ON THE CONDITIONS FOR PERFECT ABSORPTION OF SOUND BY RIGIDLY-BACKED LAYERS OF POROUS MATERIALS

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ABSTRACT

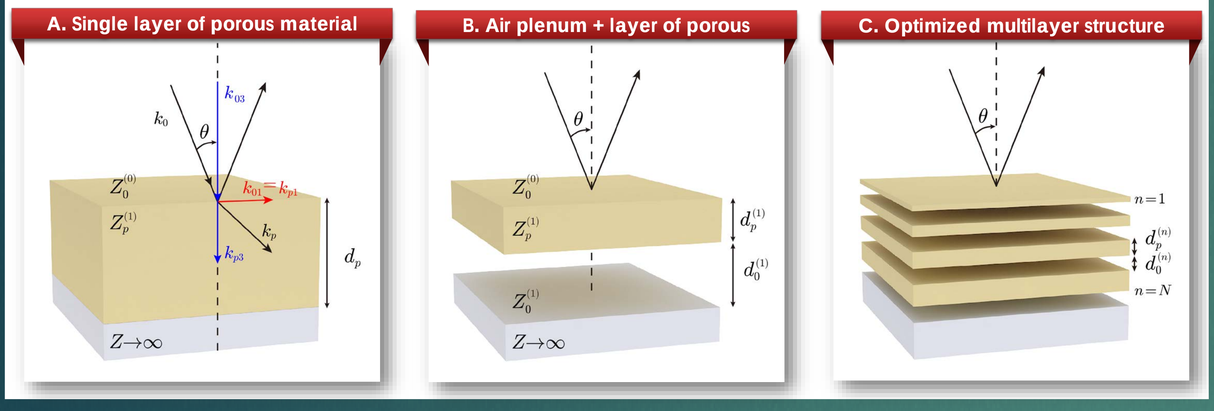
We present the conditions to observe perfect sound absorption by rigidly-backed layers of rigid-frame porous materials. We theoretically analyze (1) a single layer of porous material, (2) a layer of porous material with an air gap (air plenum) and (3) an optimized multilayer structure.

MODEL

Transfer Matrix Method: each layer is considered as a fluid with effective parameters.

$$\begin{bmatrix} p \\ v_3 \end{bmatrix}_{x_3=0} = \mathbf{T} \begin{bmatrix} p \\ v_3 \end{bmatrix}_{x_3=L}. \quad \mathbf{T} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} = \prod_{n=1}^{N} \mathbf{T}_p^{(n)} \mathbf{T}_0^{(n)},$$

The reflection properties are calculated from the elements of the full transfer matrix.

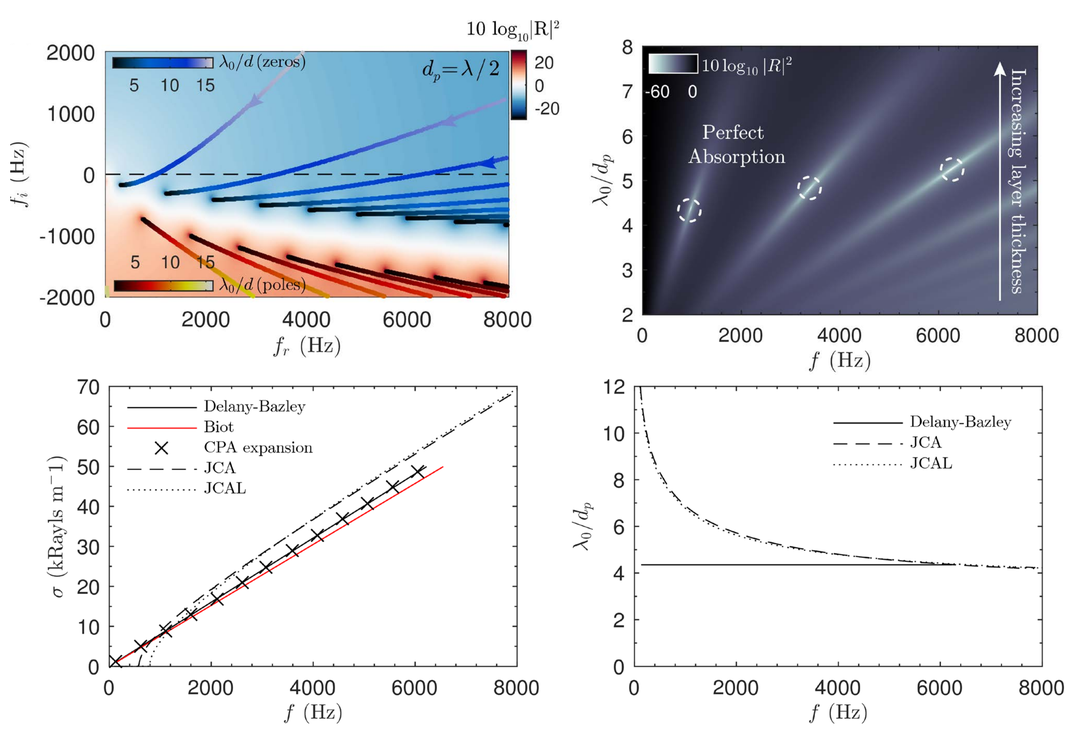


A. SINGLE LAYER OF POROUS MATERIAL

NORMAL INCIDENCE

Perfect absorption is observed when the material is thickness reaches some length:

- **Delany and Blazley model** → $L=\lambda_0/4.3$, being λ_0 defined by the Biot's frequency.
- **Jhonson-Champoux-Allard-(Lafarge)** → $L>\lambda_0/4$, but complex behavior.



OBLIQUE INCIDENCE

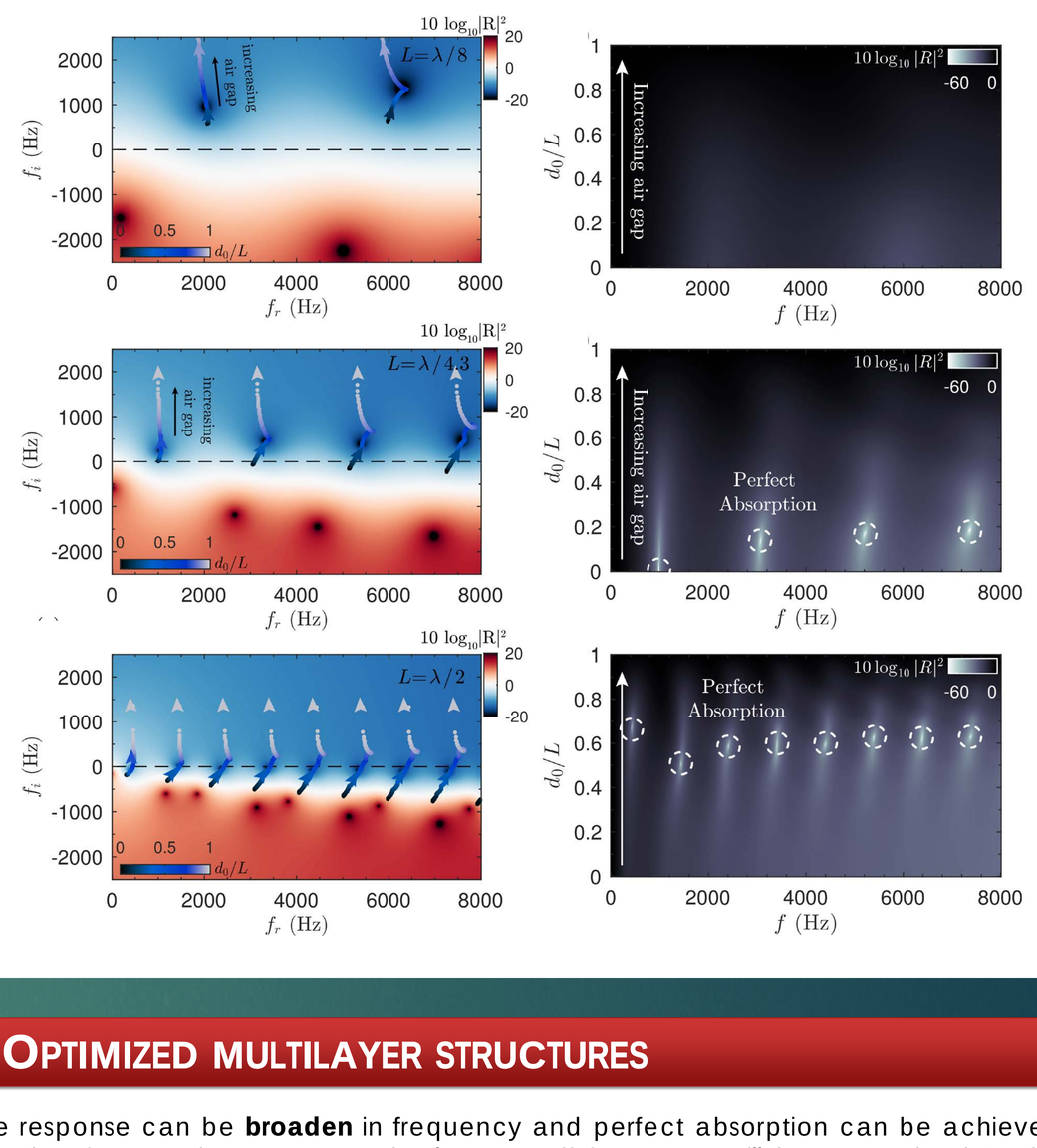
Perfect absorption is also observed, but for other angles and frequencies.

- For materials **thinner** than $L=\lambda_0/4.3$: PA is can be achieved eventually
- For materials **thicker** than $L=\lambda_0/4.3$: PA it is NOT posible : (evaluate the complex plane)

B. AIR PLENUM

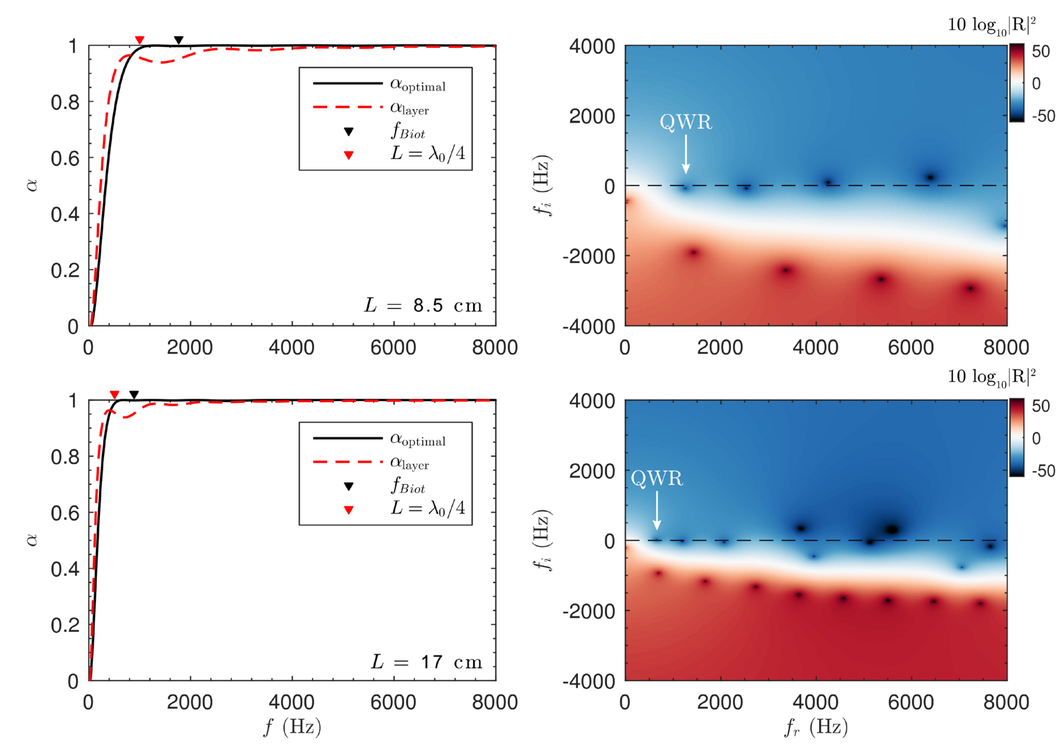
Perfect absorption can only be achieved for layers of porous material **thicker** than the optimal (Biot's) → $L=\lambda_0/4.3$

- **Air plenum**> Produces the equivalent effect of reducing the effective flow resistivity of the material.



C. OPTIMIZED MULTILAYER STRUCTURES

The response can be **broaden** in frequency and perfect absorption can be achieved at other frequencies. However, the low cut-off frequency still be constrained to the QWR of the layer and the **Biot's frequency.**



CONCLUSIONS

(1) Single layer: to obtain perfect sound absorption at normal incidence and at the first quarter- wavelength resonance of a single rigidly-backed porous layer, the thickness of the material is strongly related to its flow resistivity. In particular, perfect sound absorption is observed when the quarter-wavelength resonance is around the characteristic Biot's frequency of the porous media, and the optimal thickness of the layer is **4.3 smaller** than the perfectly absorbed wavelength. We analyze the behaviour of the structure when the angle of incidence is tilted, showing that perfect sound absorption is also produced for other incident angles and frequencies.

(2) Air plenum: the gap allows to produce perfect sound absorption for structures thicker than the optimal one and for media with large intrinsic attenuation, i.e., for materials with high flow resistivity.

(3) Optimized multilayer structure: present broadband and perfect sound absorption. The existence of the perfect absorption is related to the impedance matching, which is produced when the intrinsic losses of the system exactly compensate the leakage of the structure due to resonance. Thus, the total thickness of any multilayer porous material structure is constrained to its quarter-wavelength resonance and material properties, because of the lack of deep-subwavelength resonance in the system.