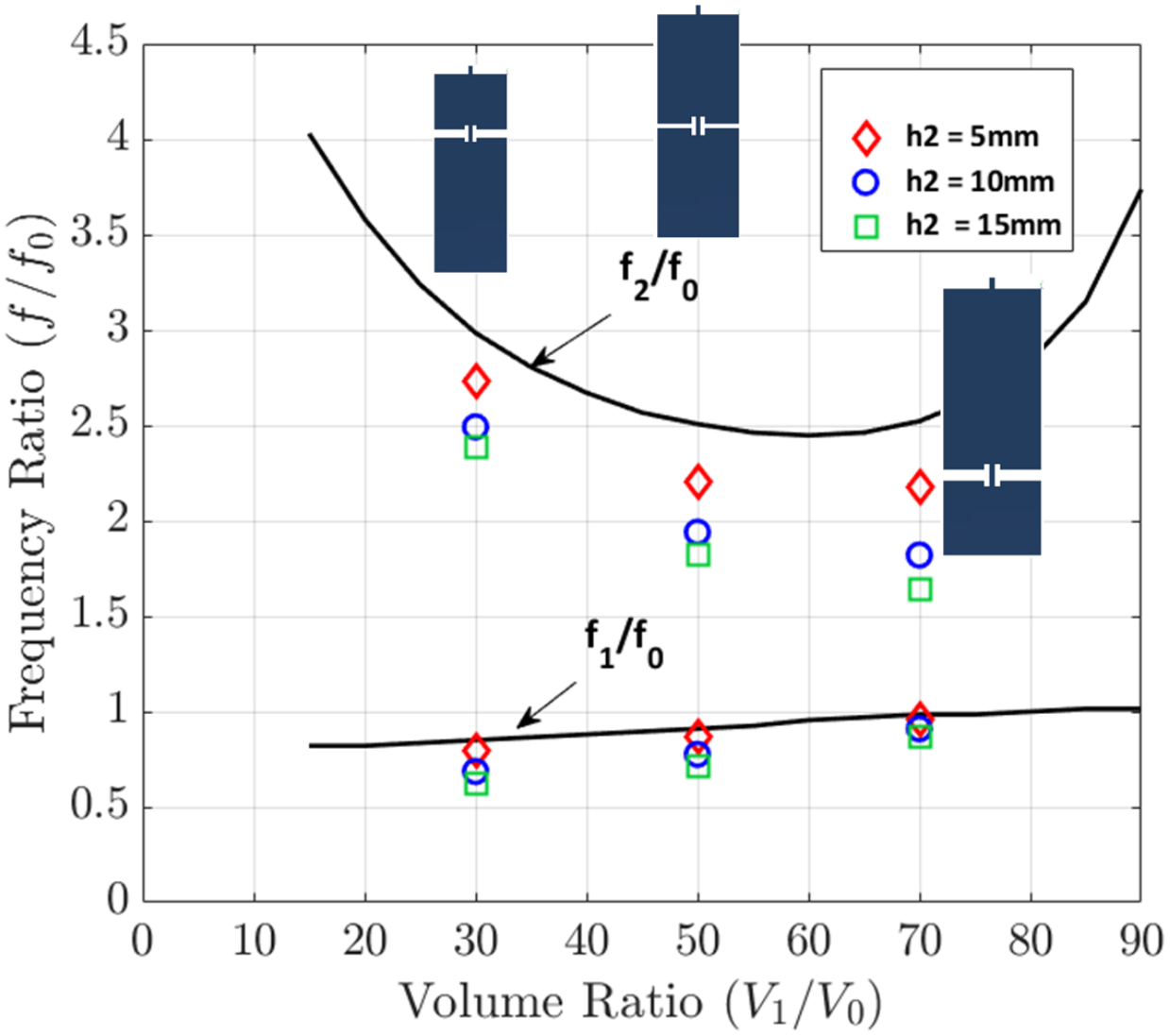



L1
L2
y/L
0.2
0
-0.2
-0.4
-0.6
0
T/4
T/2
3T/4
T
5T/4
3T/2
7T/4
2T
Time
1
-1
10
5
0
-5
-10
Non-Dimensional Pressure




1
-1
15
10
5
0
-5
-10
-15
Non-Dimensional Pressure
0.2
0
-0.2
-0.4
-0.6
y/L
L1
L2
0
T/4
T/2
3T/4
T
5T/4
3T/2
7T/4
2T
Time


h1 = 5mm
h1 = 10mm
h1 = 15mm
f_2/f_0
f_1/f_0
Frequency Ratio (f/f_0)
Volume Ratio (V_1/V_0)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
10
20
30
40
50
60
70
80
90
100


h2 = 5mm
h2 = 10mm
h2 = 15mm
f_2/f_0
f_1/f_0
Frequency Ratio (f/f_0)
Volume Ratio (V_1/V_0)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
10
20
30
40
50
60
70
80
90

Future Works

- Design and manufacture targeted Metamaterials
- Building a wave guide - experiments
- Experiments on neck effect
- Aerialist test campaign

Thanks