Smart Mitigation of flow-induced Acoustic Radiation and Transmission for reduced Aircraft, surface traNSport, Workplaces and wind enERgy noise

Effect of flow on the acoustic behavior of a vibrating cantilever beam liner

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Introduction

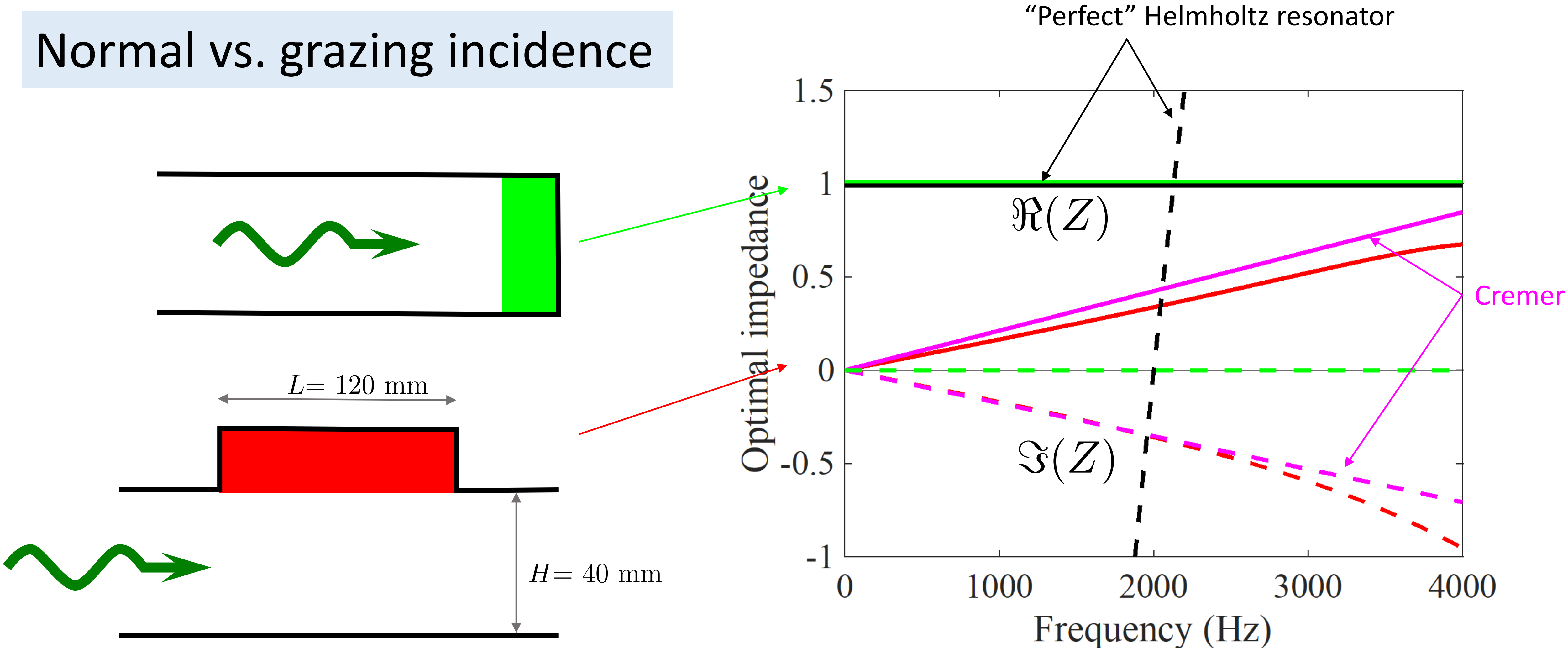
Everything that was said in the previous talk is interesting

but …

1) it corresponds to a normal incidence and not a grazing incidence
2) it does not take into account the effect of the flow

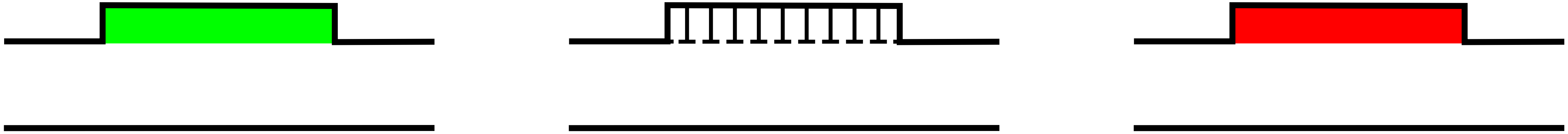
Introduction

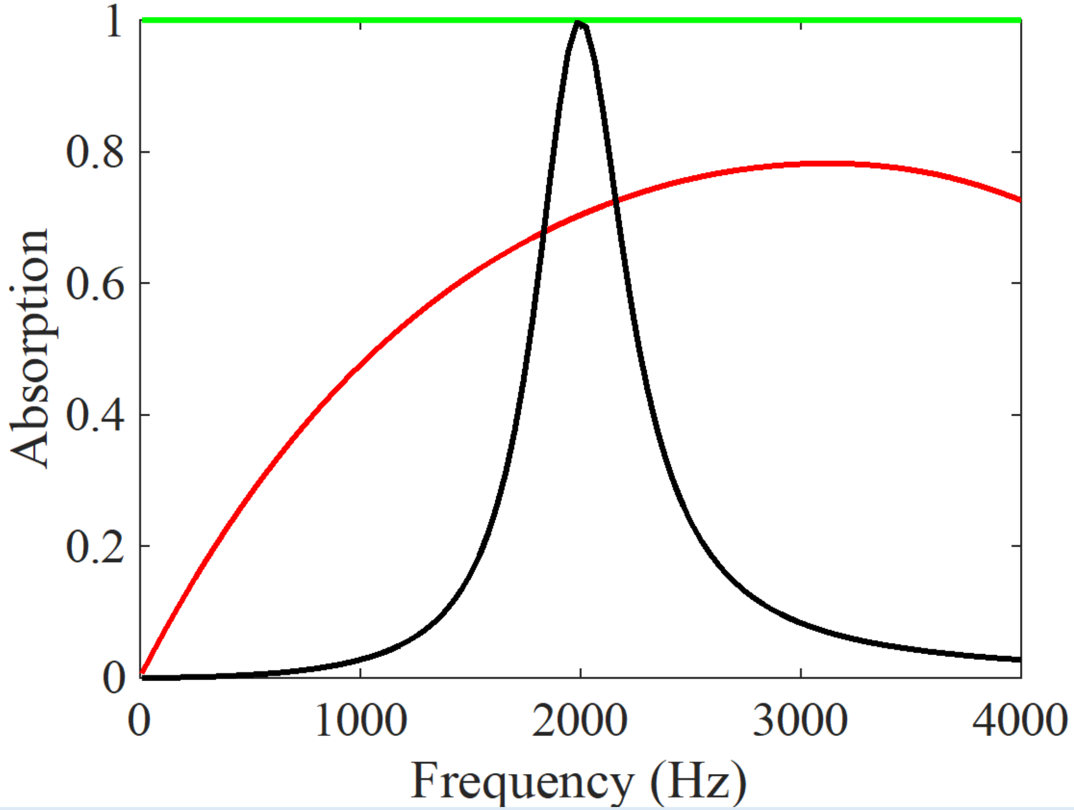
Normal vs. grazing incidence

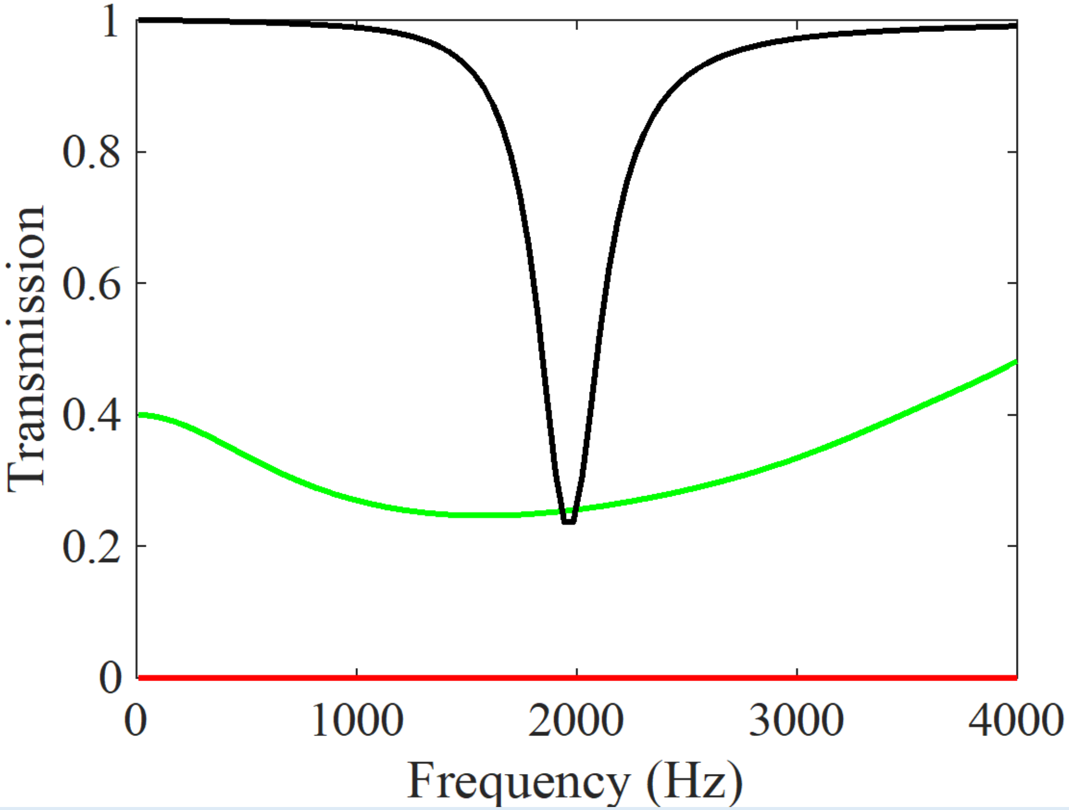


Introduction

$Z = 1$ $\qquad Z = 1 + i(\hat{f} - 1/\hat{f})/C$ $\qquad Z_{\text{opt}}$

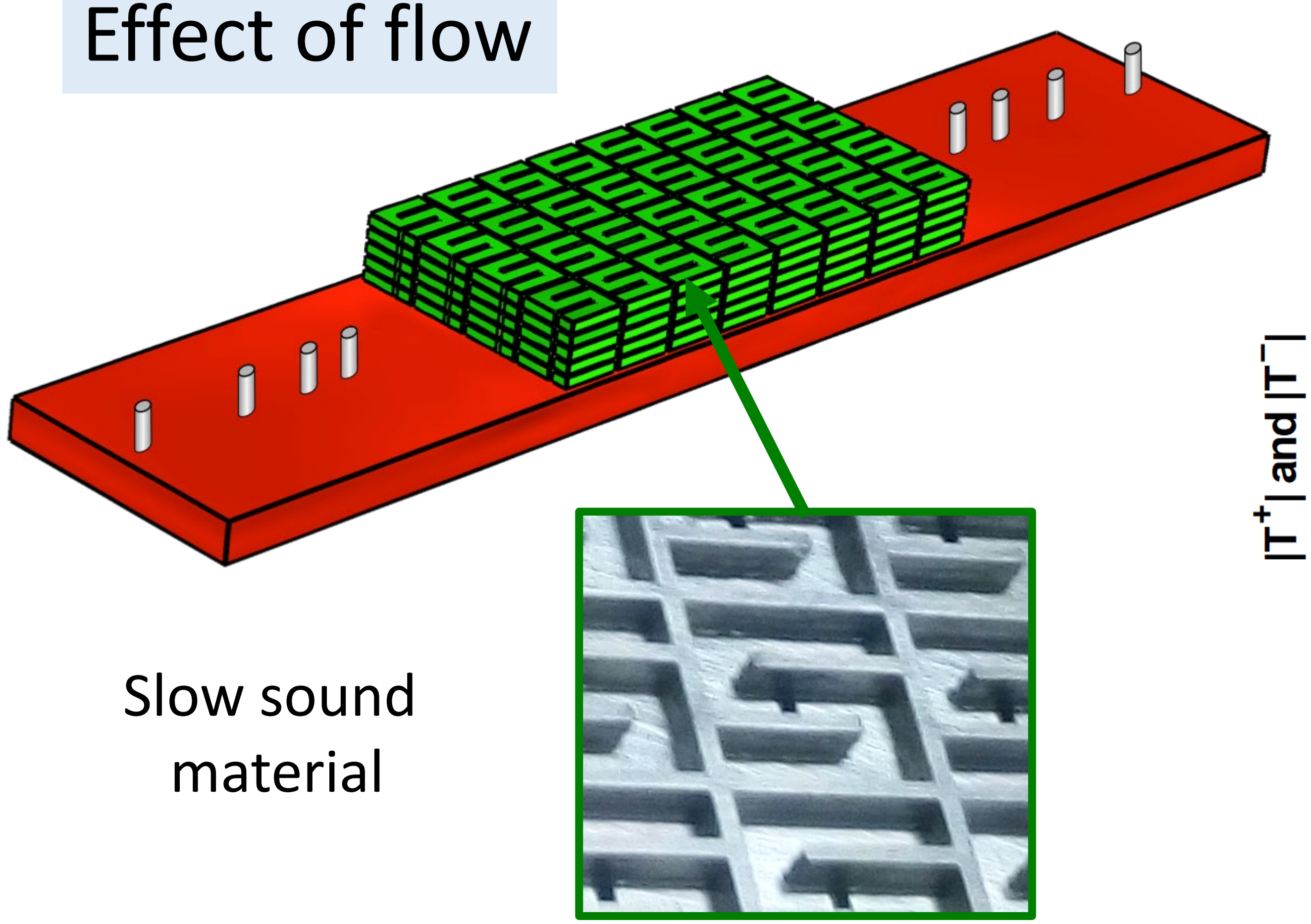




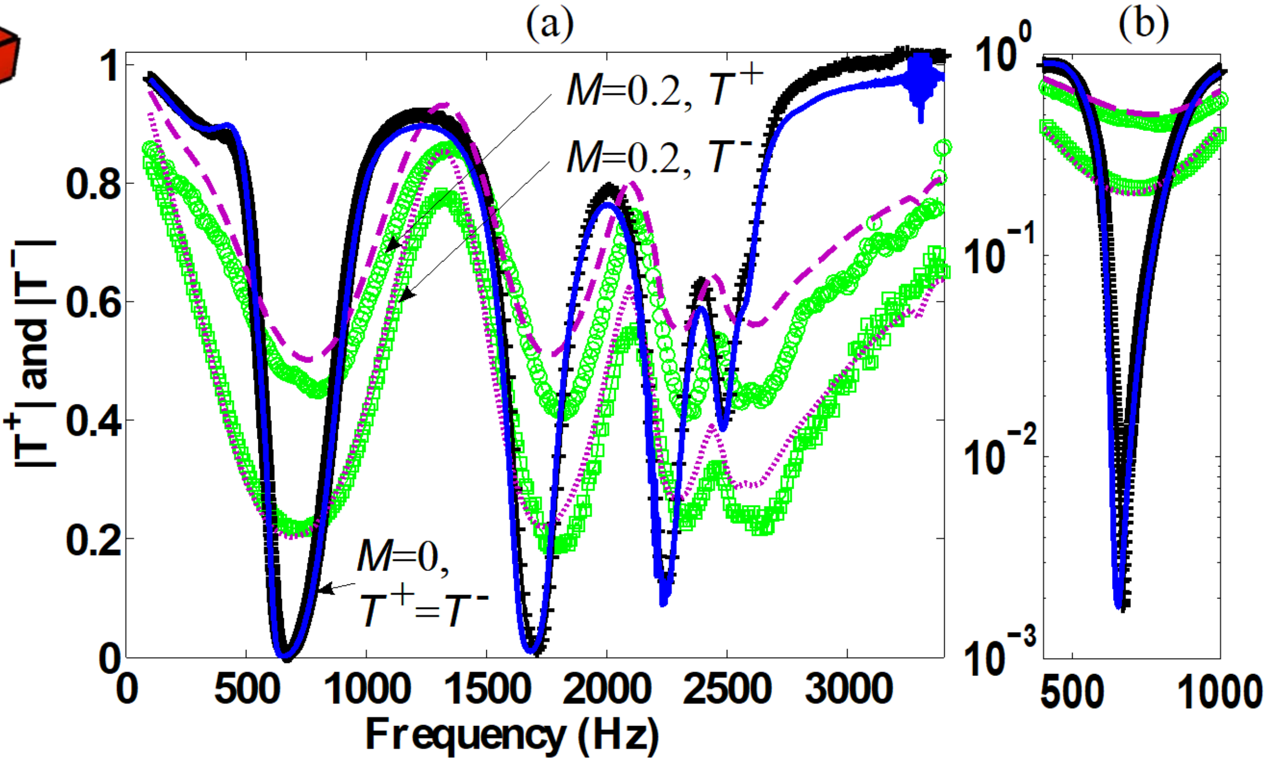


Introduction

Effect of flow



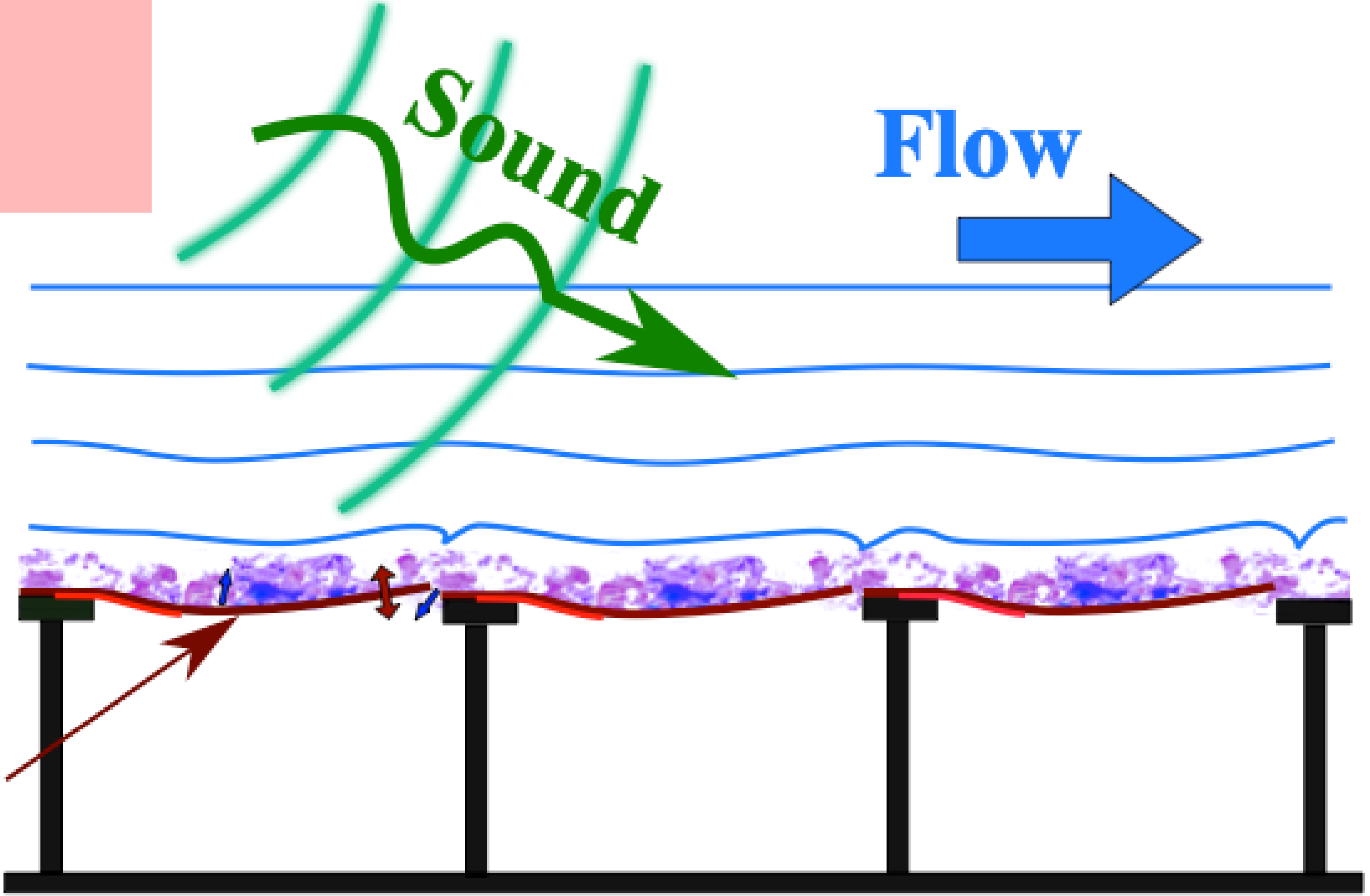
Slow sound material



Aurégan, Y., Farooqui, M., & Groby, J. P.
Low frequency sound attenuation in a flow duct using a thin slow sound material.
JASA, *139*(5), EL149 **(2016).**

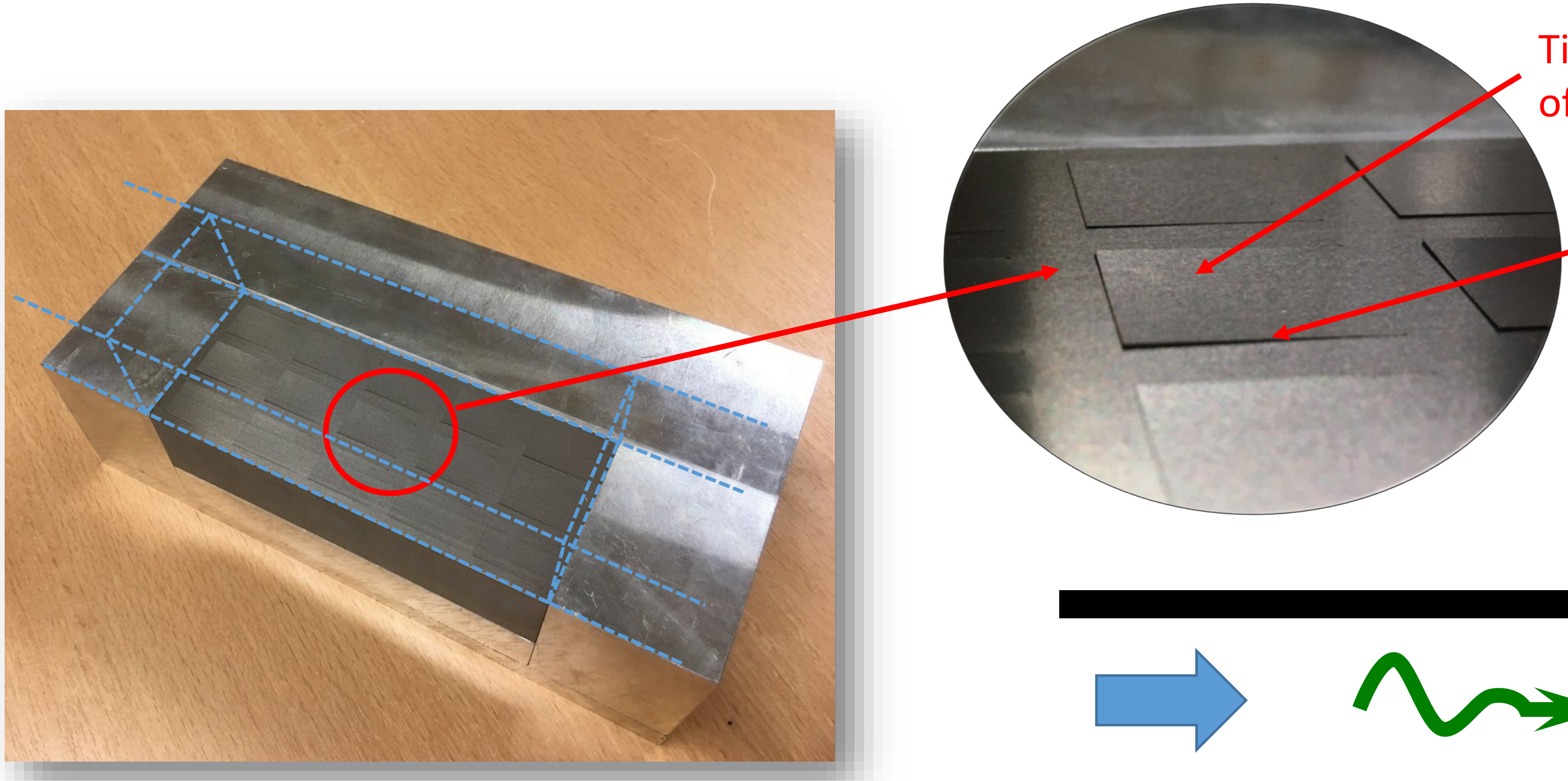
Introduction

How respond a cantilever beam material in a duct wall with a grazing flow ?



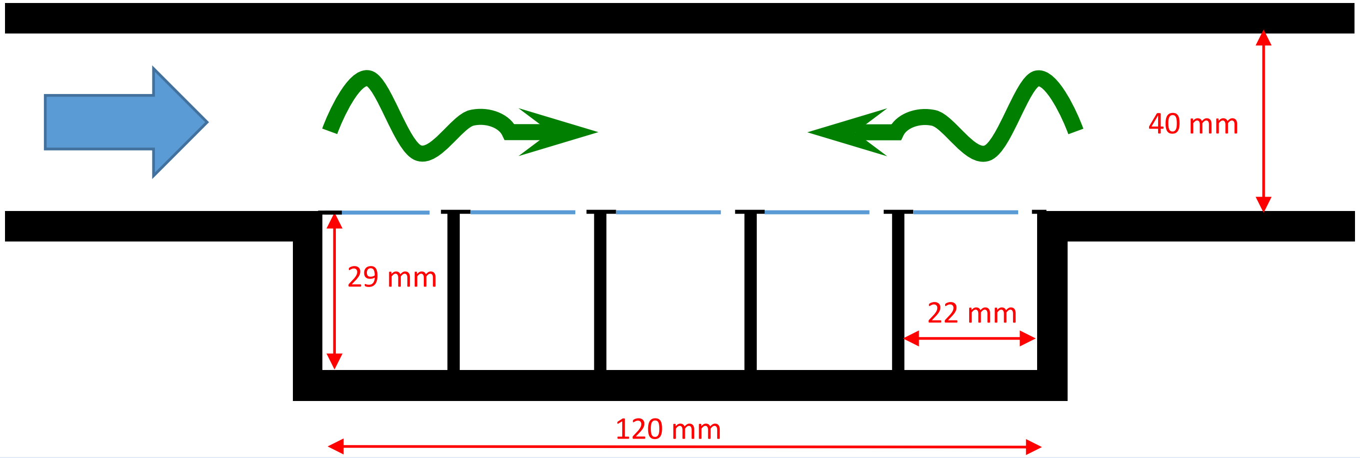
Cantilever Beam

Micro-slit systems



Titanium plate
of thickness 0.1 mm

Micro-slit by laser-cutting
opening 30 µm



⇒ 2D model

Multi-Modal Method

First Step: Numerical investigation of 1 beam + cavity

Propagation without flow

$$k^2 P - \omega^2 P - \mathrm{d}_\mathrm{y}^2 P = 0$$

Beam

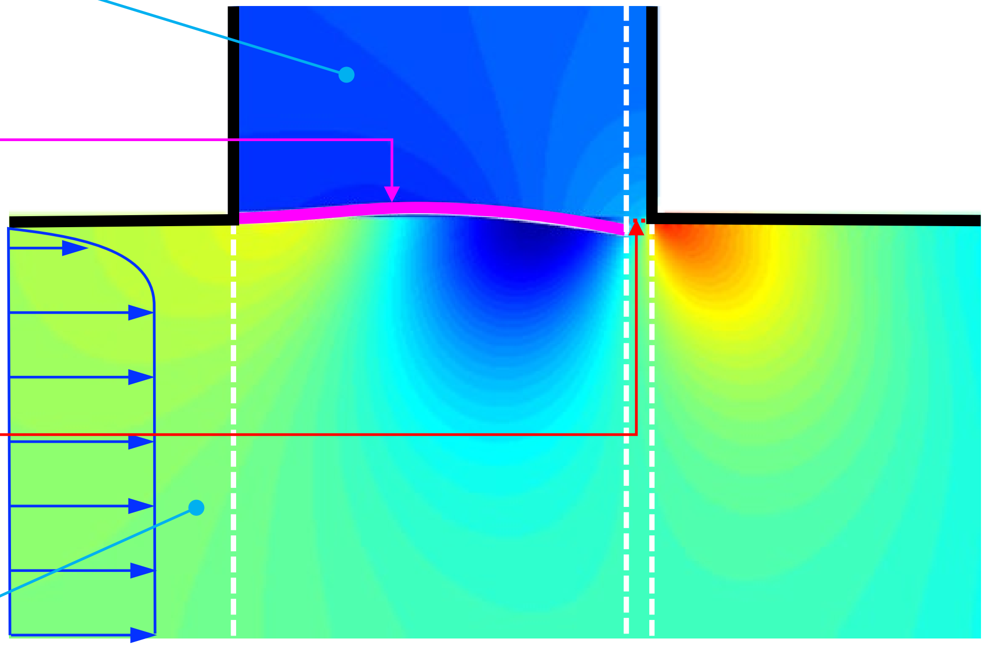
$$\begin{cases} k^4 \delta - k_M^2 \delta = -C[p]_{y=1} \\ \mathrm{i}\omega\delta = V(y=1) \end{cases}$$

Resistance

$$[p]_{y=1} = R\,V$$

Propagation in a shear flow

$$\begin{cases} \mathrm{i}(\omega - M\,k)V = -\mathrm{d}_\mathrm{y} P \\ \left(1 - M^2\right) k^2 P + 2\omega M k P - \omega^2 P - \mathrm{d}_\mathrm{y}^2 P = -2\mathrm{i}\,\mathrm{d}_\mathrm{y} M\,kV \end{cases}$$



Pressure

$$p = P(y)\mathrm{e}^{\mathrm{i}(\omega t - kx)}$$

Vertical velocity

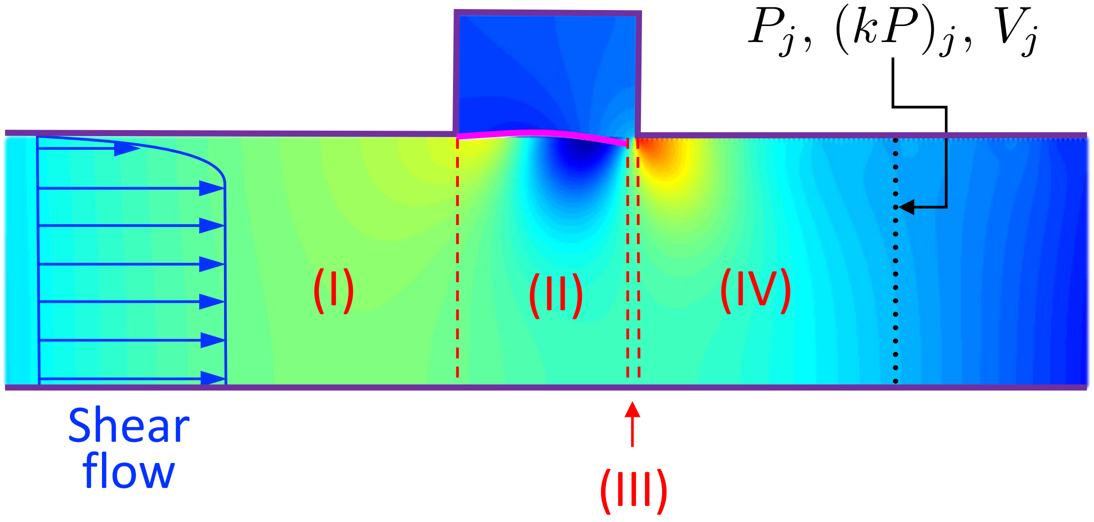
$$v = V(y)\mathrm{e}^{\mathrm{i}(\omega t - kx)}$$

Beam displacement

$$d = \delta\,\mathrm{e}^{\mathrm{i}(\omega t - kx)}$$

Multi-Modal Method

First Step: Numerical investigation of 1 beam + cavity

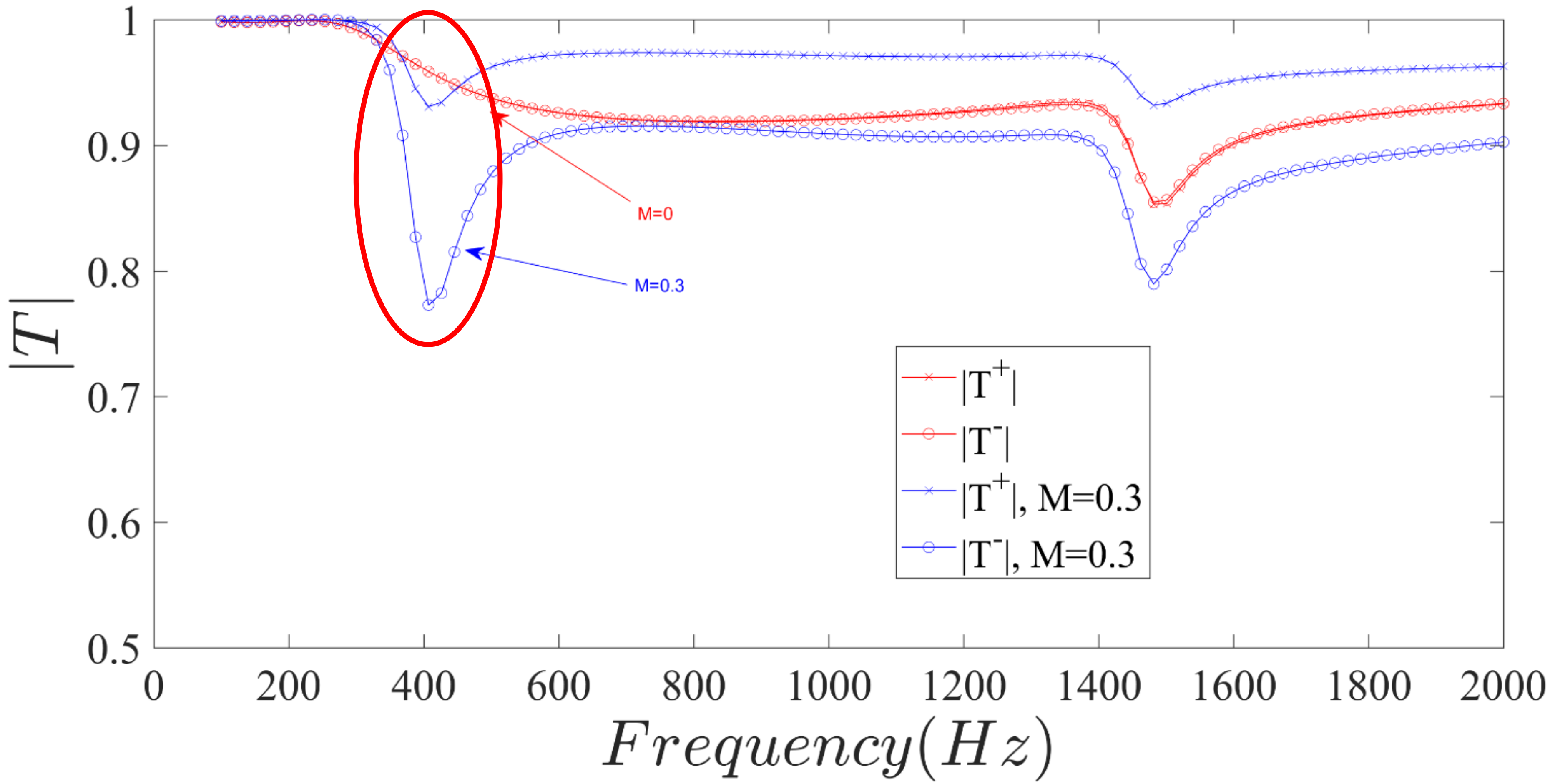


Computed by MultiModal method:

1) Discretized by Finite difference method in the transverse direction.
2) The wavenumbers and the mode shapes are computed in each zone (I, II, III and IV).
3) The unknown amplitudes of modes are computed as a function of the amplitude of the incident modes by matching the fields between the different zones.

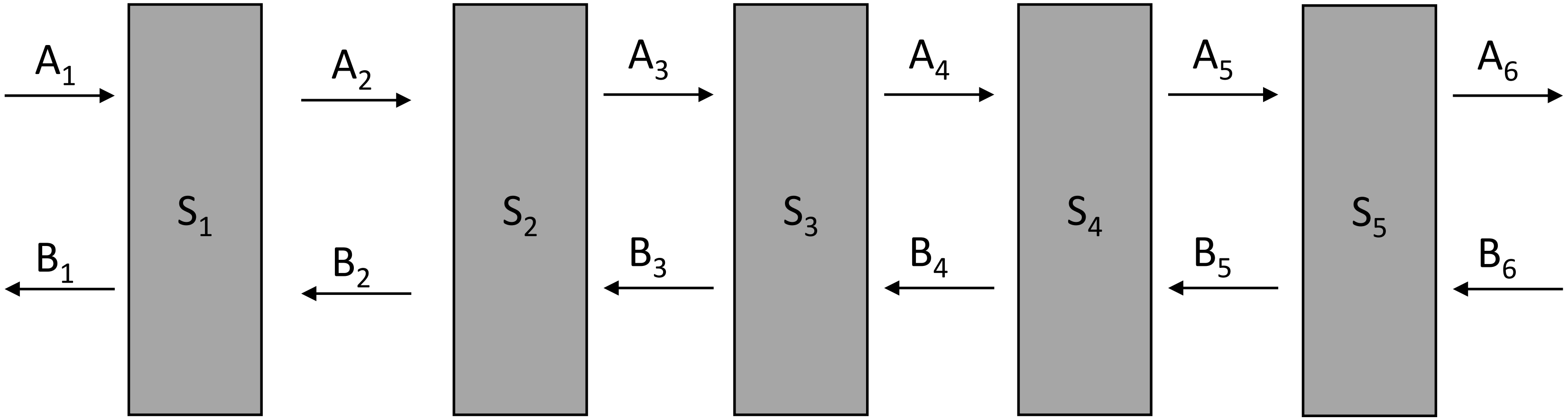
⇒ Scattering matrix and fields

Multi-Modal Method Modelling



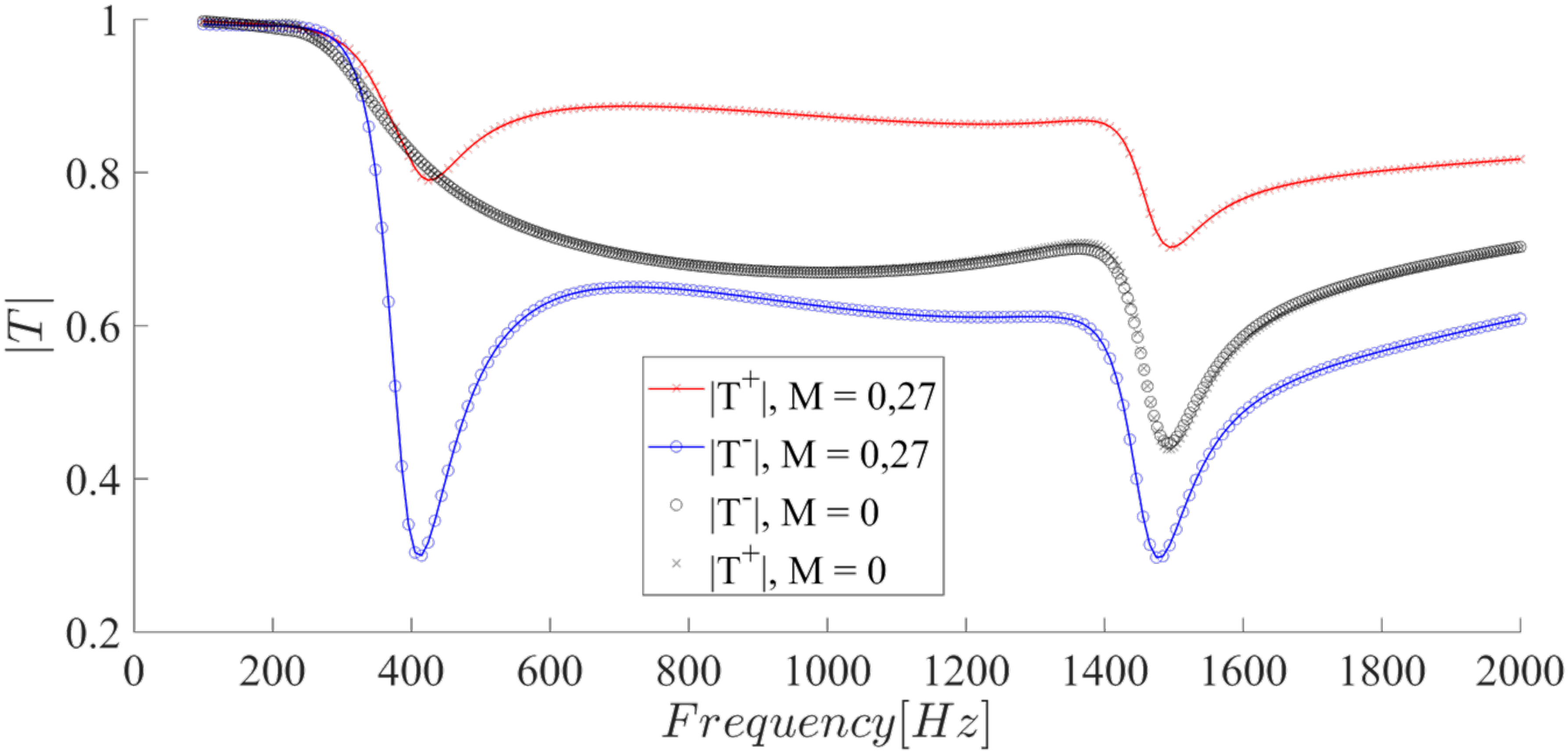
Multi-Modal Method Modelling

Then, to go from one beam to a 5 by 3 beams configurations, we can compose the final scattering matrix, due to the inner linearity of the system



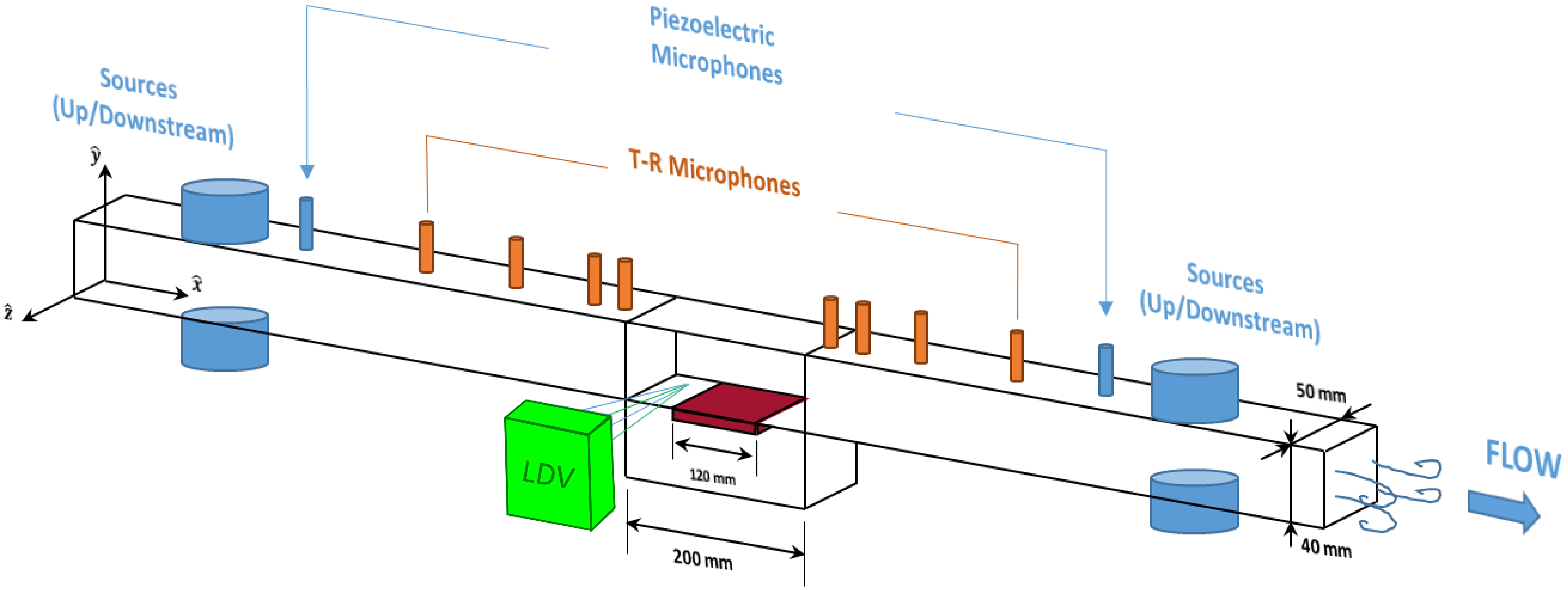
$$\begin{bmatrix} A_6 \\ B_1 \end{bmatrix} = [S_{tot}] \begin{bmatrix} A_1 \\ B_6 \end{bmatrix} = [S_1] \otimes \cdots \otimes [S_5] \begin{bmatrix} A_1 \\ B_6 \end{bmatrix}$$

Multi-Modal Method Modelling

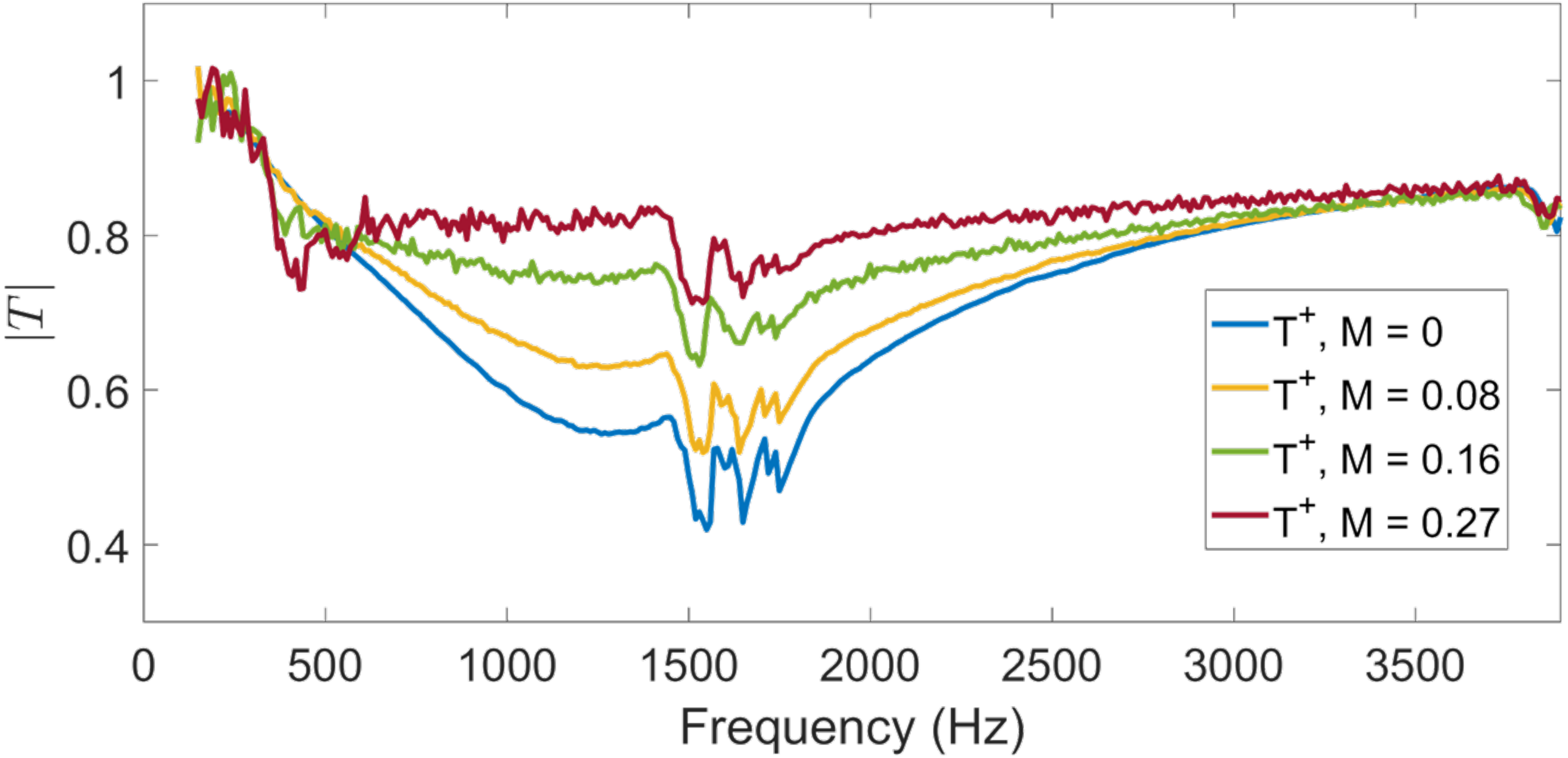


Global Transmission curves are therefre obtained by the composition of 5 sequences of beam and resistive zones, preceded and followed by a rigid tube

Acoustic measurements Setup

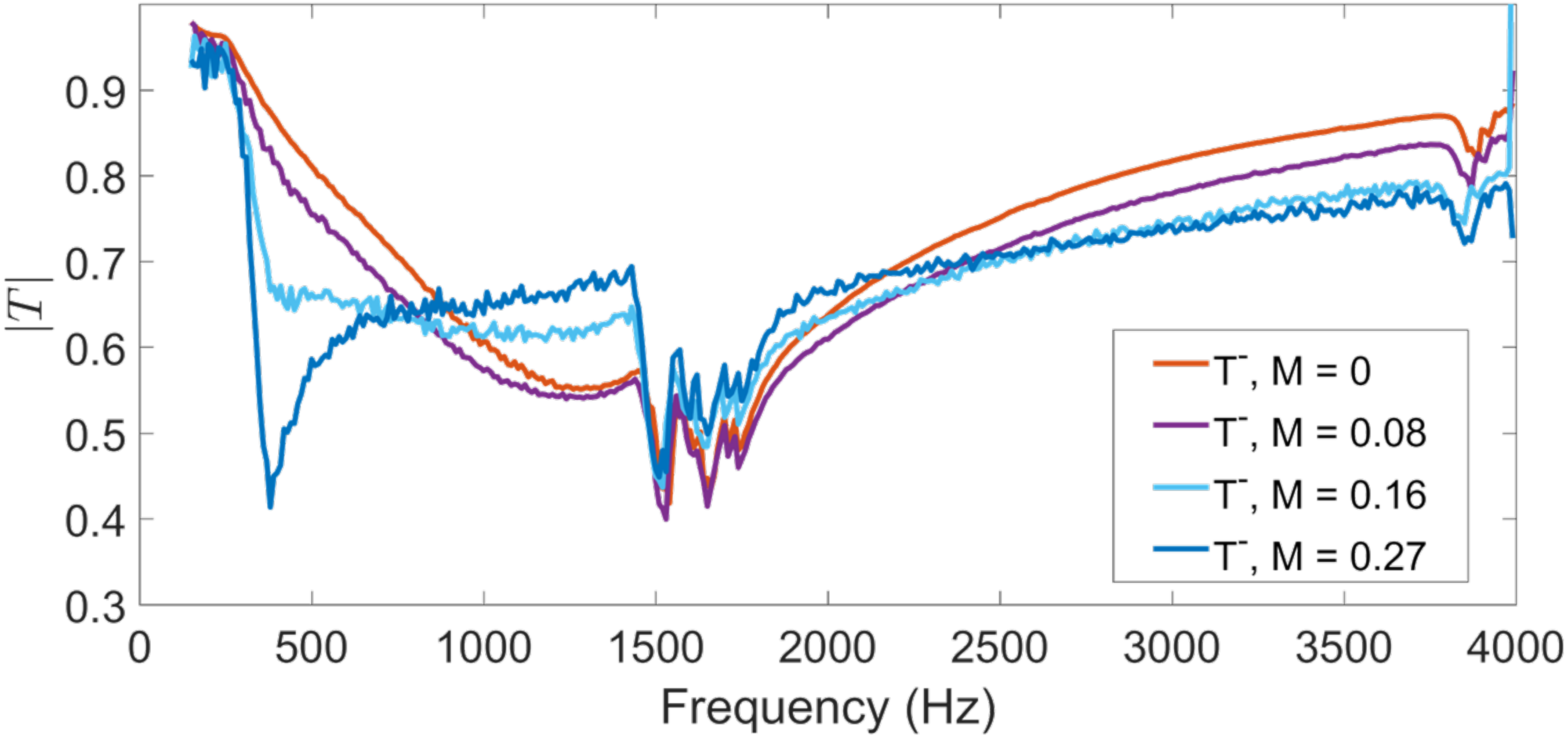


Acoustic Measurements



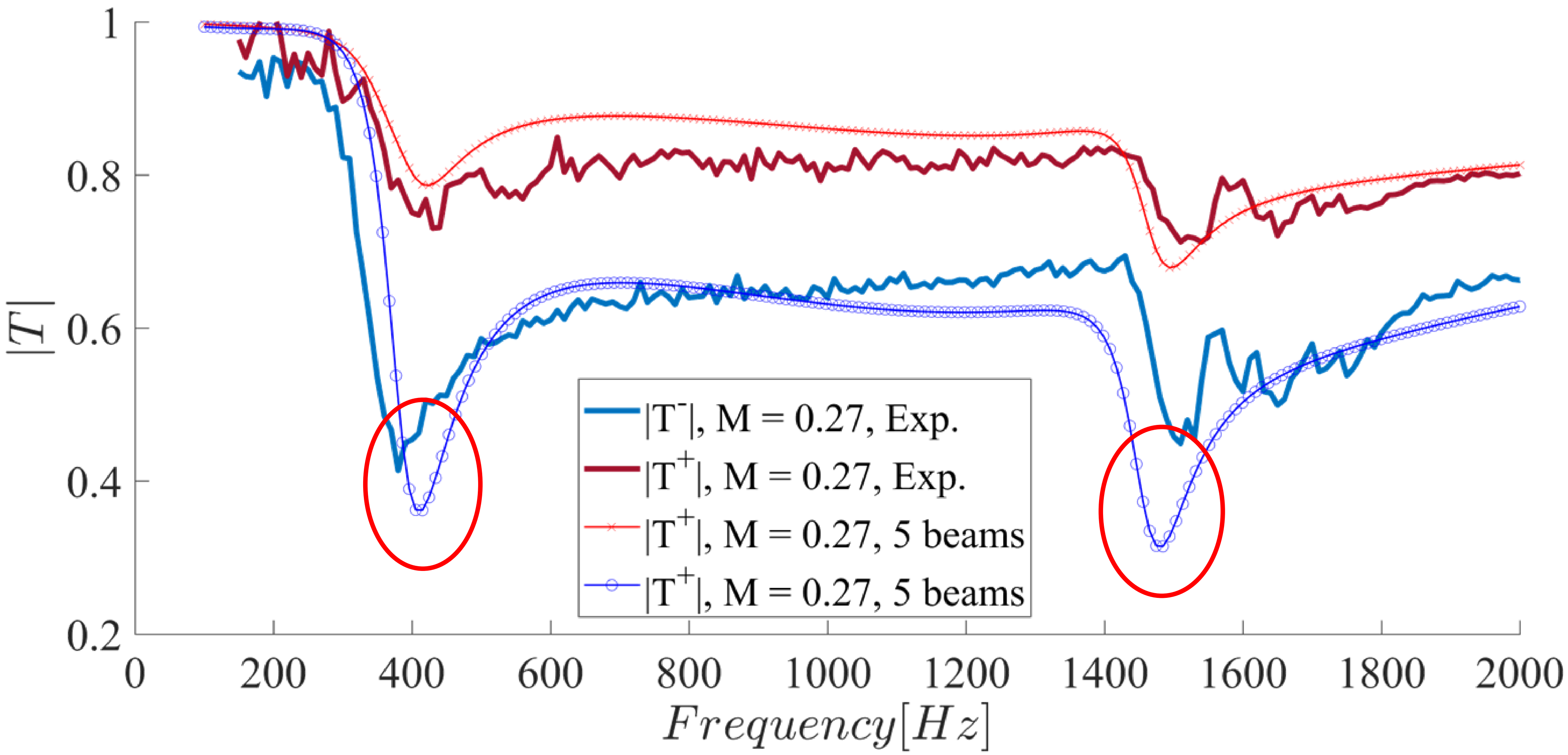
Source in Upstream position

Acoustic Measurements



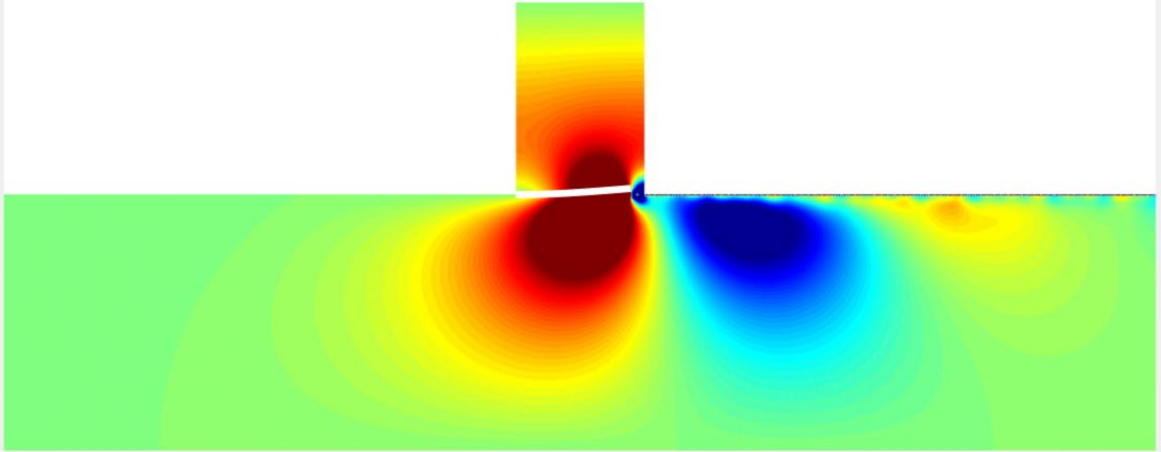
Source in Downstream position

Acoustic Measurements vs MM Method

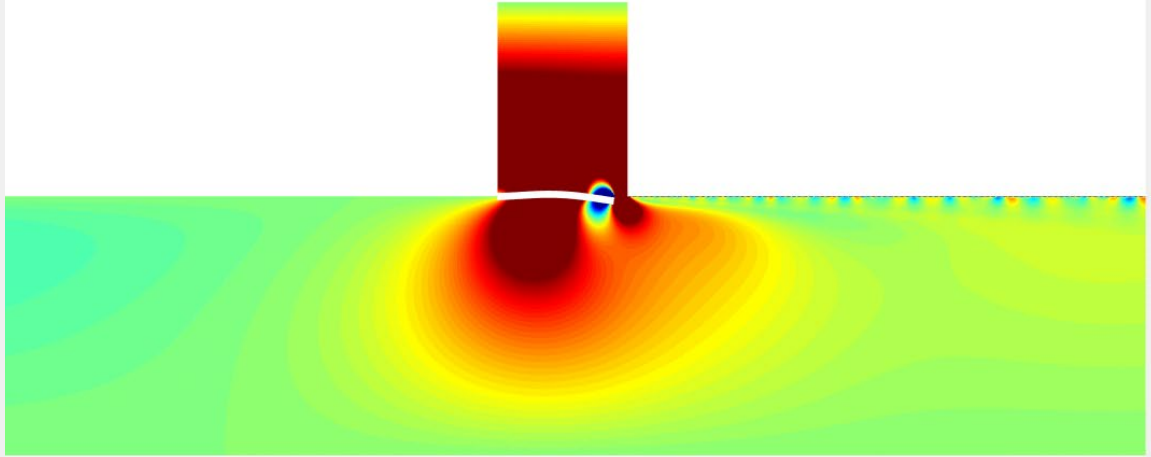


MM Method

Velocity Fields



@ 405 Hz



@ 1480 Hz

Conclusions

Analysis on vibrating beams shows that the behaviour of these elements changes drastically in a grazing configuration

The modelling with a Multi-Modal Method seems to correctly describe the aeroacoustic behaviour of the cantilever beams both from a qualitatively and quantitatively point of view

Both Resonance frequencies and Transmission values are well predicted

Future works will focus on an optical investigation by the means of the Laser Doppler Velocimetry (LDV) technique