3D single-phase elastic metamaterial for low-frequency wave filtering

Ana Carolina Azevedo Vasconcelos[1]; Dr. Dingena L. Schott[1]; Dr. Alejandro M. Aragón[2]; Dr. Jovana Jovanova[1]

a.c.azevedovasconcelos@tudelft.nl; d.l.schott@tudelft.nl; a.m.aragon@tudelft.nl; j.jovanova@tudelft.nl;

[1]Department of Maritime & Transport Technology (MTT) ; [2]Department of Precision and Microsystems Engineering (PME)

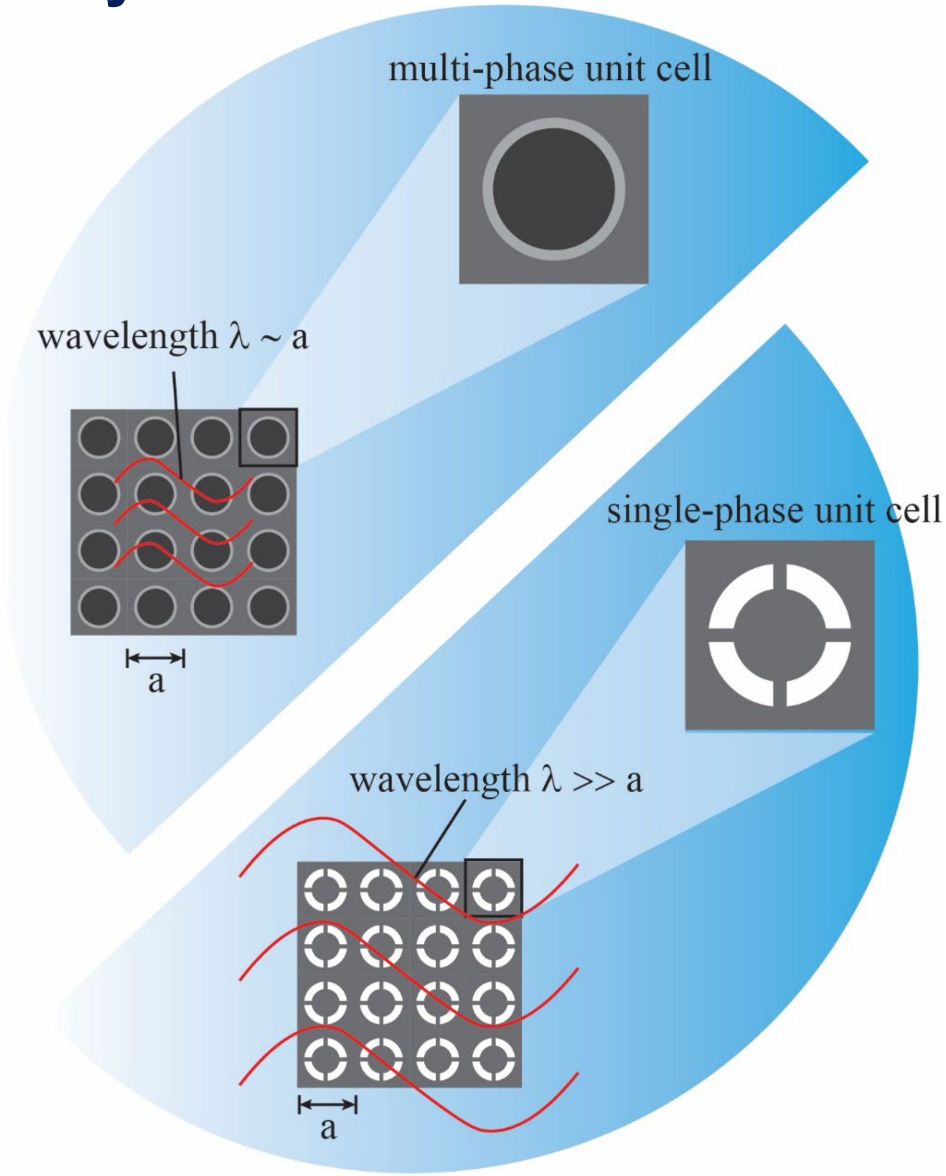
Faculty of Mechanical, Maritime and Materials Engineering (3mE)

Delft University of Technology

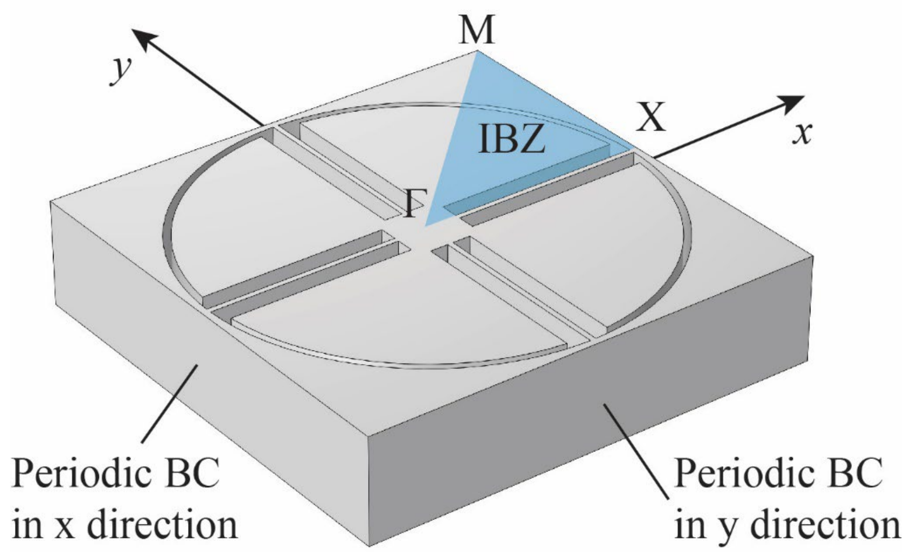
TU Delft

The increase of monopile dimensions has driven the high noise level to low-frequency regions

Single-phase unit cells can be designed to attenuate low-frequency waves



Due to the unit cell symmetry, the Irreducible Brillouin Zone (IBZ) corresponds to the shaded area



Geometric Parameters - Resonator			
a	Unit cell size	w_g	Beam's path width
R_1	Cavity radius	l_g	Beam's path length
R_2	Resonator radius	w_b	Beam width
h	Unit cell thickness	l_b	Beam length

From Bloch-Floquet theorem:

$$\mathbf{u}(\mathbf{x}+\mathbf{a}) = \mathbf{u}(\mathbf{x})e^{i(\mathbf{k}\cdot\mathbf{a}-\omega t)}$$

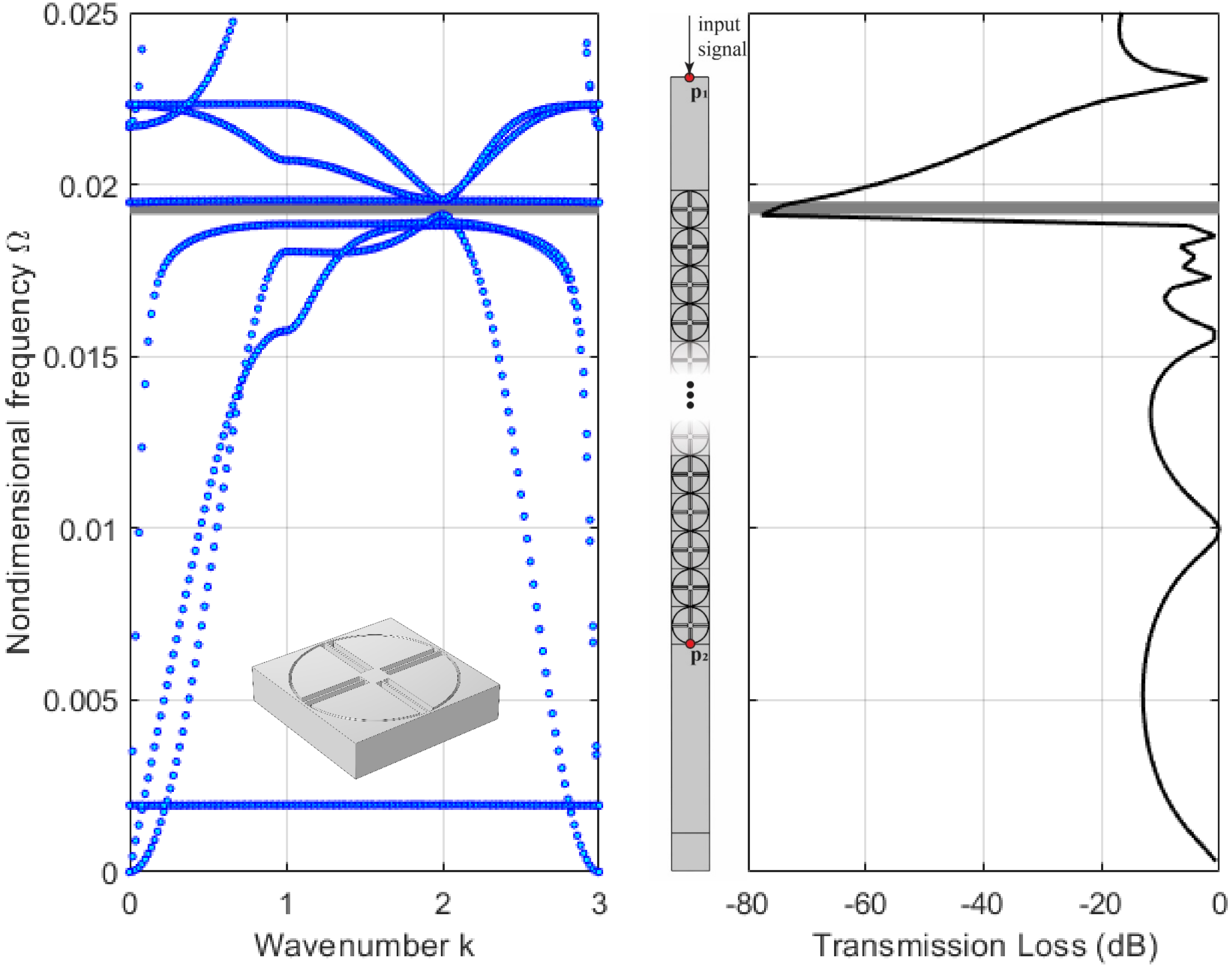
$\mathbf{u} \longrightarrow$ Displacement vector

$\mathbf{x} \longrightarrow$ Position vector

$\mathbf{a} \longrightarrow$ Lattice constant vector

$\mathbf{k} \longrightarrow$ Wave vector

Dispersion relation and transmission analysis can predict the resonant bandgap



Dispersion Relation

$$\Omega = \frac{f * a}{c}$$

$f \longrightarrow$ Eigenfrequency

$a \longrightarrow$ Unit cell size

$c \longrightarrow$ Wave speed

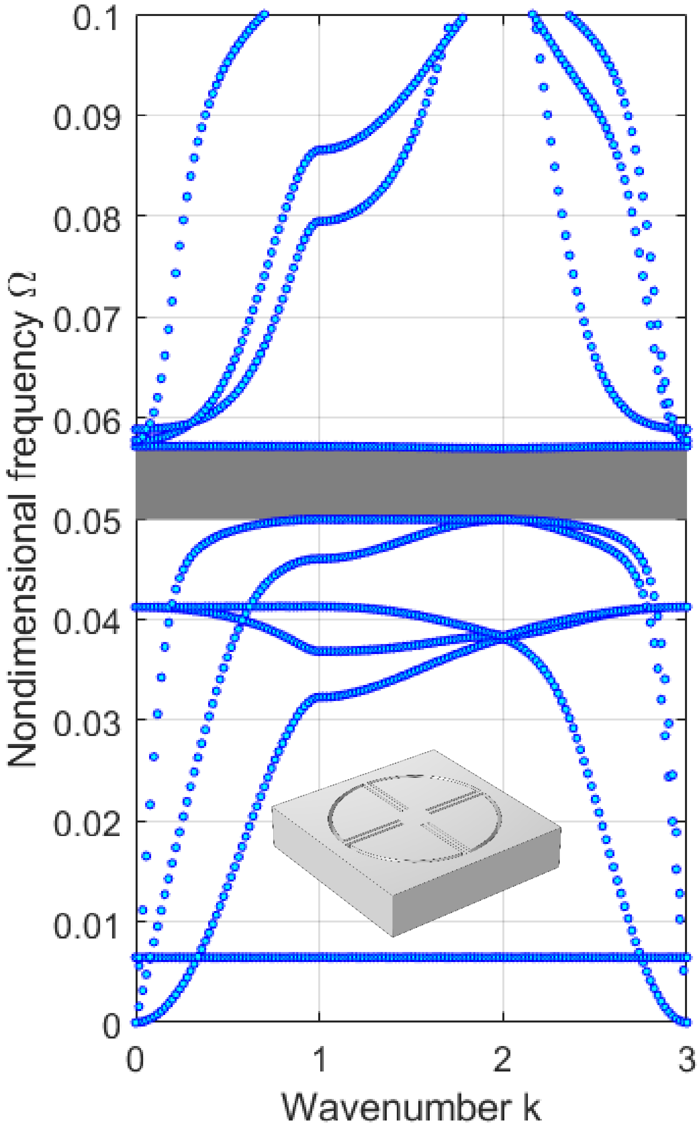
$\mathbf{k} \longrightarrow$ Nondimensional wave vector regarding to unit cell size

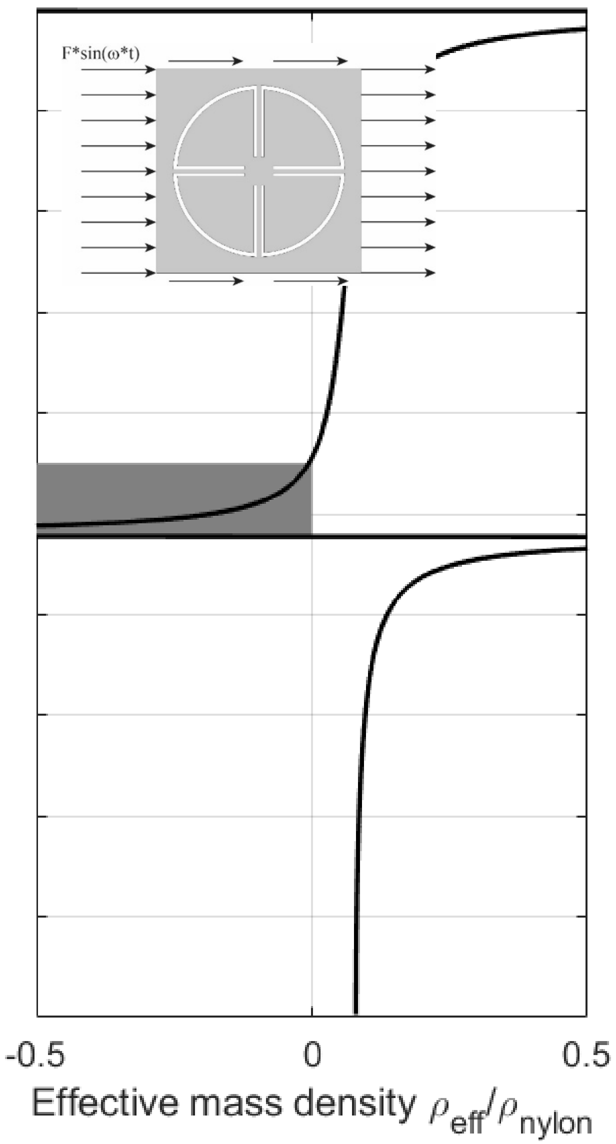
Transmission Analysis

$$\mathrm{TL(dB)} = 20 \ \log\left(\frac{\|\mathbf{p_2}\|}{\|\mathbf{p_1}\|}\right)$$

$\mathbf{p_i} \longrightarrow$ Displacements measured at points i = 1,2

The effective mass density also highlights the resonant bandgap





Applying harmonic force at the unit cell boundaries and solving

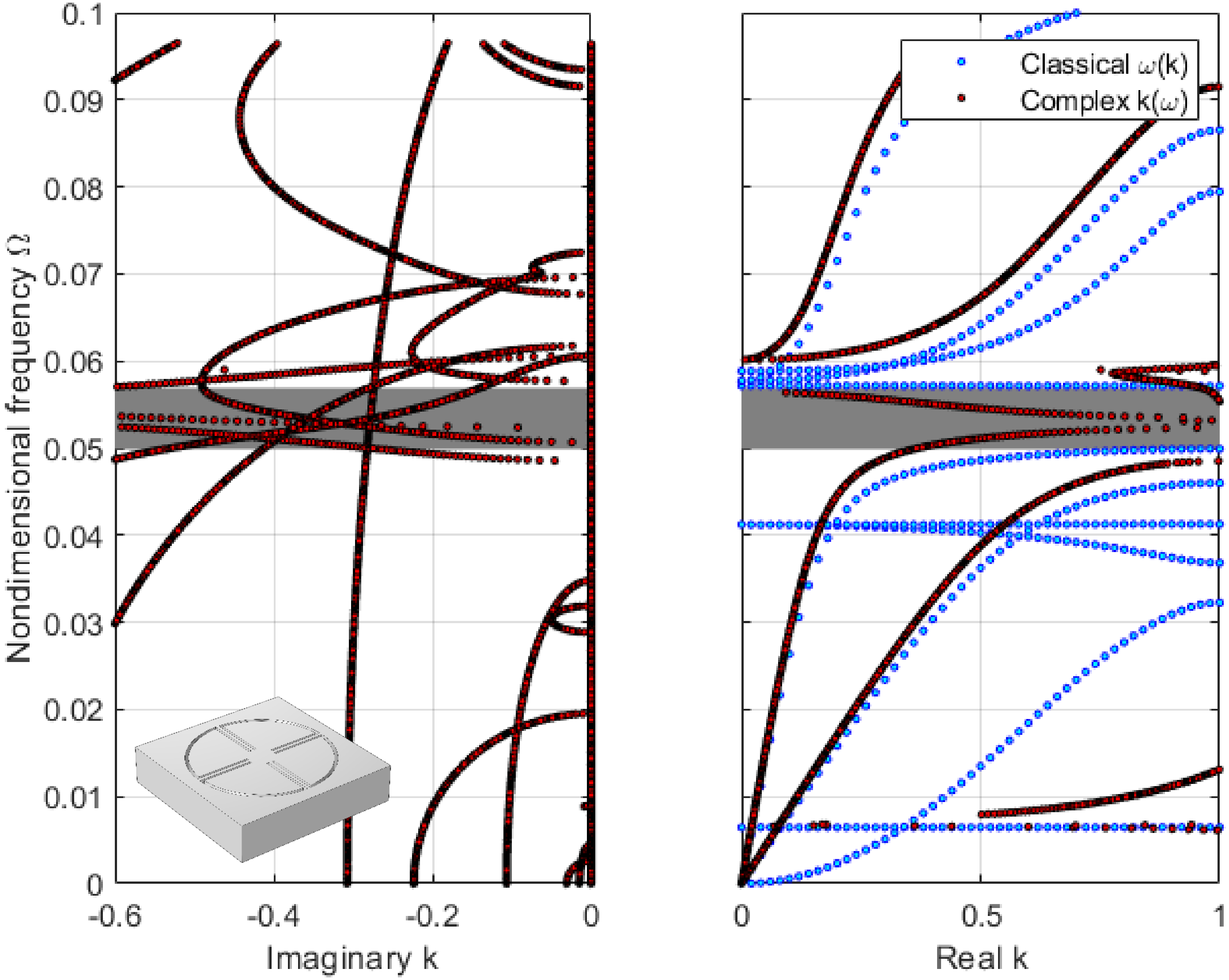
$$(\mathbf{K} - \omega^2\mathbf{M})\mathbf{U} = \mathbf{F}$$

The boundary displacements are evaluated. The effective mass density is defined as

$$\rho_{\text{eff}}(\omega) = -\frac{1}{A}\frac{F_{\text{bound}}}{\omega^2 U_{\text{bound}}}$$

$U, F_{\text{bound}} \longrightarrow$ Displacement and force measured at the external boundaries

The attenuation at the BG can be observed by obtaining the complex band structure



Dispersion Relation

Classical approach

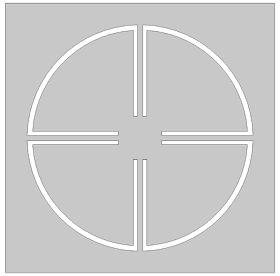
$\omega(\mathbf{k}) \longrightarrow$ Real wave vector;
Only real part of the band structure;
Only propagating Bloch modes.

Complex approach

$\mathbf{k}(\omega) \longrightarrow$ Real frequency;
Complex band structure
Evanescent and
propagating Bloch modes.

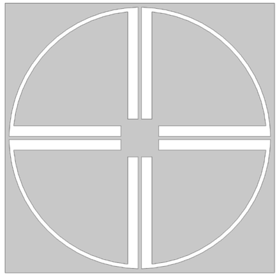
The wave filtering process is performed by the combination of unit cells with different topologies

UC1

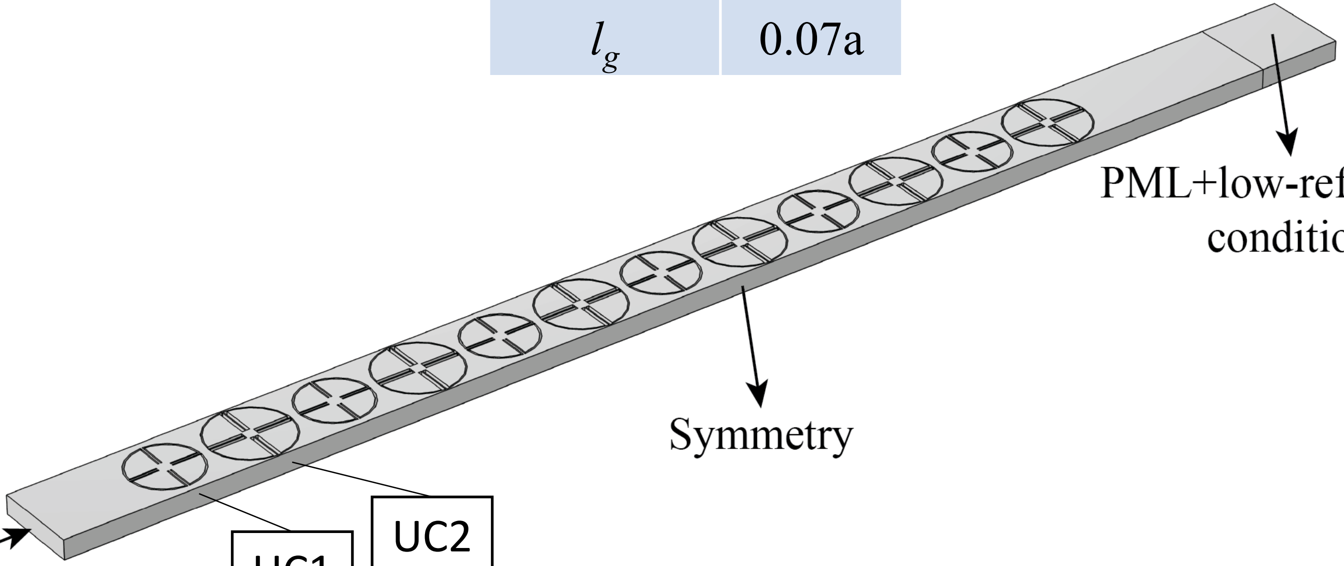


Properties	Size
R_1	0.42a
R_2	0.4a
w_b	0.02a
w_g	0.05a
l_g	0.08a

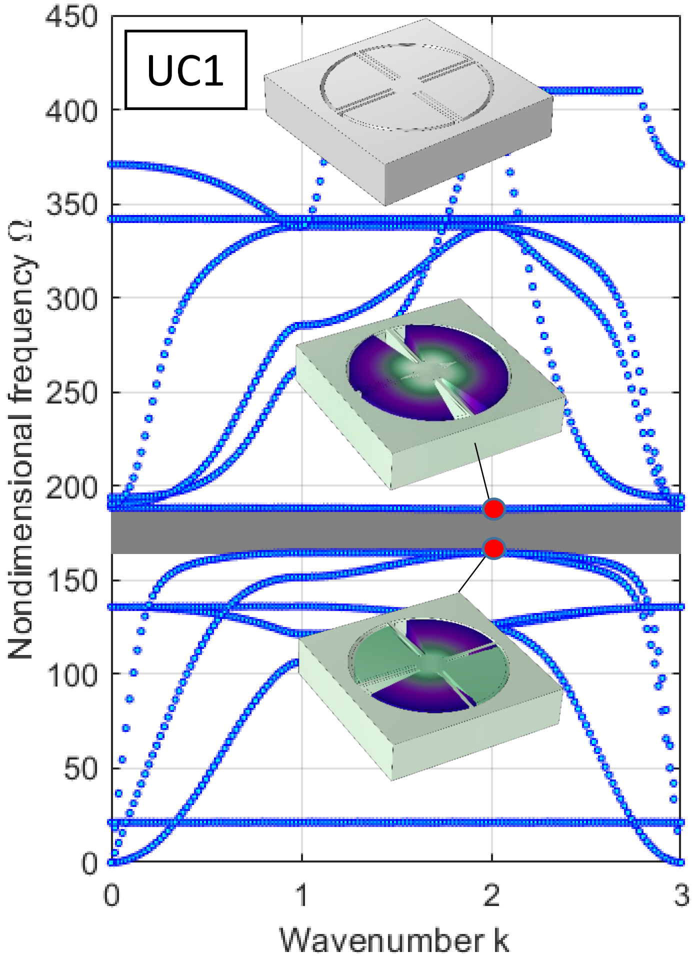
UC2

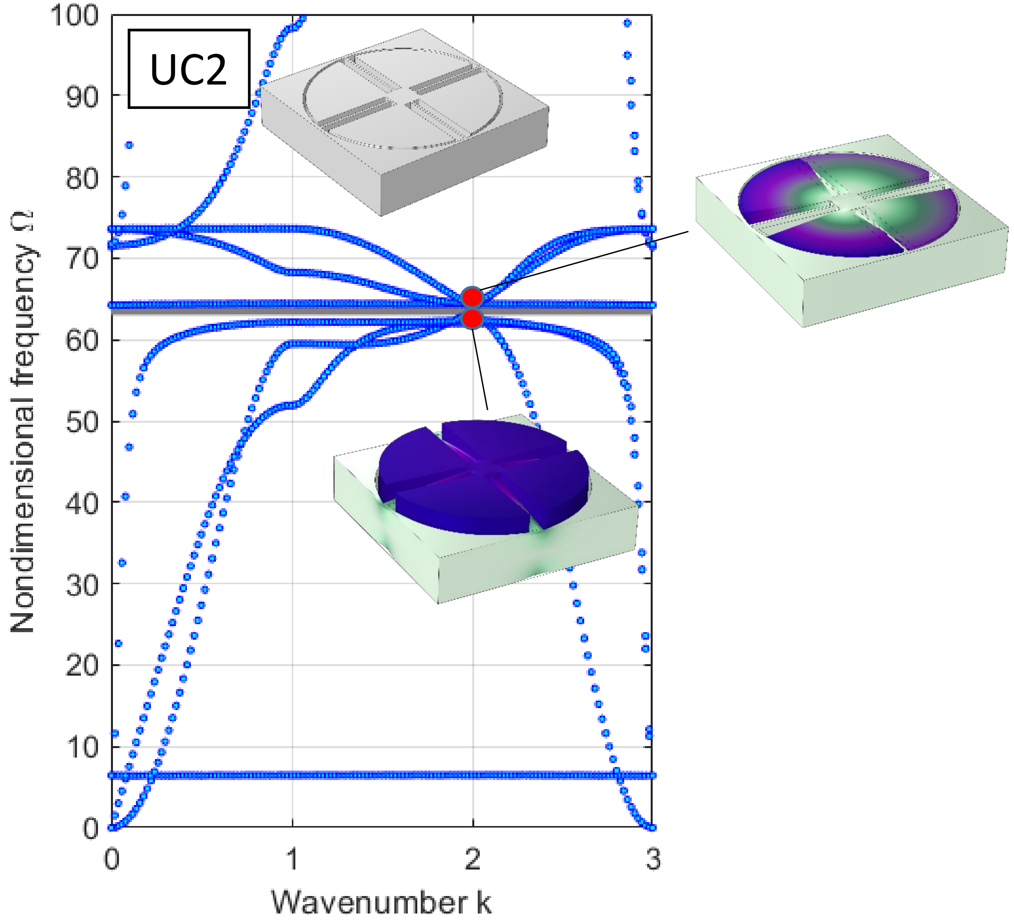


Properties	Size
R_1	0.485a
R_2	0.47a
w_b	0.012a
w_g	0.09a
l_g	0.07a

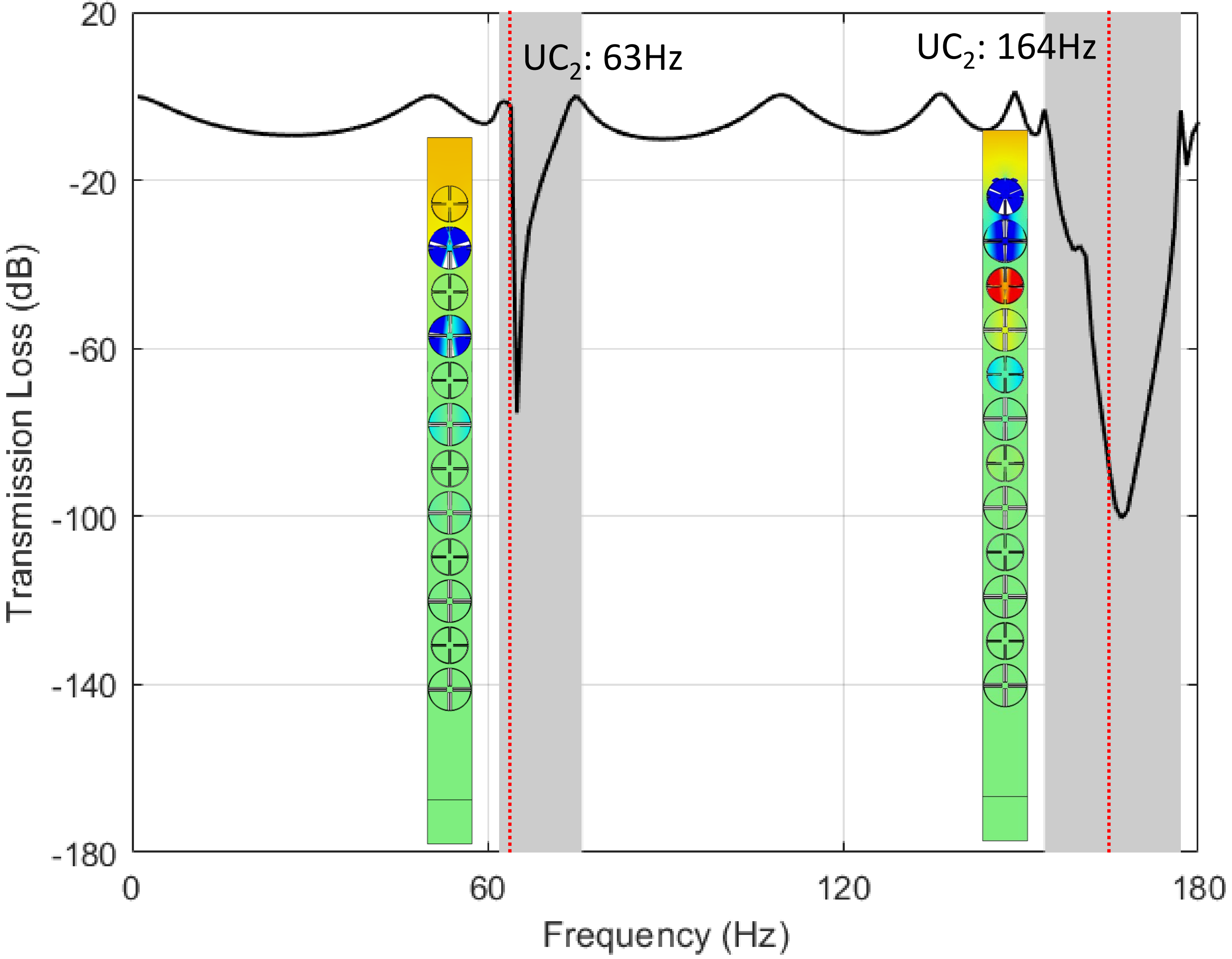


The wave filtering process is performed by the combination of unit cells with different topologies

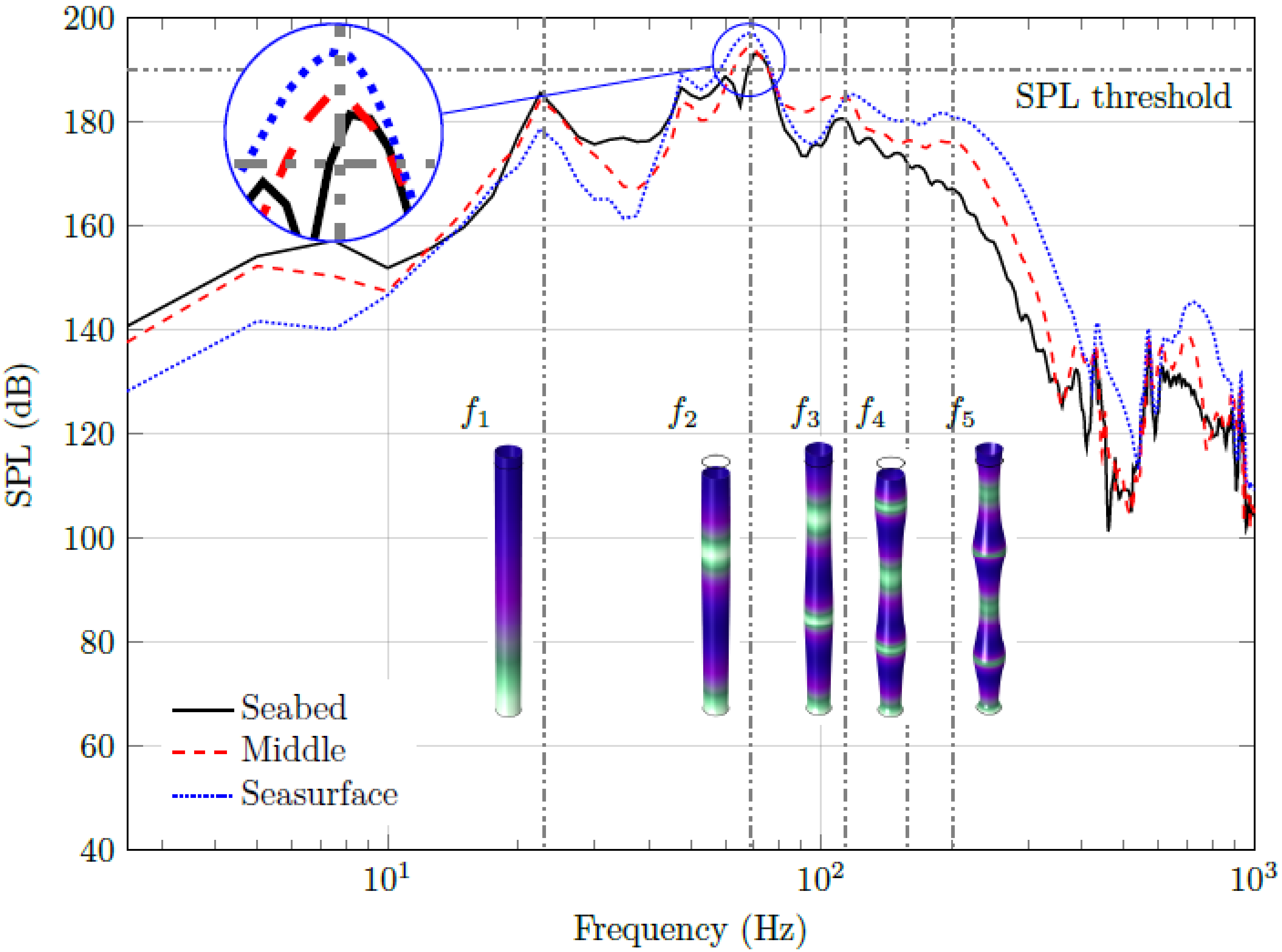




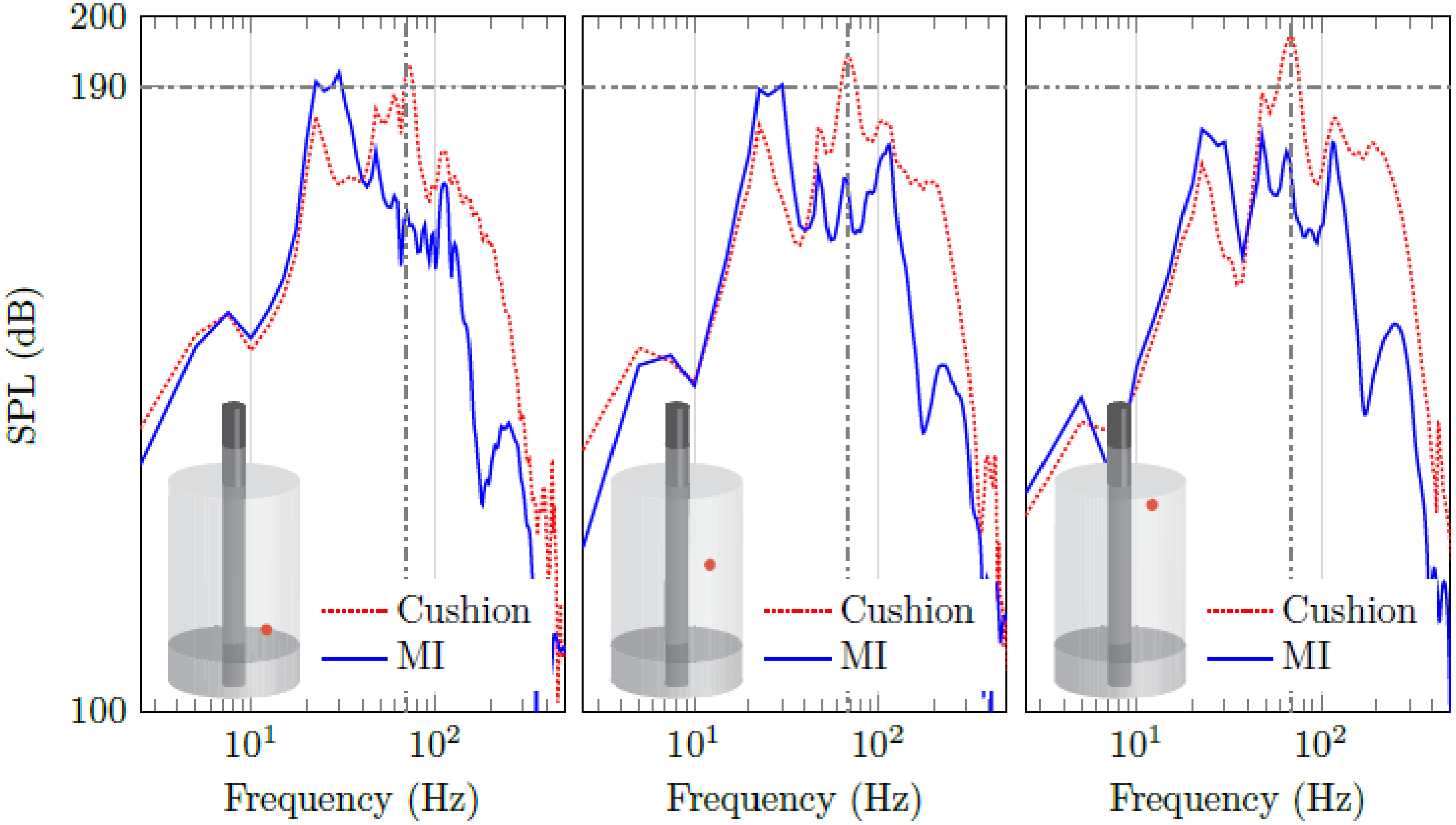
The wave attenuation is reached at the frequency ranges of the resonant bandgaps

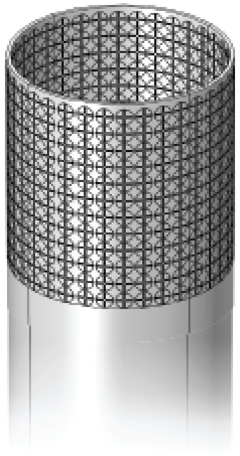


The high noise levels are associated to the monopile eigenmodes



The single-phase unit cells can reduce the low-frequency noise during the pile driving process





Invitation

Title: Energy dissipation and damping of additively manufactured Nitinol lattice structures under compressive loading

Presenter: Zhaorui Yan – TU Delft

Thank for your attention!

A.C.AzevedoVasconcelos@tudelft.nl

TU Delft