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Ultra-Thin and In-Parallel perfect sound absorbers

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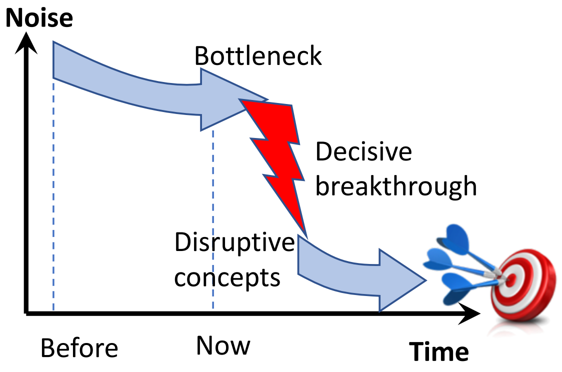
Introduction



For a long time, humans have wanted to reduce aircraft noise ...

Introduction

Cutaway view of the air inlet with classical liner

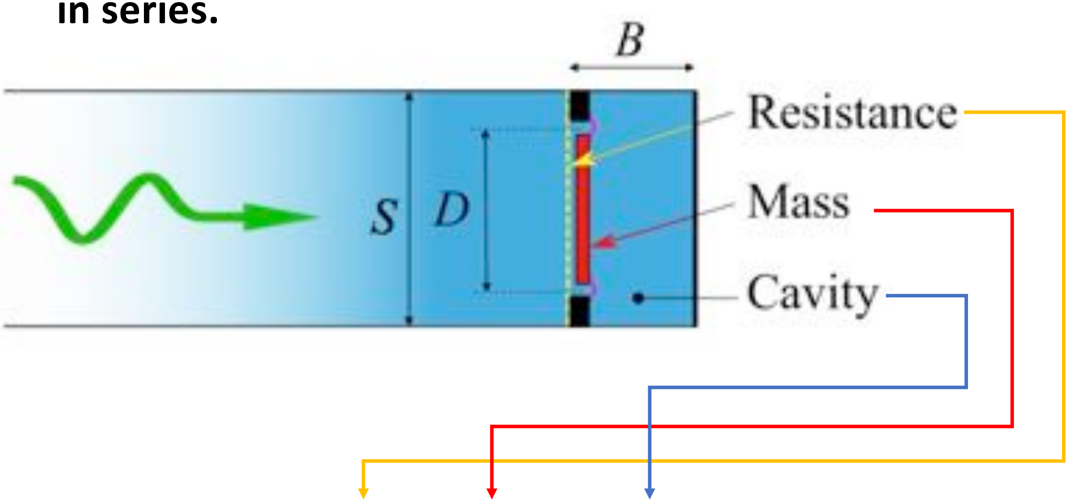
New concepts of plane

↓

Need for high efficiency and new concepts

Generalized Helmholtz Resonator

The generalized Helmholtz resonator (GHR) is composed of a moving mass, a spring due to the cavity and a resistance in series.



$$Z = \frac{p}{\rho_0 c_0 v} = \frac{R}{\sigma} + \frac{j\hat{\omega}L}{\sigma} + \frac{1}{j\hat{\omega}C}$$

POA = $\sigma = \frac{A_D}{A_S}$

$$\hat{\omega} = \frac{\omega}{\omega_c}$$

Generalized Helmholtz Resonator

If the target is to have a perfect absorption $Z = 1$
when $\omega = \omega_c$
The impedance can be written

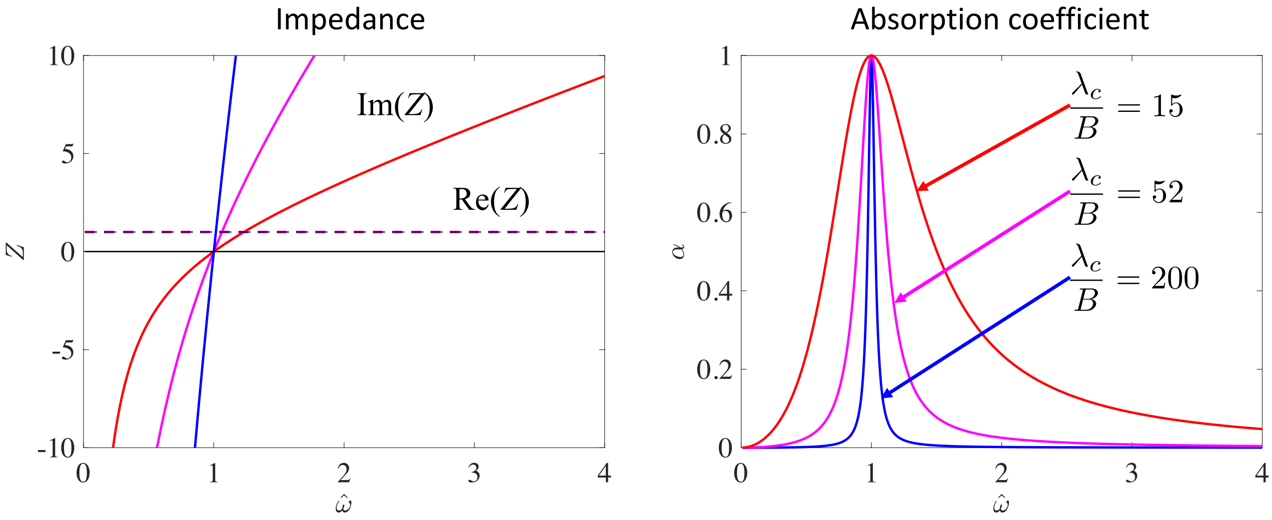
$$Z = 1 + \frac{1}{C}\left(\mathrm{j}\hat{\omega} + \frac{1}{\mathrm{j}\hat{\omega}}\right)$$

dependent on a single parameter $C = 2\pi\dfrac{B}{\lambda_c}$

witch is inversely proportional to the subwavelength ratio.

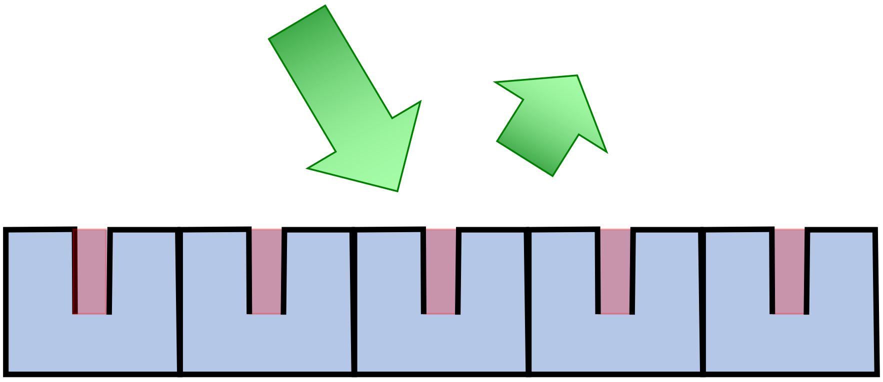
	$f_c = 650$ Hz	$B = 35$ mm	$\dfrac{\lambda_c}{B} = 15$
Examples:	$f_c = 650$ Hz	$B = 10$ mm	$\dfrac{\lambda_c}{B} = 52$
	$f_c = 170$ Hz	$B = 10$ mm	$\dfrac{\lambda_c}{B} = 200$

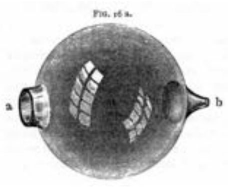
Generalized Helmholtz Resonator



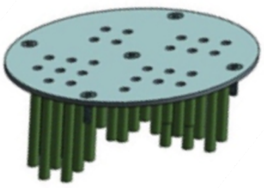
- It is possible to have perfect absorption at any frequency and at any cavity thickness.
- As the subwavelength ratio increases, the absorption peak becomes increasingly sharp.

Generalized Helmholtz Resonator

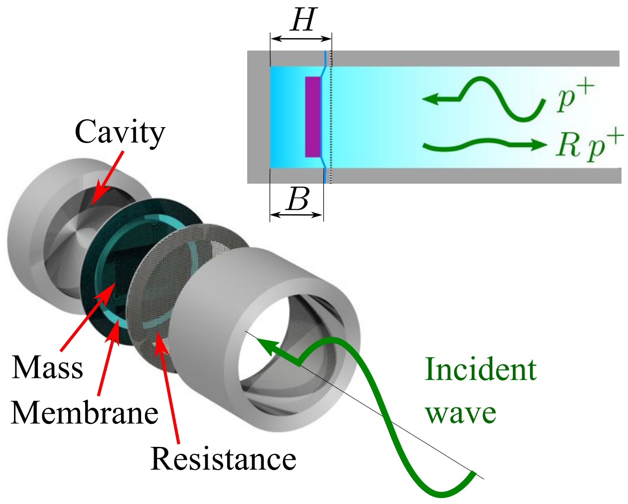


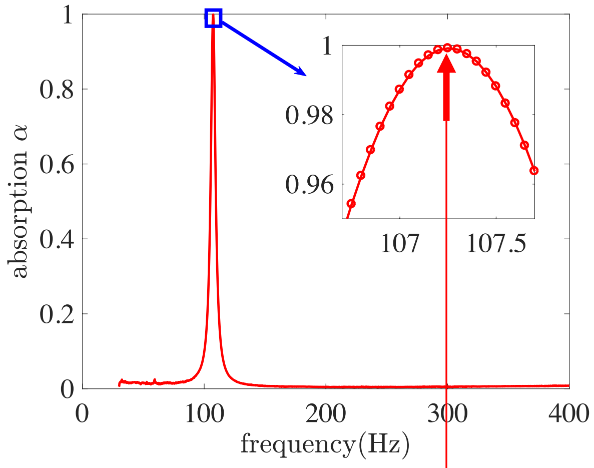


In classical Helmholtz resonator, the mass and the resistance are linked in the neck.



Generalized Helmholtz Resonator





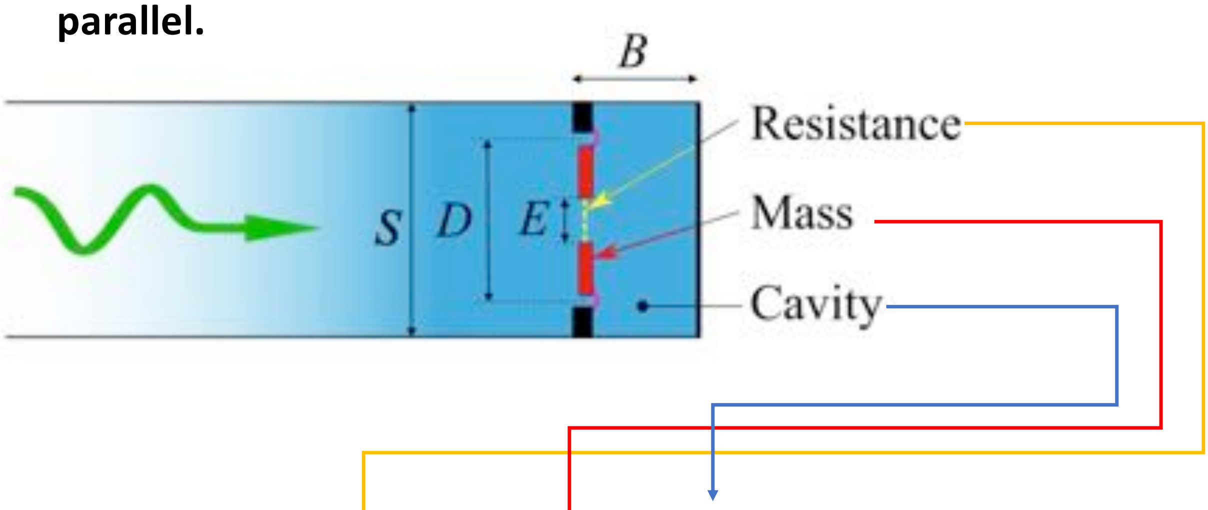
$$H = 16 \text{ mm}$$

$$\lambda = 3.23 \text{ m} = 202\ H$$

Aurégan, Y. (2018). Ultra-thin low frequency perfect sound absorber with high ratio of active area. *Applied Physics Letters*, *113*(20), 201904.

In parallel Helmholtz resonators

The in parallel Helmholtz resonator (IPHR) is composed of a spring due to the cavity, a moving mass and a resistance in parallel.



$$Z = \frac{1}{1/R' + 1/\mathrm{j}\hat{\omega}L'} + \frac{1}{\mathrm{j}\hat{\omega}C}$$

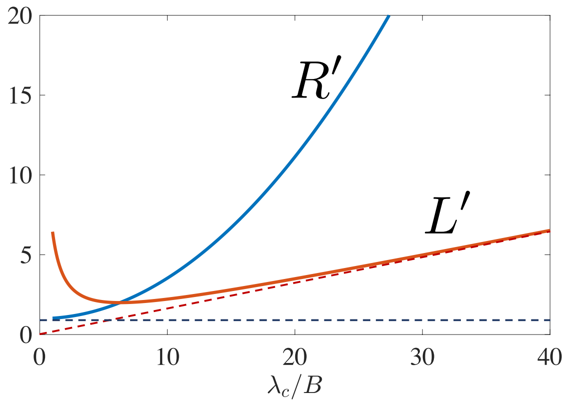
R', L' take into account the POA

In parallel Helmholtz resonators

If the target is to have a perfect absorption $Z = 1$ when $\omega = \omega_c$

The resistance and the inductance can be written

$$R' = \frac{1+C^2}{C^2} \qquad L' = \frac{1+C^2}{C}$$

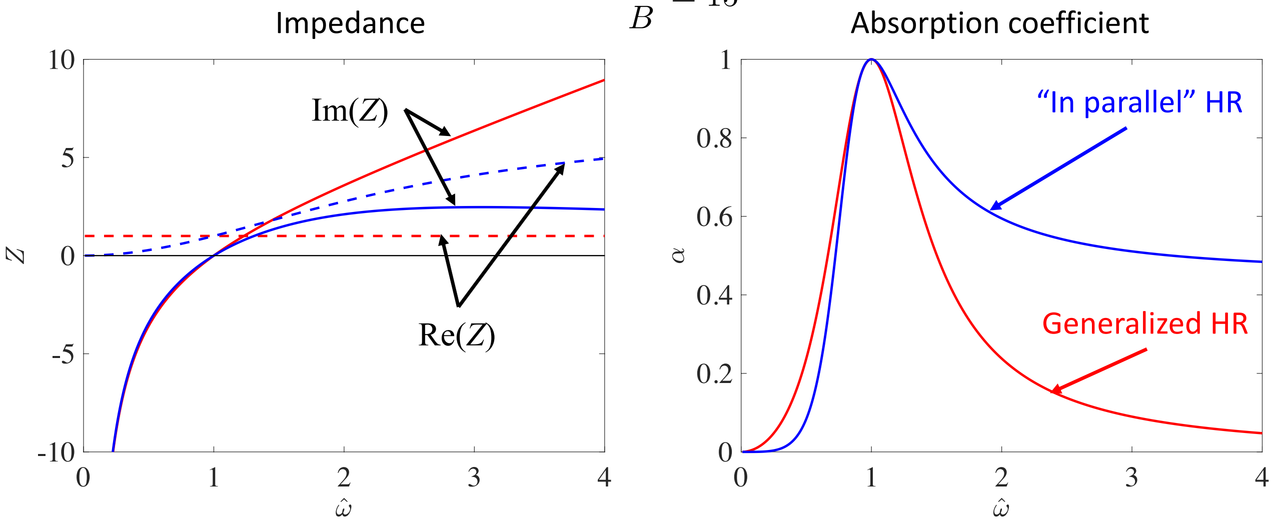


dependent on a single parameter $C = 2\pi\frac{B}{\lambda_c}$

witch is inversely proportional to the subwavelength ratio.

“In parallel” Helmholtz resonators

$$\frac{\lambda_c}{B} = 15$$

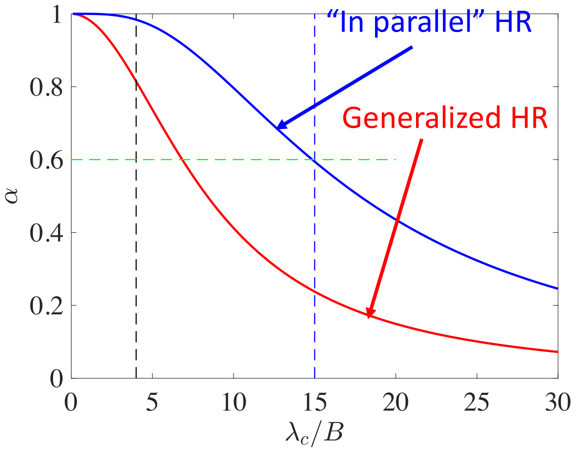


- The “in parallel” HR can also have a perfect absorption at any frequency and at any cavity thickness.
- When the subwavelength ratio is not to high, the absorption is substantially higher at mid-frequencies with a IPHR than with a GHR.

“In parallel” Helmholtz resonators

$$B = \frac{\lambda_c}{4}$$

Absorption
Coefficient
for $\hat{\omega} = 2$



The “in parallel” HR increases the frequency band where the liner is efficient compared to the generalized HR.

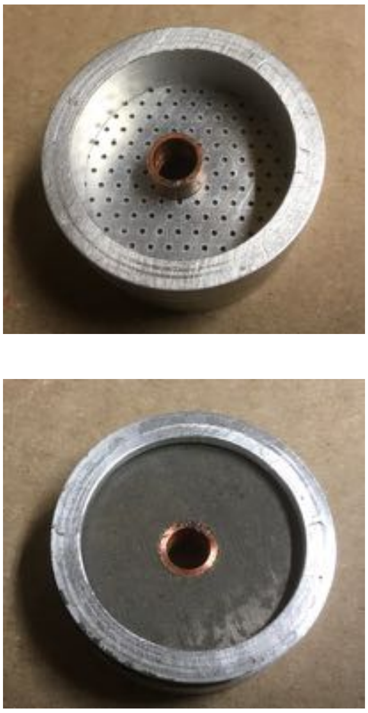
Choice: $\frac{\lambda_c}{B} = 15 \longrightarrow$ $R' = 6.70$ $L' = 2.81$

Choice: $f_c = 650 \text{ Hz}$

$\downarrow$

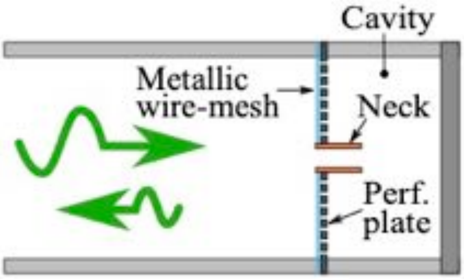
$B = 35 \text{ mm}$

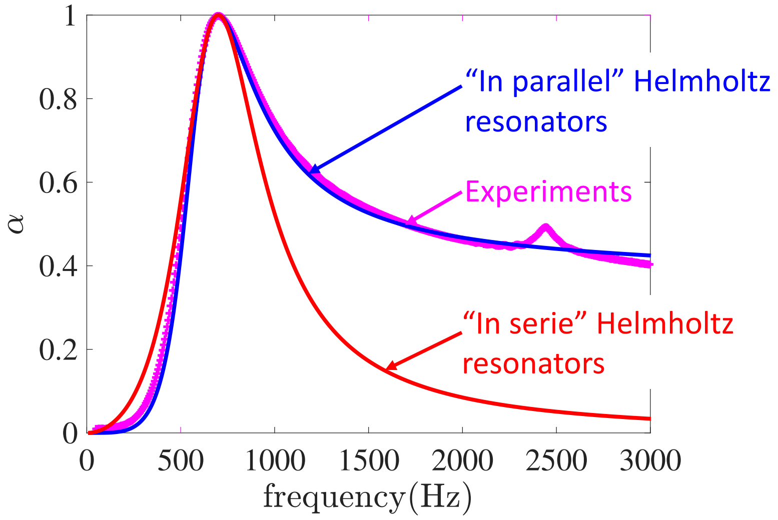
“In parallel” Helmholtz resonators



$$B = 30\ \text{mm}$$

$$\frac{\lambda_c}{B} = 16.4$$

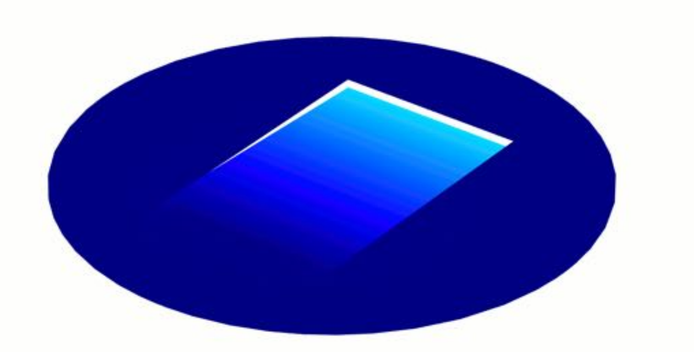


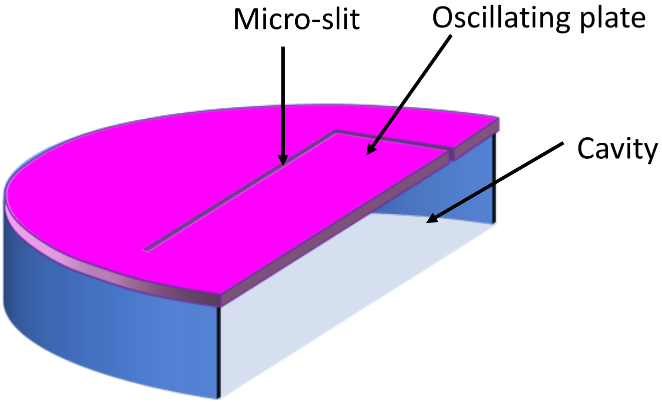


Aurégan, Y., & Farooqui, M. (2019). In-parallel resonators to increase the absorption of subwavelength acoustic absorbers in the mid-frequency range. *Scientific reports*, *9*(1), 11140.

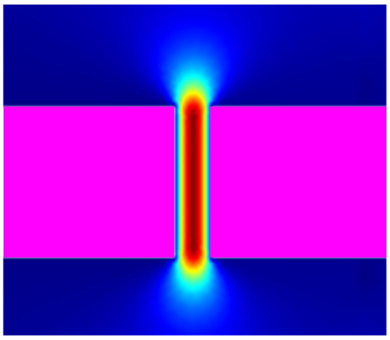
“In parallel” Helmholtz resonators

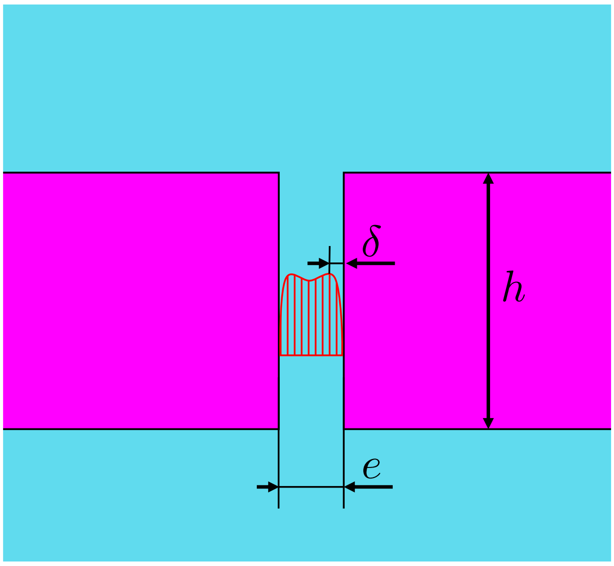
- A bending beam is more suitable with flow
- Avoid adding stiffness to the system





Micro-slits

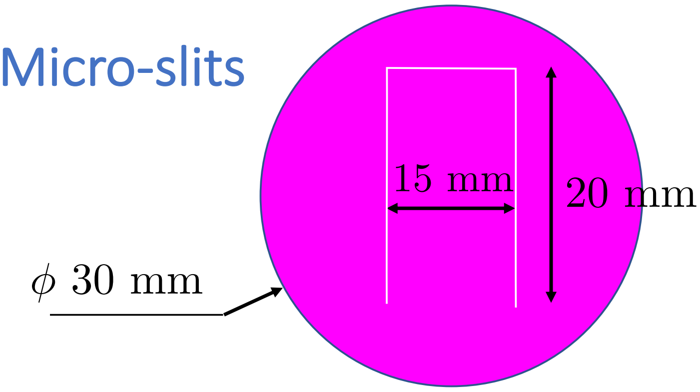


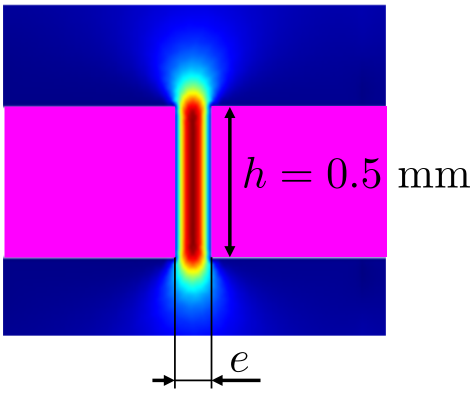


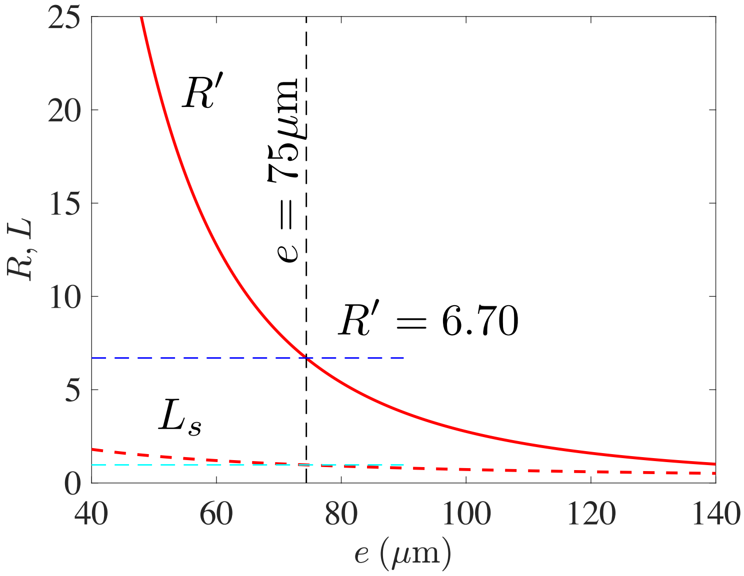
$$\mathrm{j}\omega\rho_0 h\bar{v} = \left(1 - \frac{\tanh(\gamma e/2)}{\gamma e/2}\right)\Delta p \qquad \gamma = \frac{1+\mathrm{j}}{\delta} \qquad \delta = \sqrt{\frac{2\mu}{\omega\rho_0}}$$

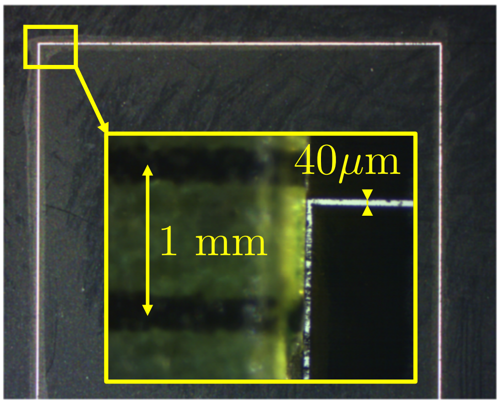
$$\boxed{Z_s = \mathrm{j}\frac{S}{S_s}\frac{\omega h}{c_0}\left(1 - \frac{\tanh(\gamma e/2)}{\gamma e/2}\right)^{-1}}$$

Micro-slits



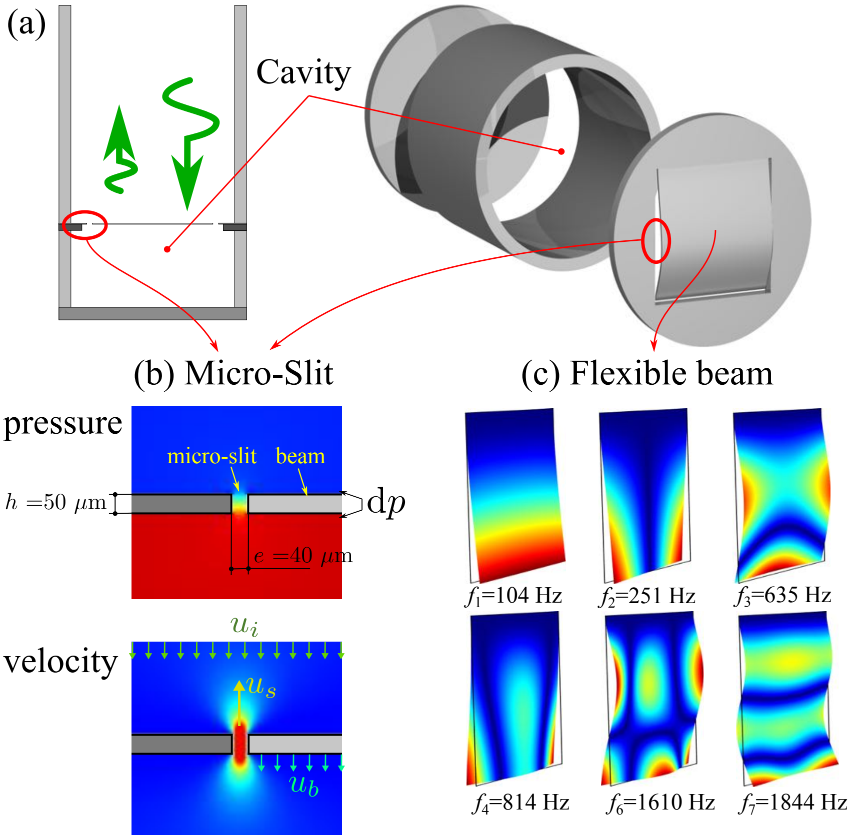




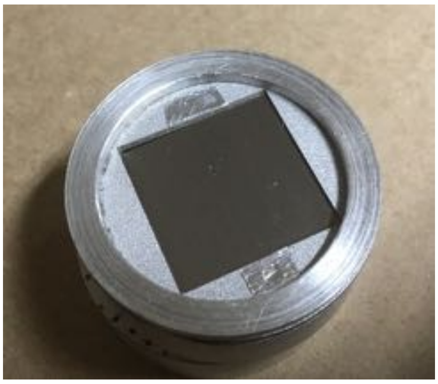


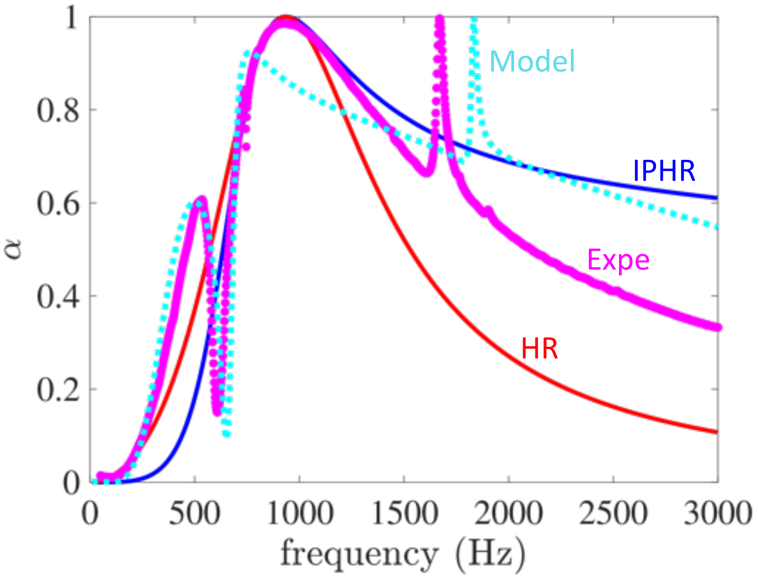
$\mathrm{POA}_{\mathrm{slit}} = 0.9$ %

“In parallel” Helmholtz resonators with micro-slits



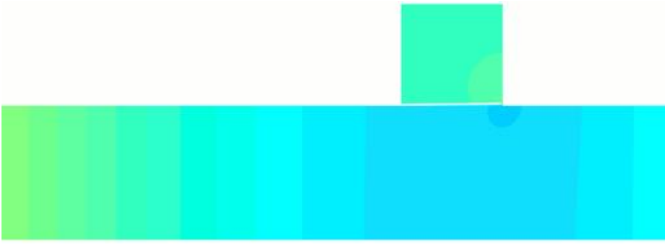
“In parallel” Helmholtz resonators with micro-slits





Perspectives

- Use the cantilever beam with micro-slit material in a duct wall with flow



- Transformation in a semi-active system