Exemples de stimulateurs tactiles basés sur le confinement d'ondes

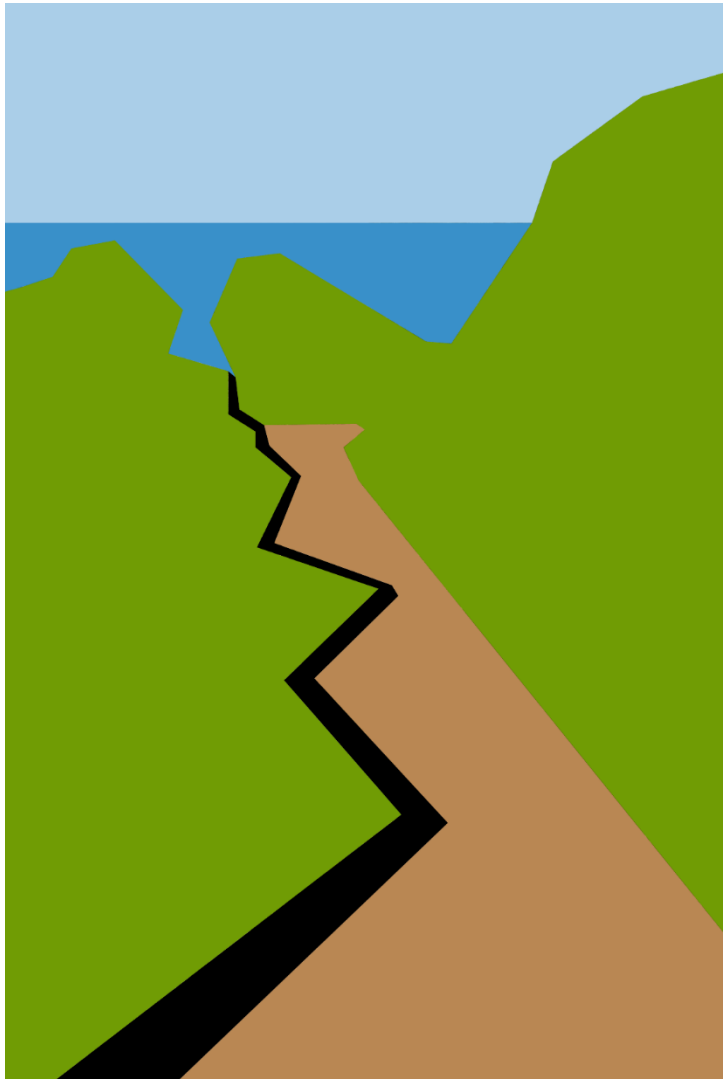
Ayoub Ben Dhiab

6 avril 2021

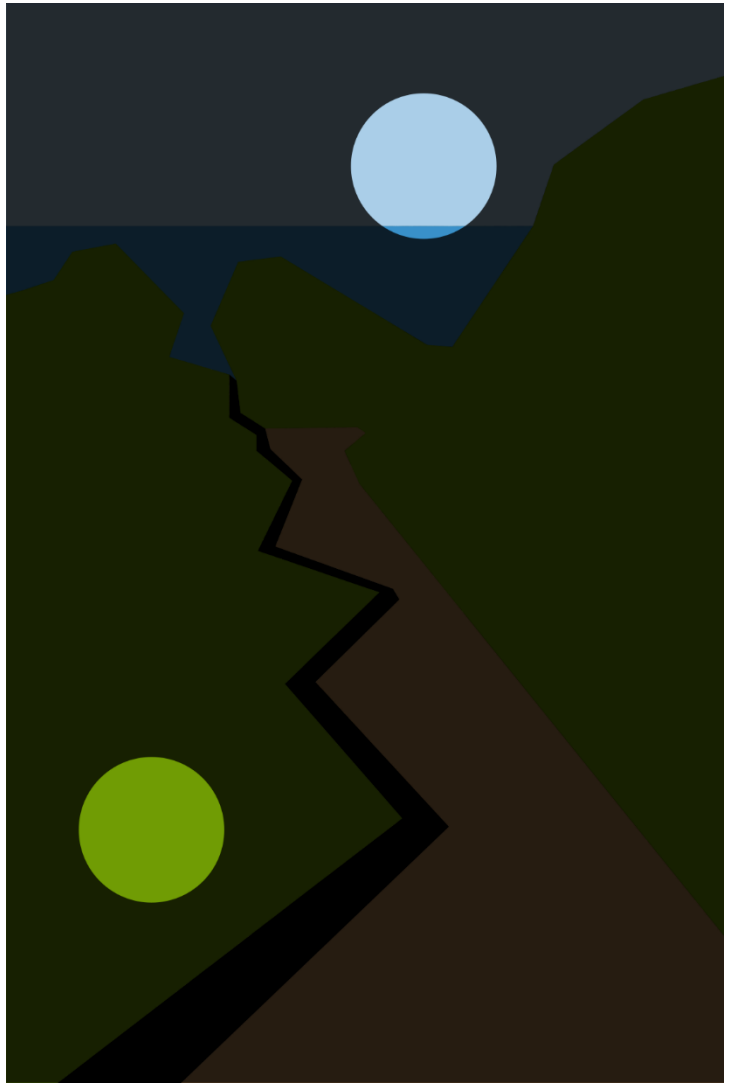
DE LA RECHERCHE À L'INDUSTRIE

Etat de l’art – Problème

Image Vibratoire

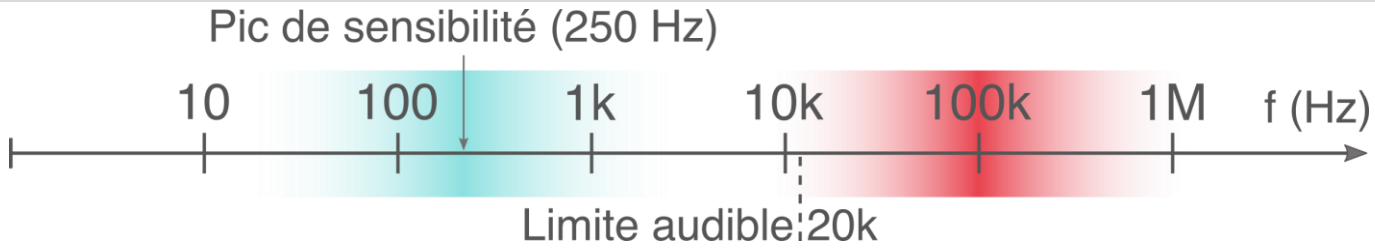


Vue Tactile

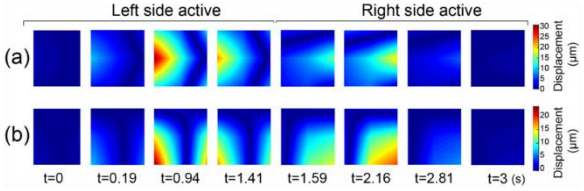


Répartition énergie

Approches par Contrôle



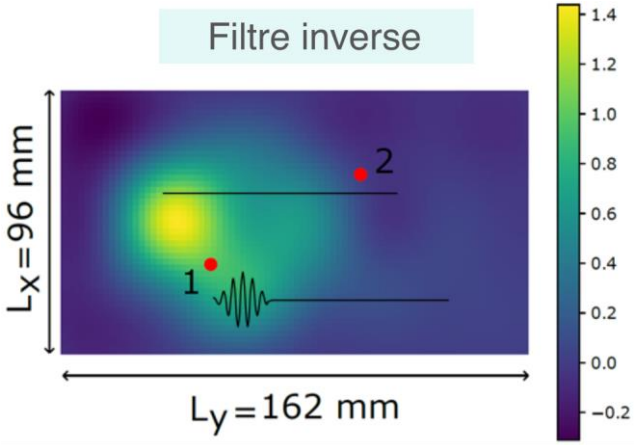
Optimisation fréquence/amplitude



Evolution of vibration maps for vibrotactile flow under the hand

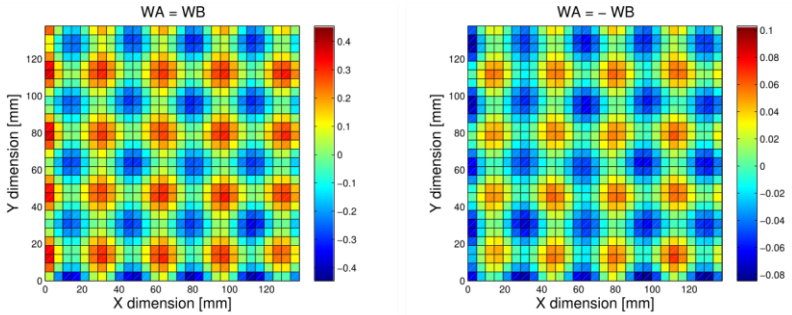
[Emgin & al. 2019]

Filtre inverse



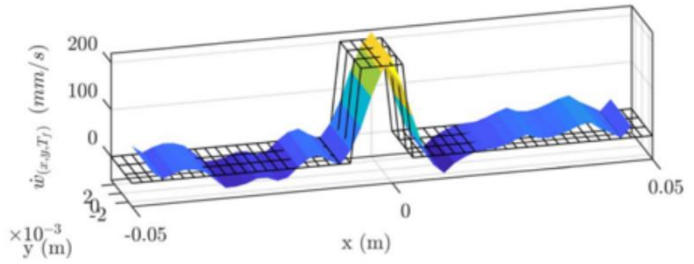
[Pantera & al. 2019]

Superposition modale



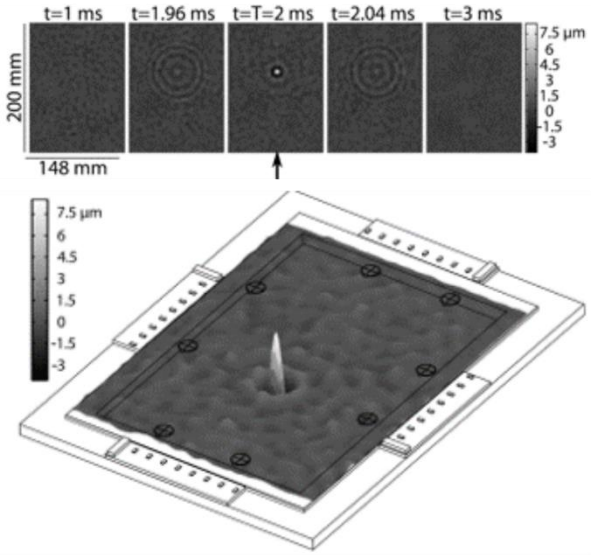
Plate's deformation for several combinations modes

[Ghenna & al. 2016]



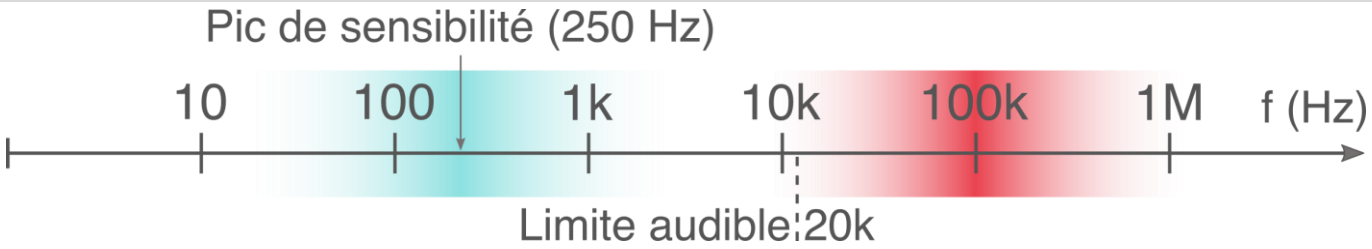
[Enferad & al. 2018]

Retournement temporel

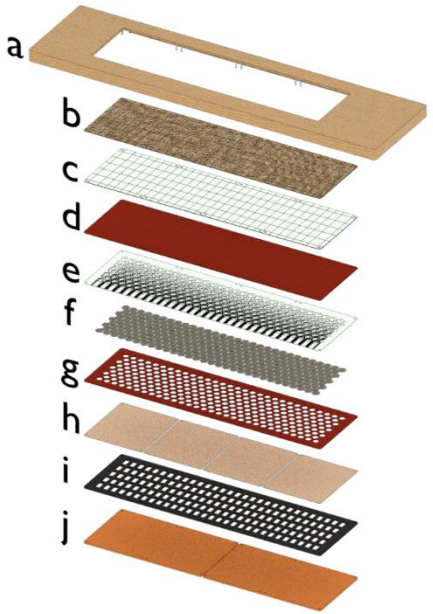


[Hudin & al. 2015]

Approches par Confinement



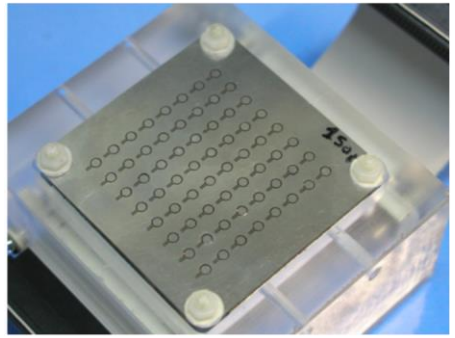
Attenuation



Multi-layered construction of the HSoundplane

[Papetti & al. 2019]

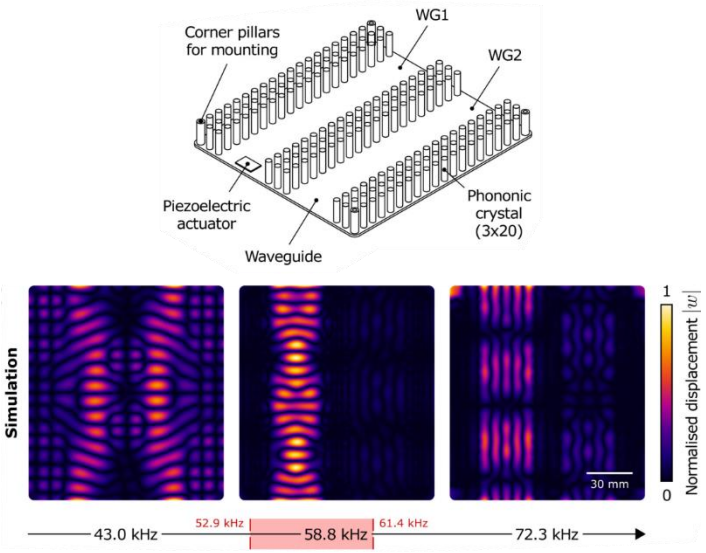
Isolation



VITAL 8 × 8 integrated laser-cut flexible membrane vibrotactile display

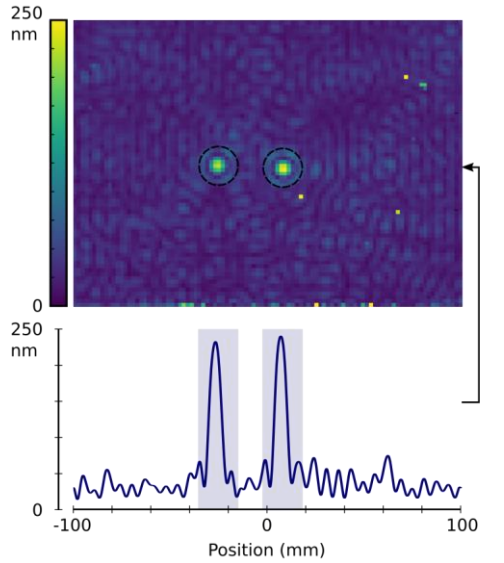
[Benali-Khoudja & al. 2006]

Méta-matériaux



[Daunizeau & al. 2021]

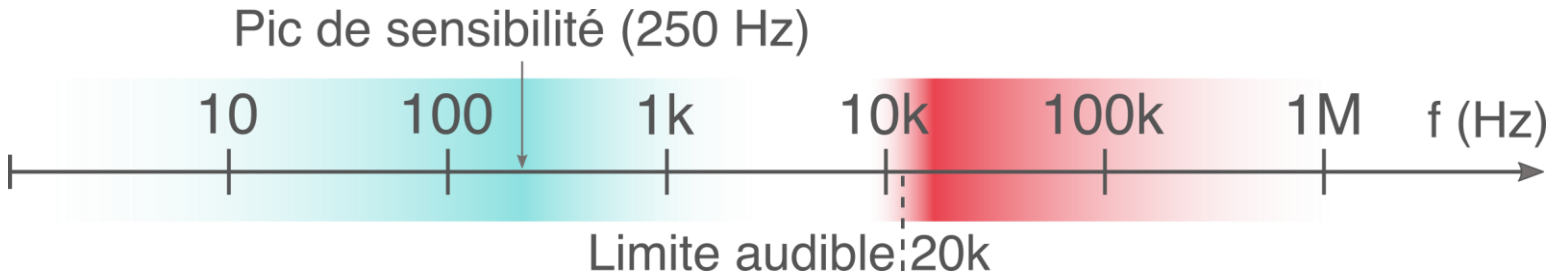
Fréquences non-rayonnantes



Quadratic mean of the measured displacement across the plate.

[Hudin & al. 2017]

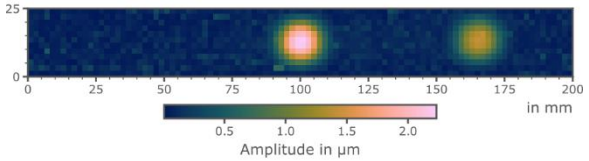
Contributions de la thèse « Confinement of Vibrations for Localized Surface Haptics »

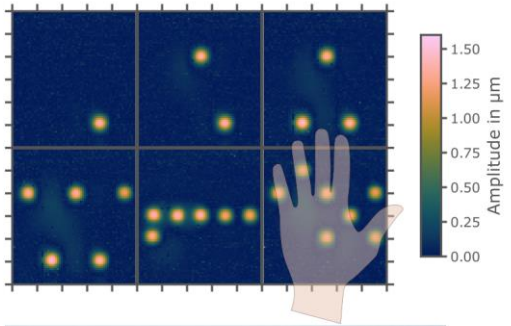


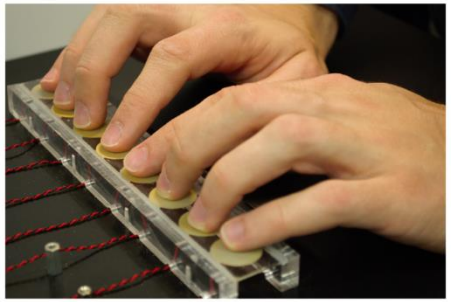
Guide d'onde

Supports périodiques

Fréquences non-rayonnantes





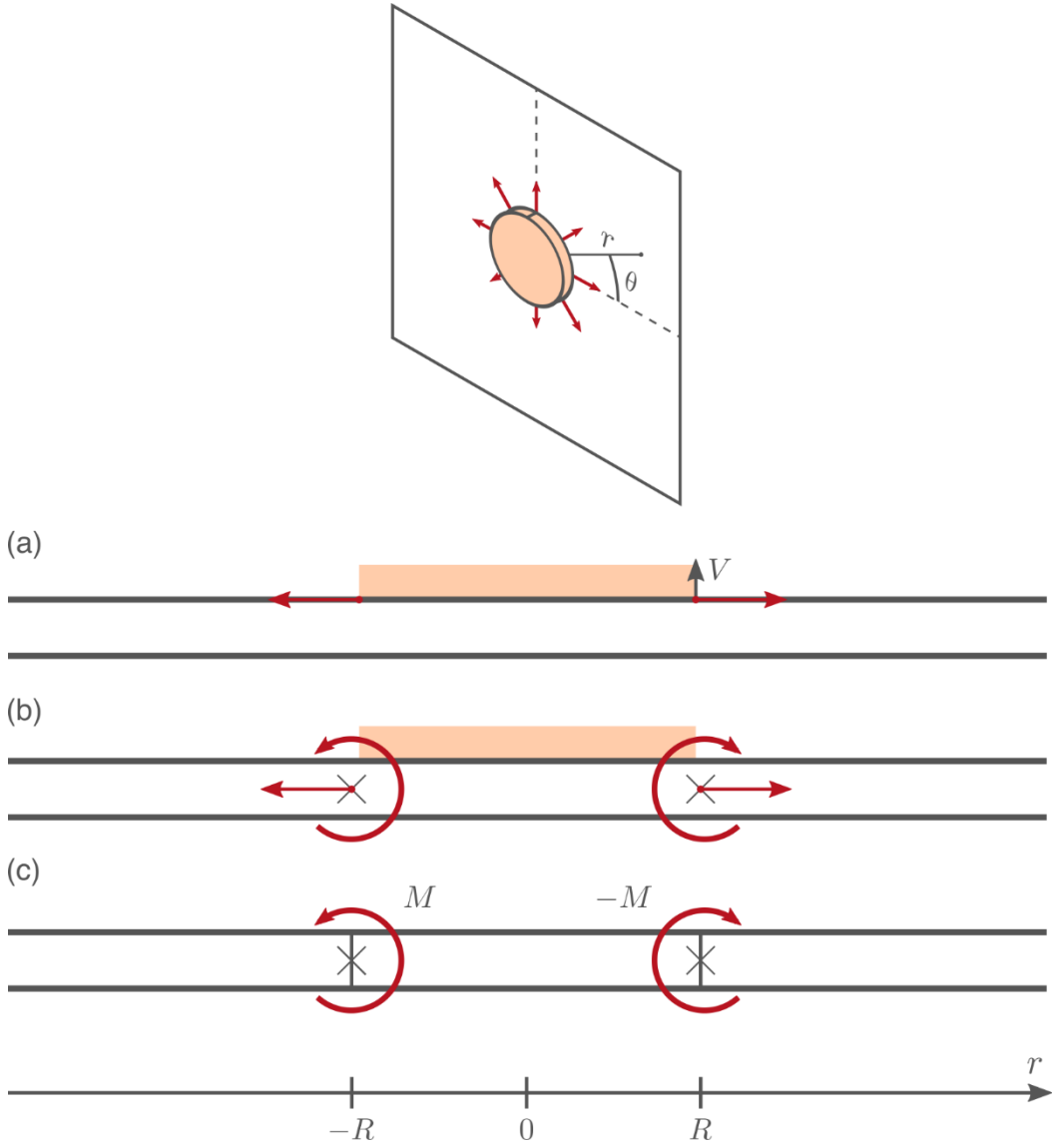


[Ben Dhiab & al., 2019]

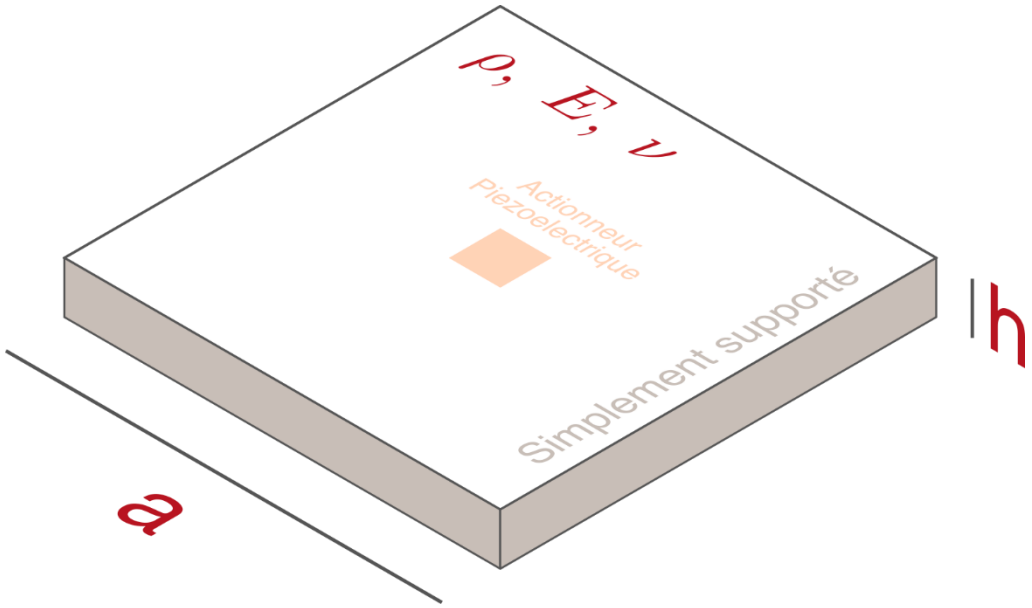
[Ben Dhiab & al., 2020]

Propagation dans les Milieux et Evanescence

Fonctionnement d’un actionneur piézoélectrique



Pin force model [Giurgiutiu, 2014]



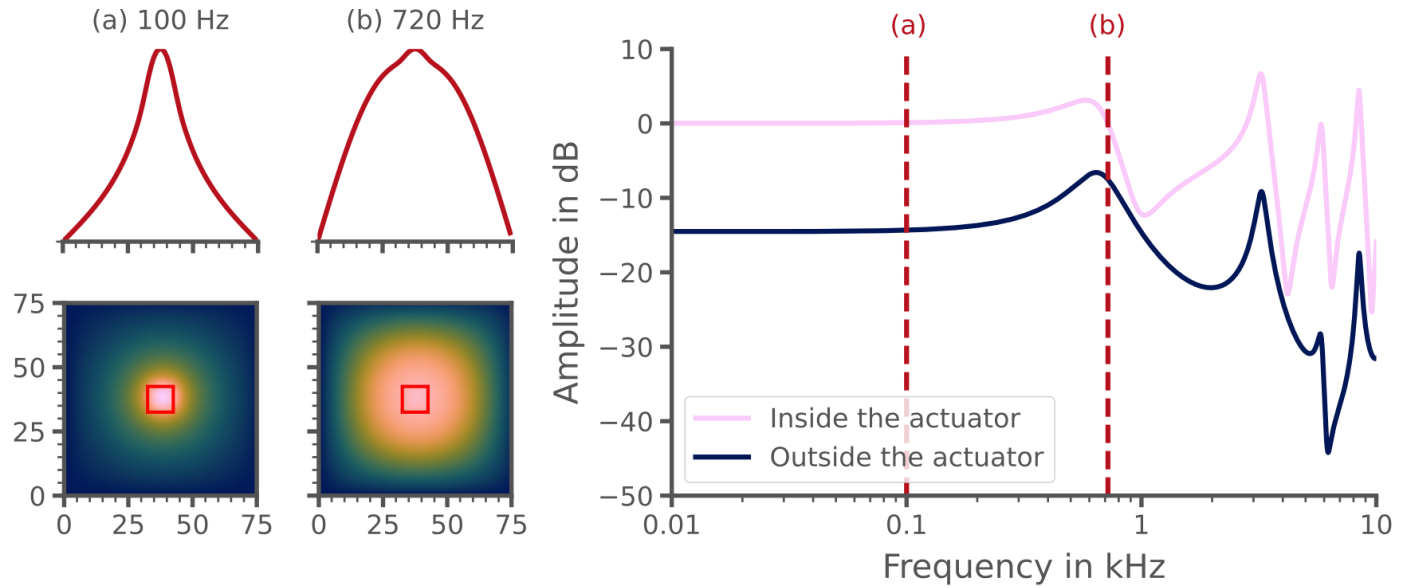


Figure 4.1: Simulation of a $75 \times 75 \times 0.7$ mm^3 glass plate excited with a square piezoelectric actuator in its center. The first resonance is around 580 Hz. (a) Before the first resonance, we have an evanescent behavior. (b) After the first mode, propagation occurs and we have a uniform distribution of vibration energy across the surface.

$$\omega_1 = 2\sqrt{\frac{D}{\rho h}\left(\frac{\pi^2}{a^2}\right)}$$

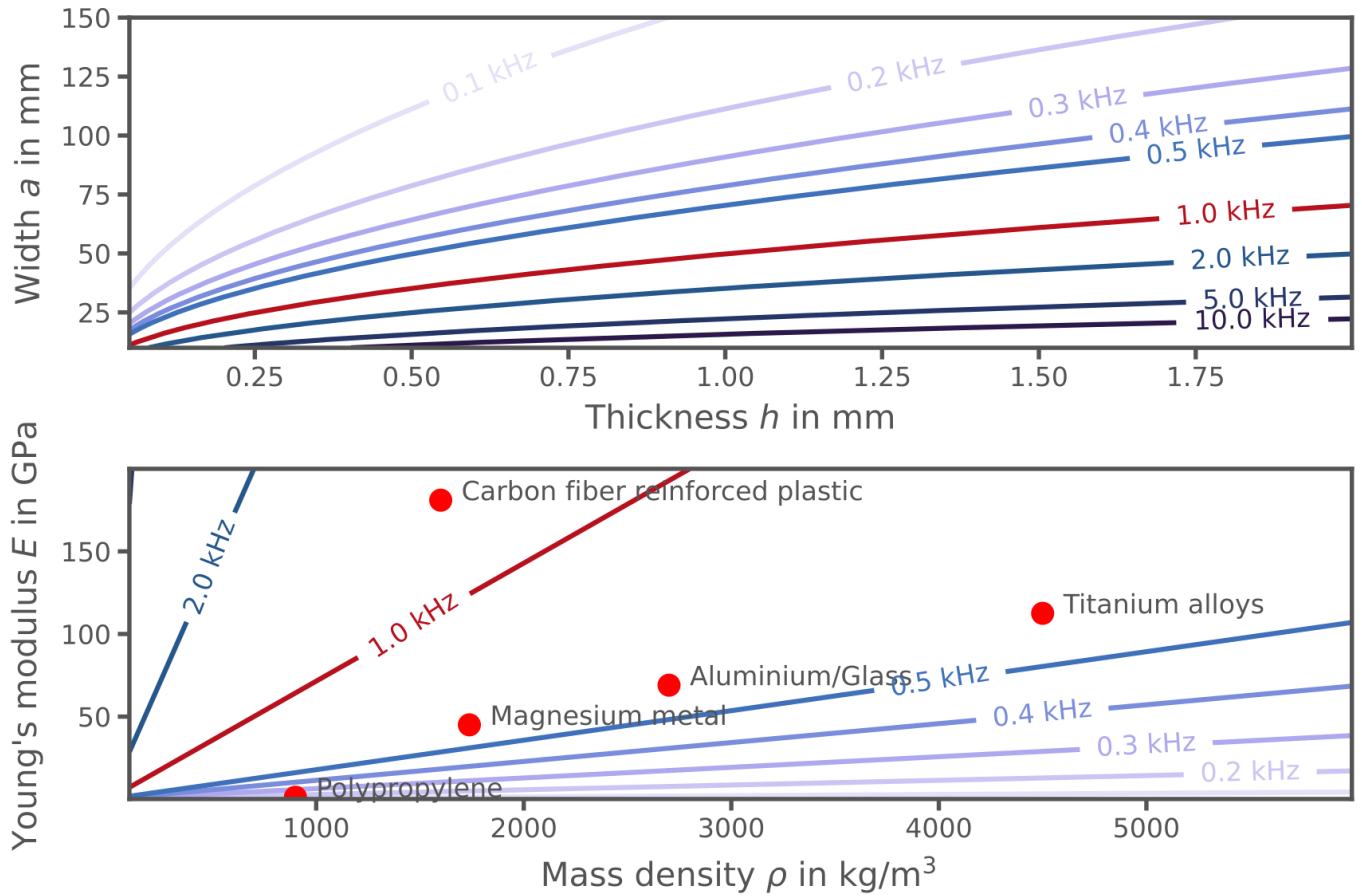
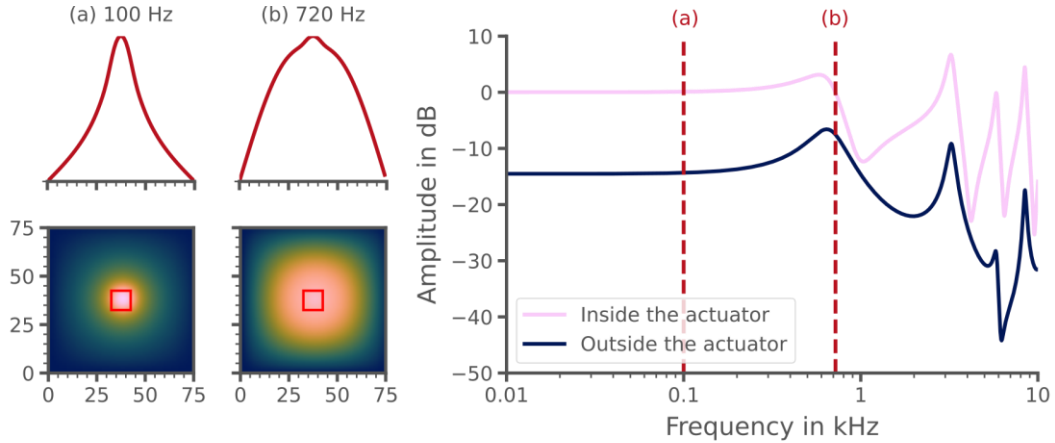


Figure 4.2: Abacus. Upper: First mode frequency abacus of a glass plate depending on its geometrical properties. Lower: First mode frequency abacus of a $75 \times 75 \times 0.7$ mm^3 plate depending on its material properties ($\nu = 0.3$).

Réflexions sur les milieux de propagation



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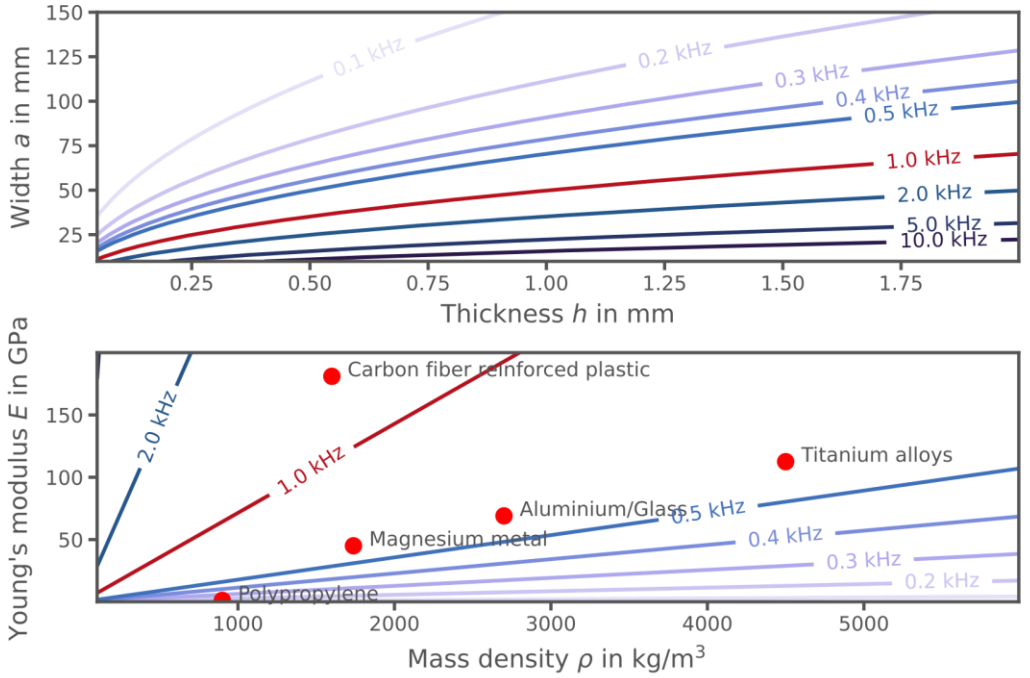

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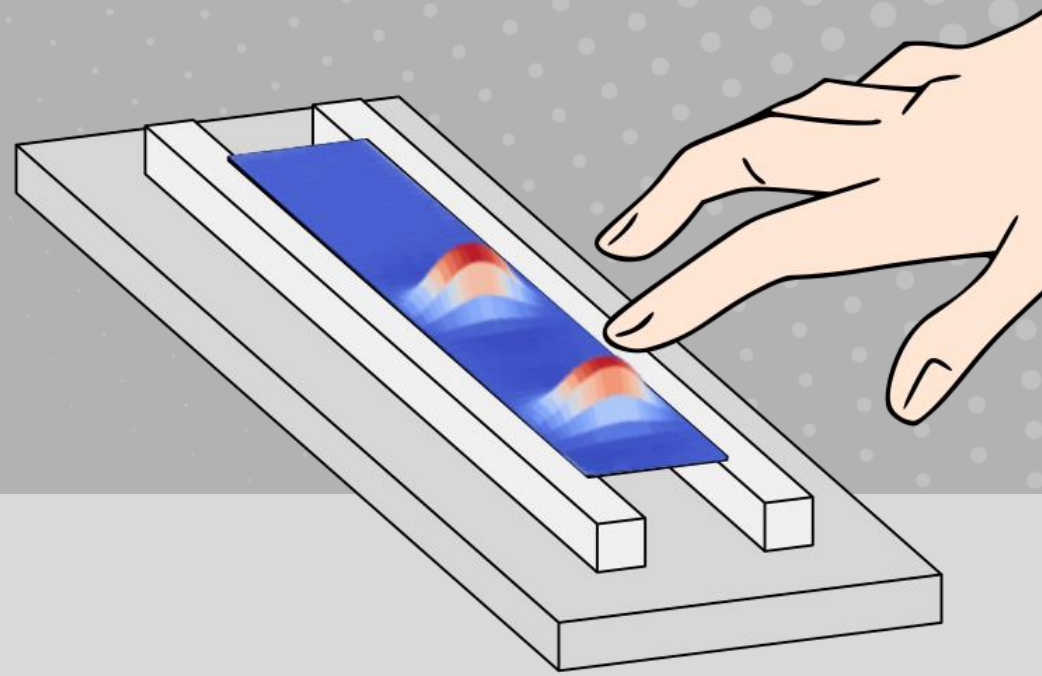
$$\omega_1 = 2\sqrt{\frac{D}{\rho h}\left(\frac{\pi^2}{a^2}\right)}$$

$\omega_1 \nearrow$
- $taille \searrow$
- $masse \searrow$
- $rigidité \nearrow$

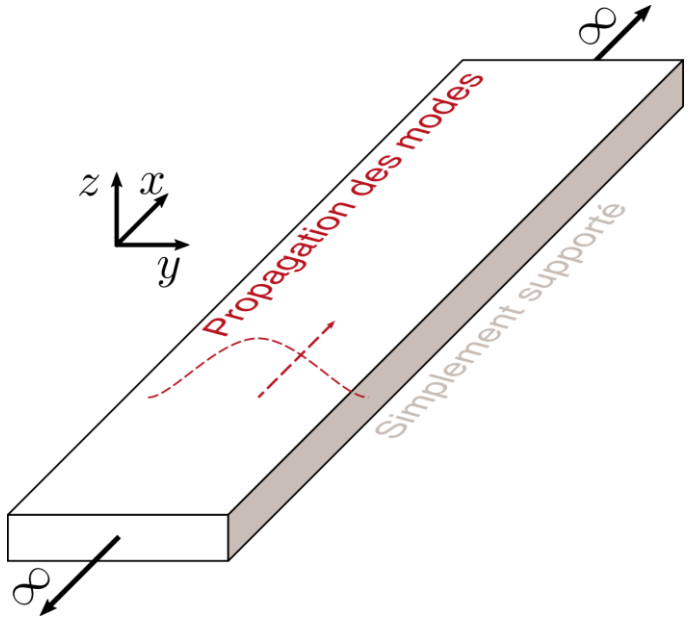
Réduire la taille $a \searrow$ → Guide d'onde

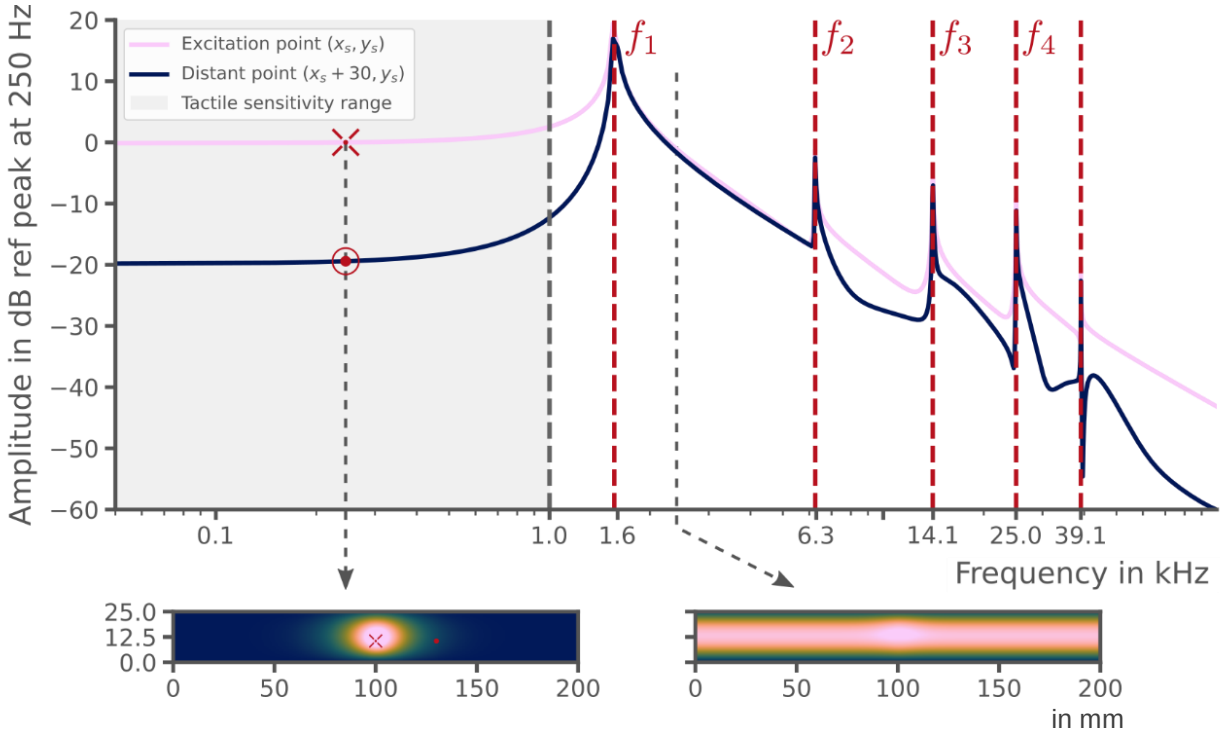
Augmenter la rigidité → Raidisseurs
+ Conditions aux limites
→ Supports périodiques

Confinement des Vibrations dans les *Guides d'Ondes*



Confinement des Vibrations dans les Guides d'Ondes – Fréquence de Coupure f_1





$$f_n = \frac{\omega_n}{2\pi} = \frac{\pi}{4\sqrt{3}} \frac{h}{W^2} \sqrt{\frac{E}{\rho(1-\nu^2)}} n^2$$

h: épaisseur

W: largeur

E: Module d'Young

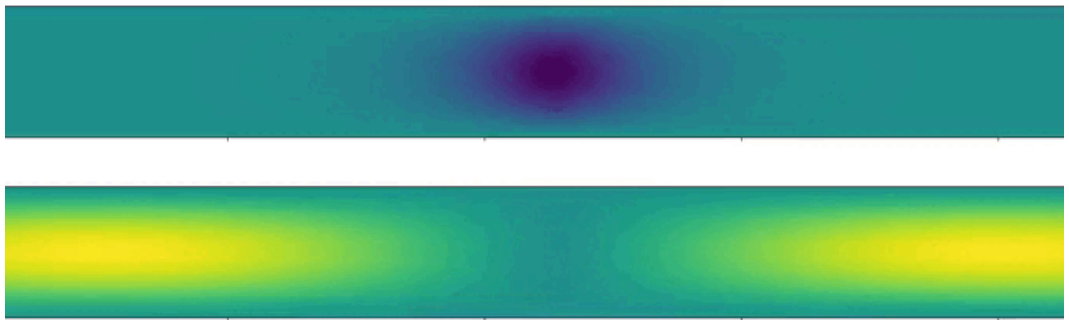
ρ: masse volumique

ν: coefficient de Poisson

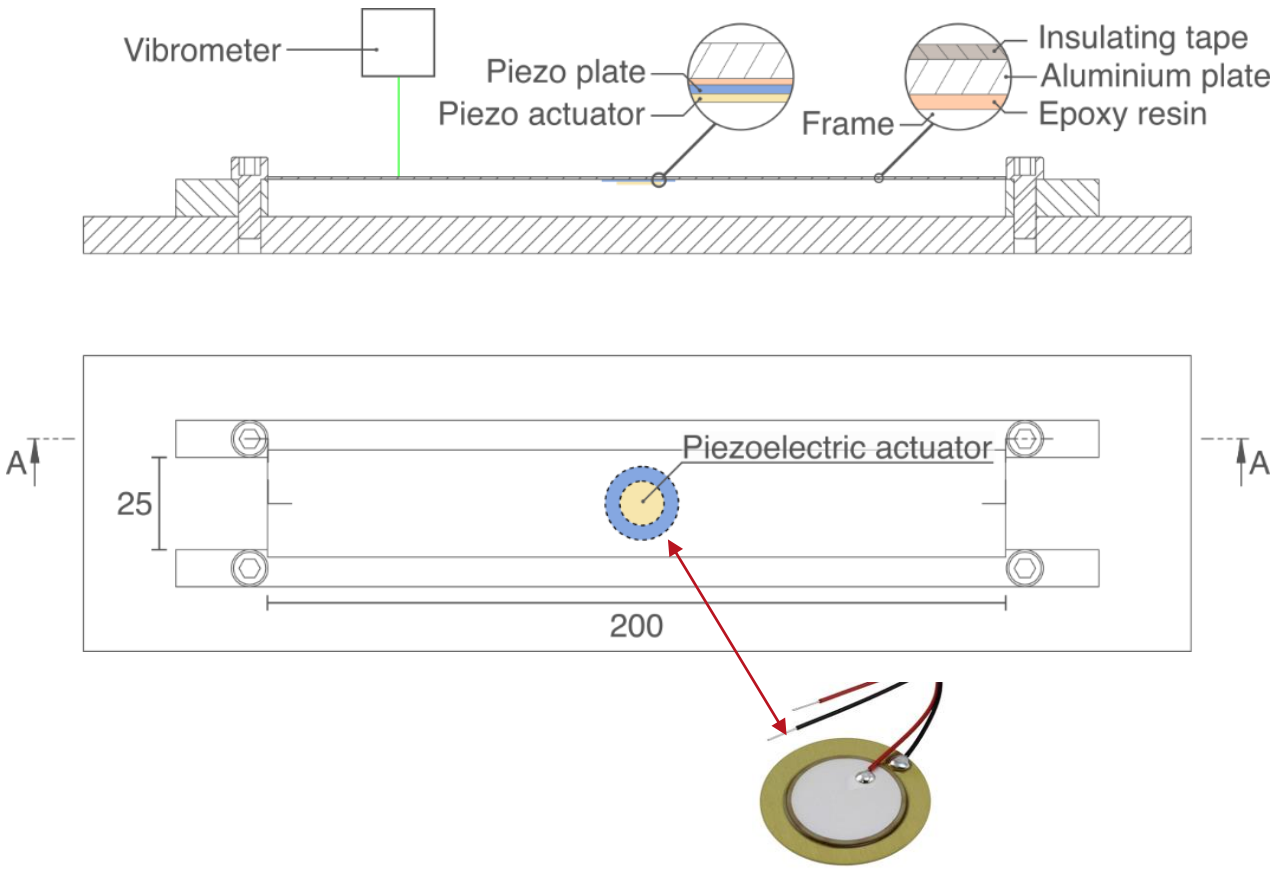
n: numéro du mode

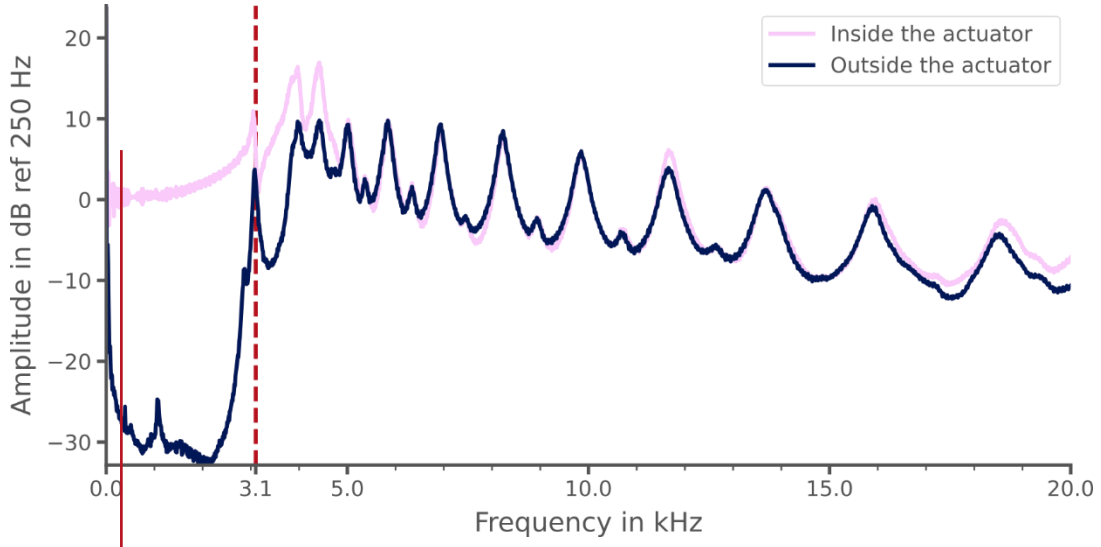
Paramètres Géométriques

Paramètres Matériaux

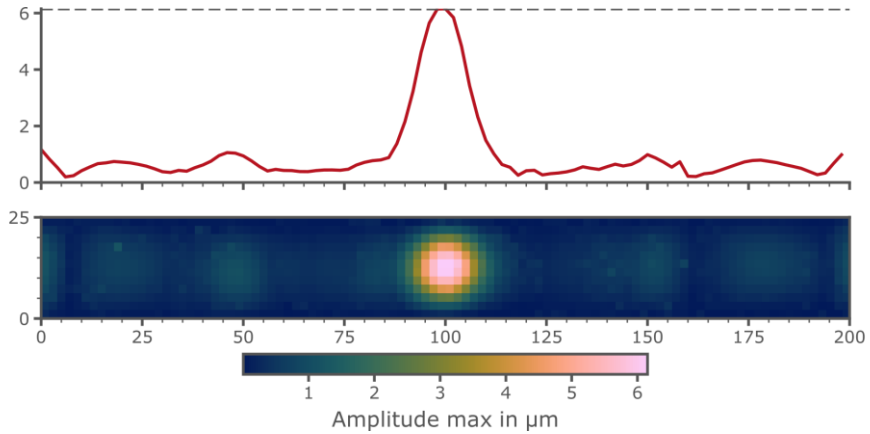


Confinement des Vibrations dans les Guides d'Ondes – *Expérimentation*

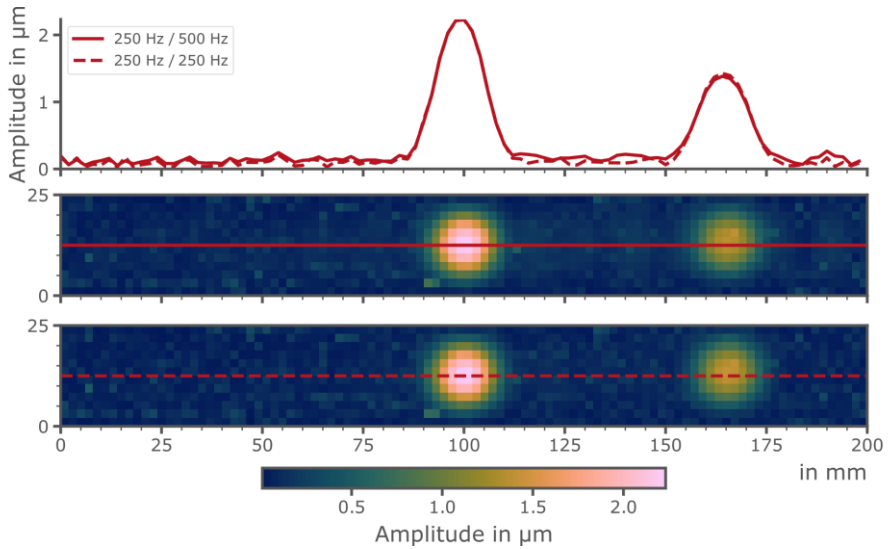




Sin / 250 Hz / 100 V



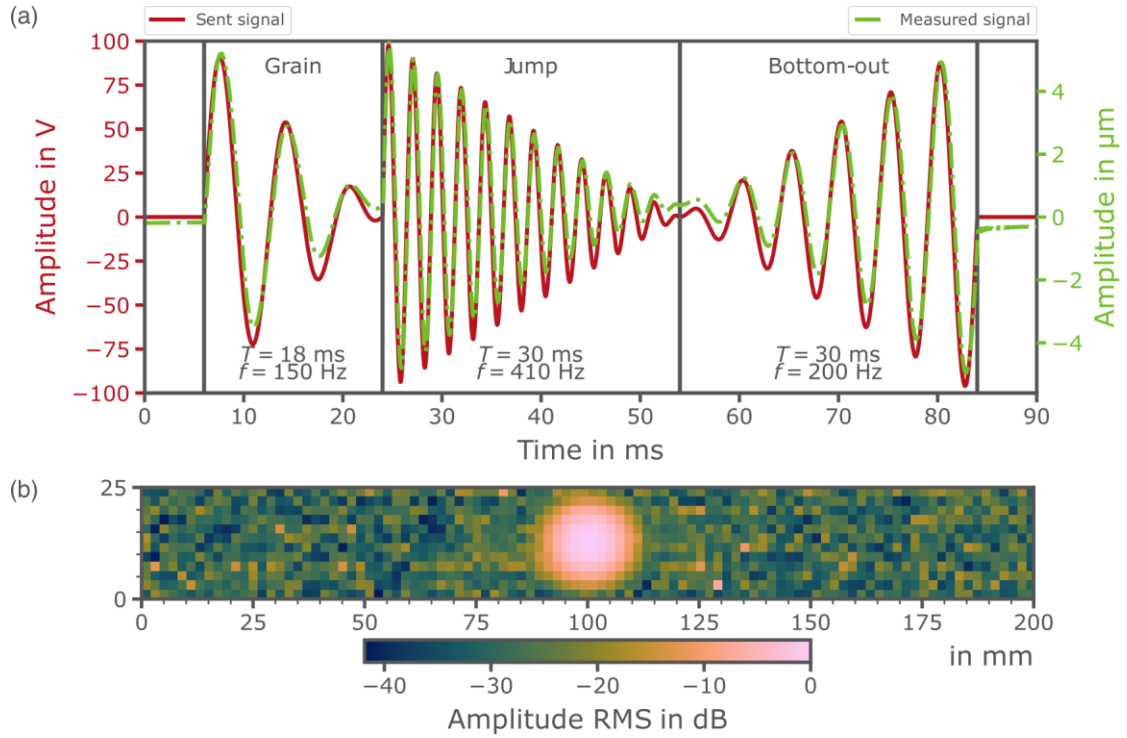
Burst / 100 V



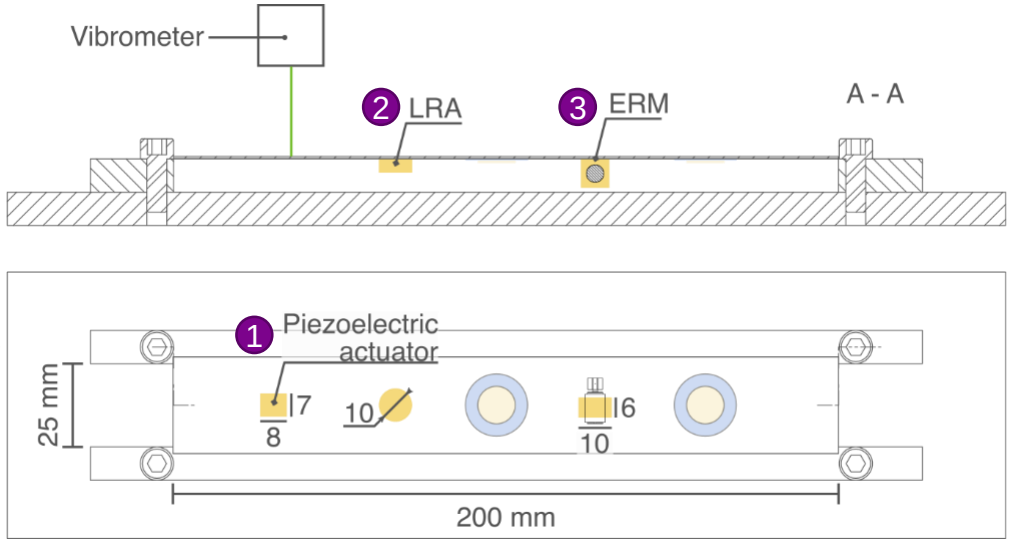
250 Hz

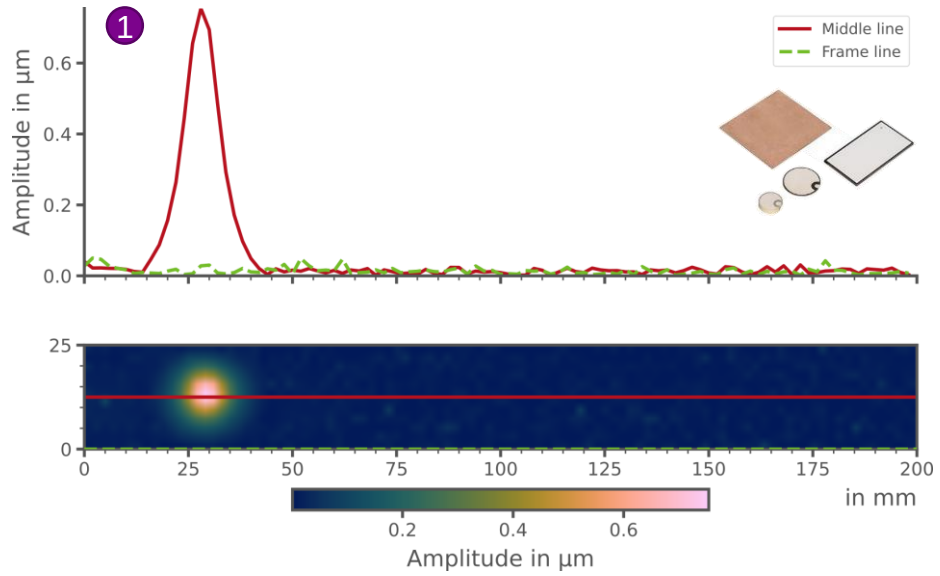
500 Hz

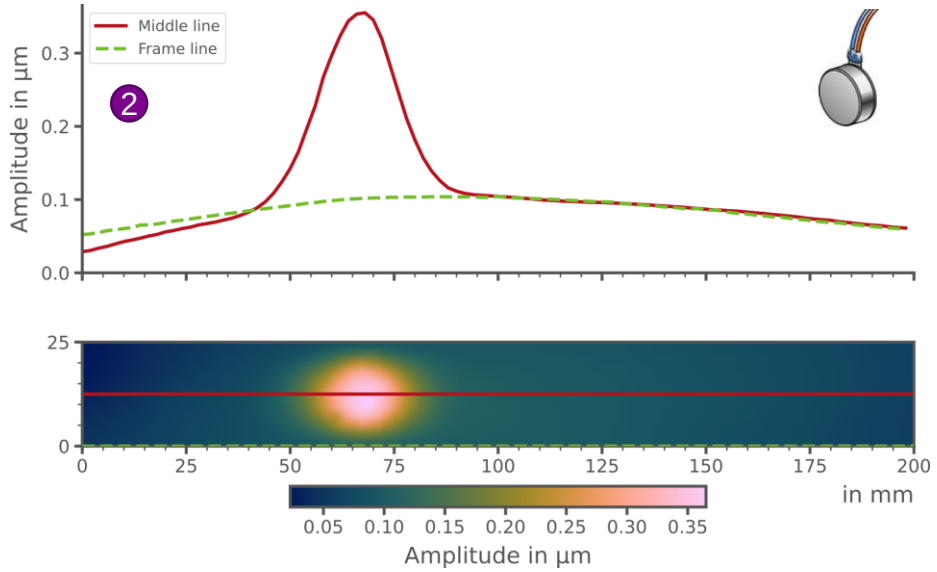
Bouton (phase d'appui) [Kim & Lee, 2013]

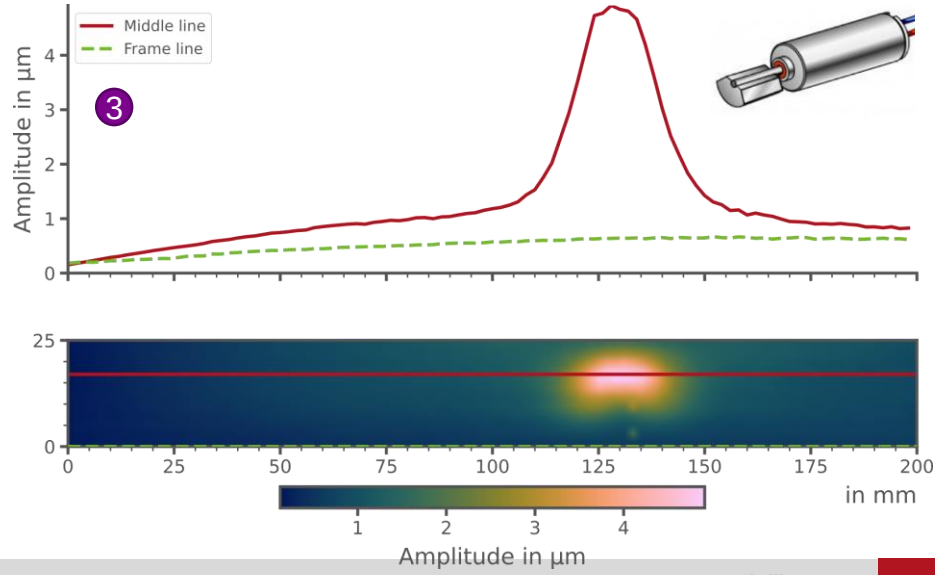


Confinement des Vibrations dans les Guides d'Ondes – *Expérimentation*

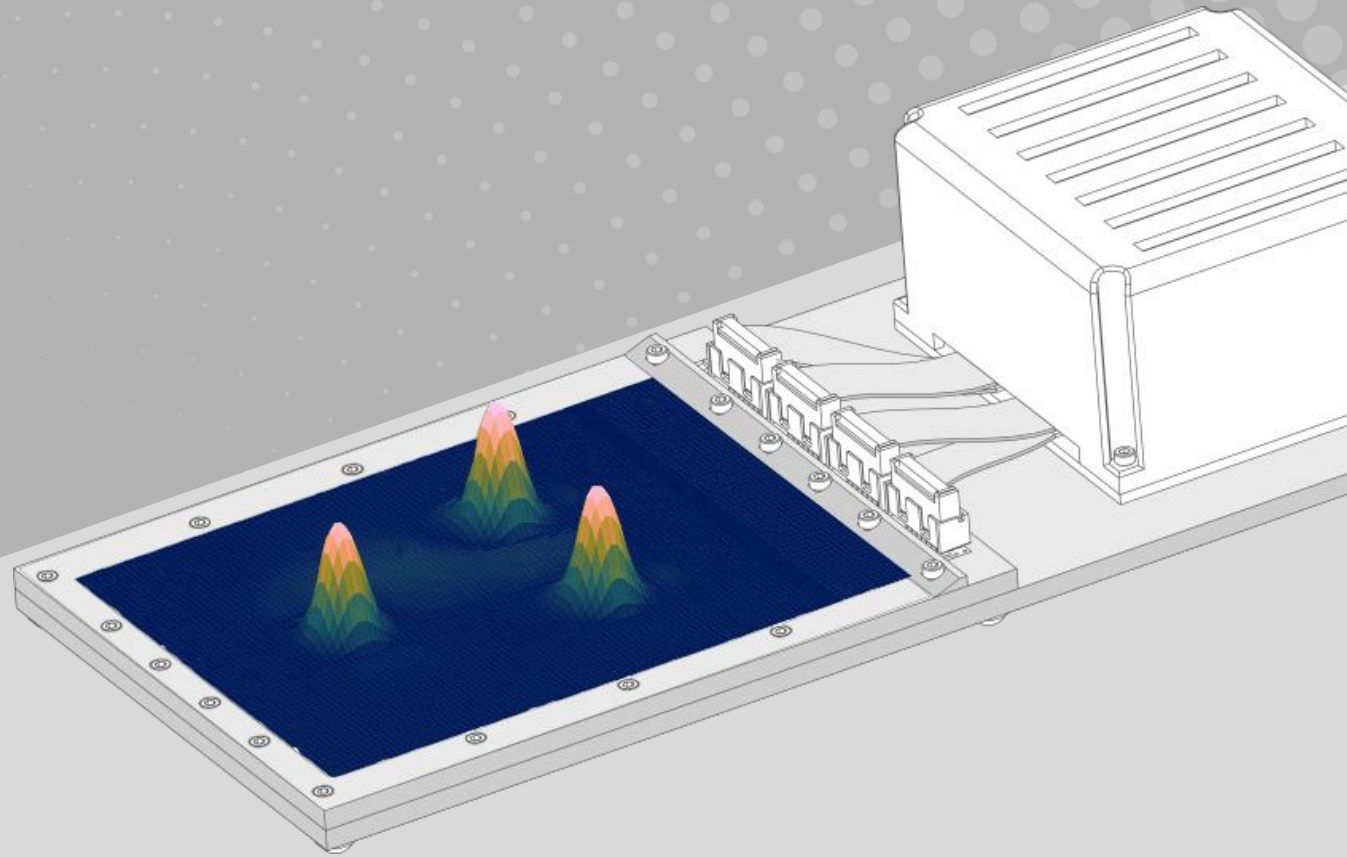


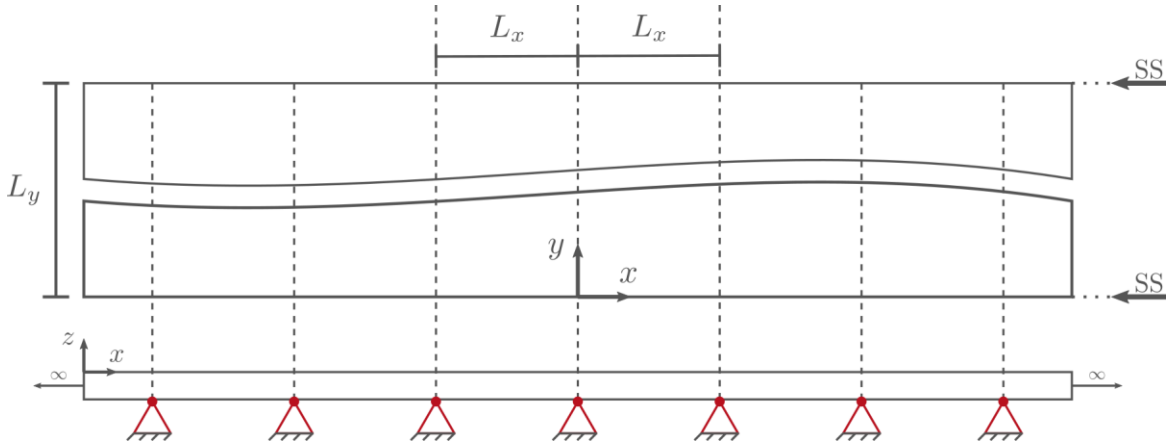


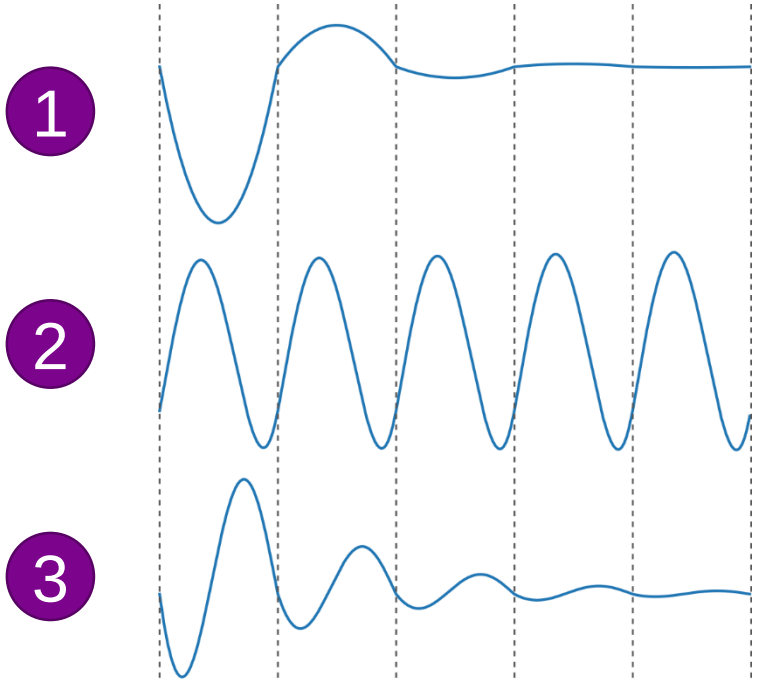


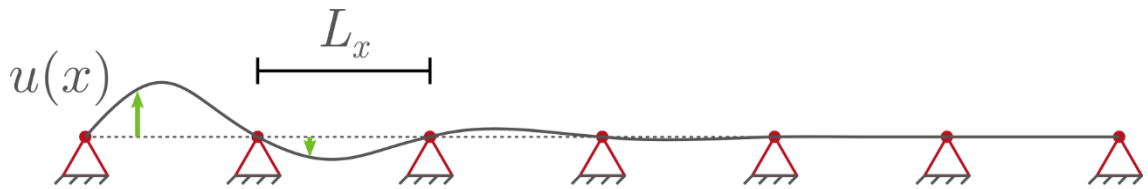


Confinement des Vibrations sur *Surfaces Etendues*





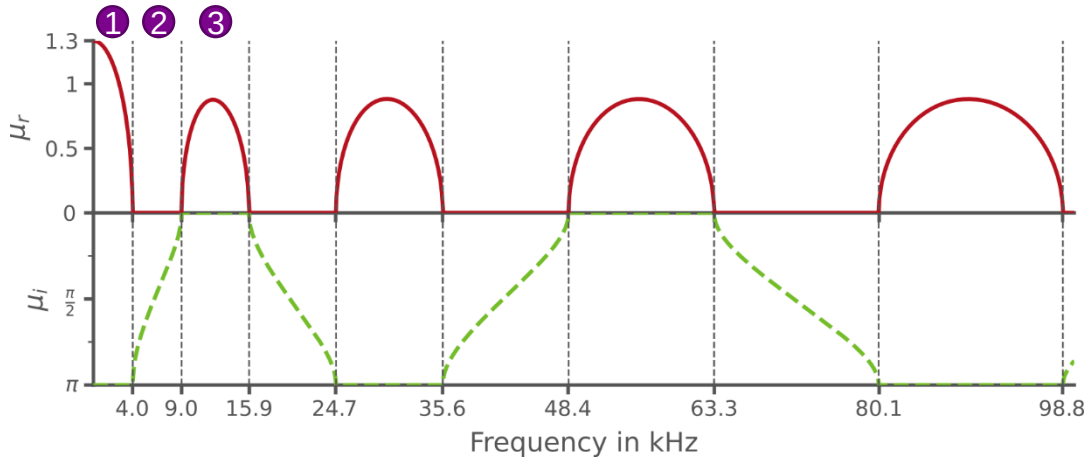


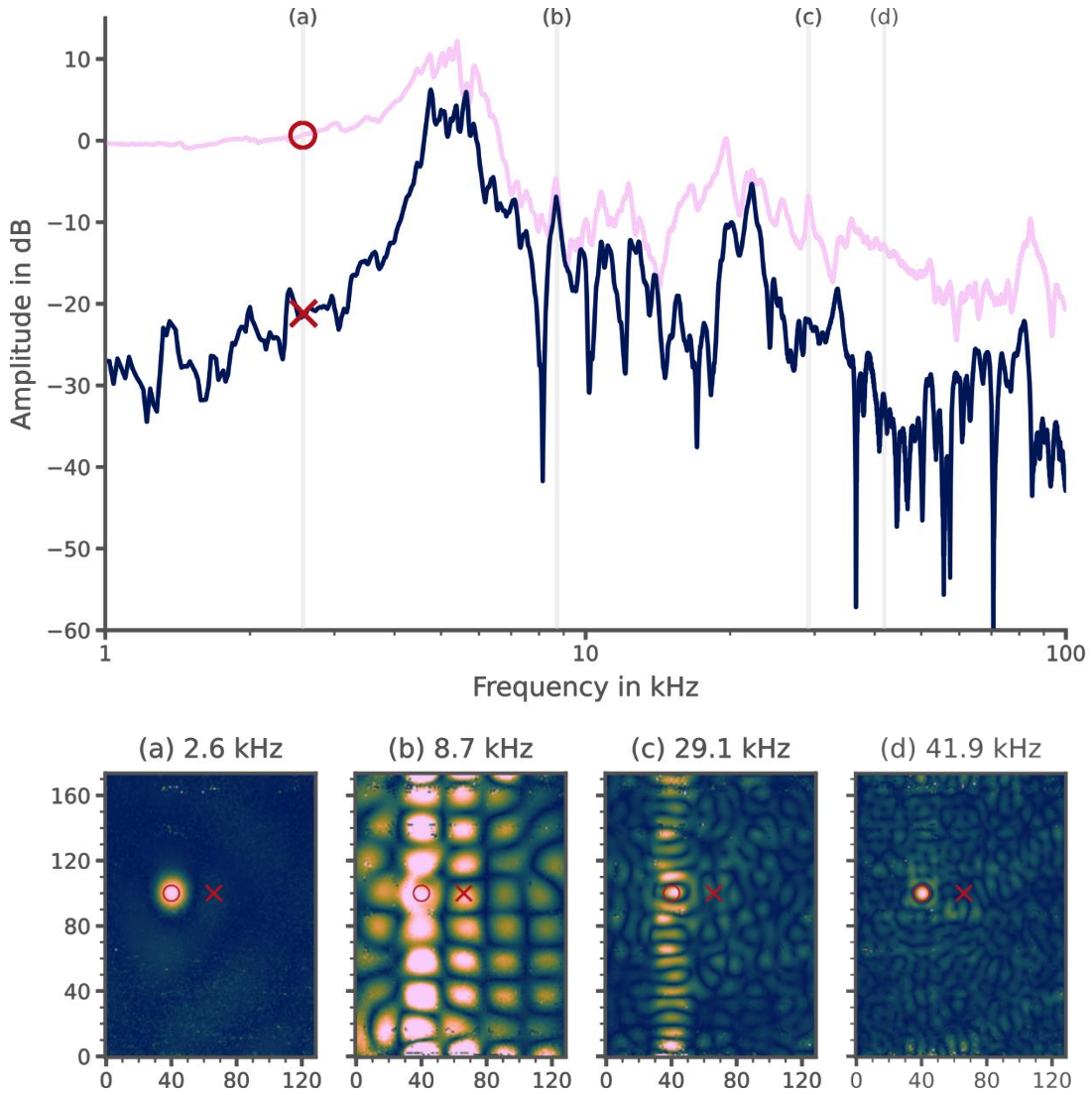


[Mead, 1986]

$$u(x + L_x) = u(x)e^{\mu}$$
$$\mu = \mu_r + j\mu_i$$

Constante de propagation d'une section à une autre.





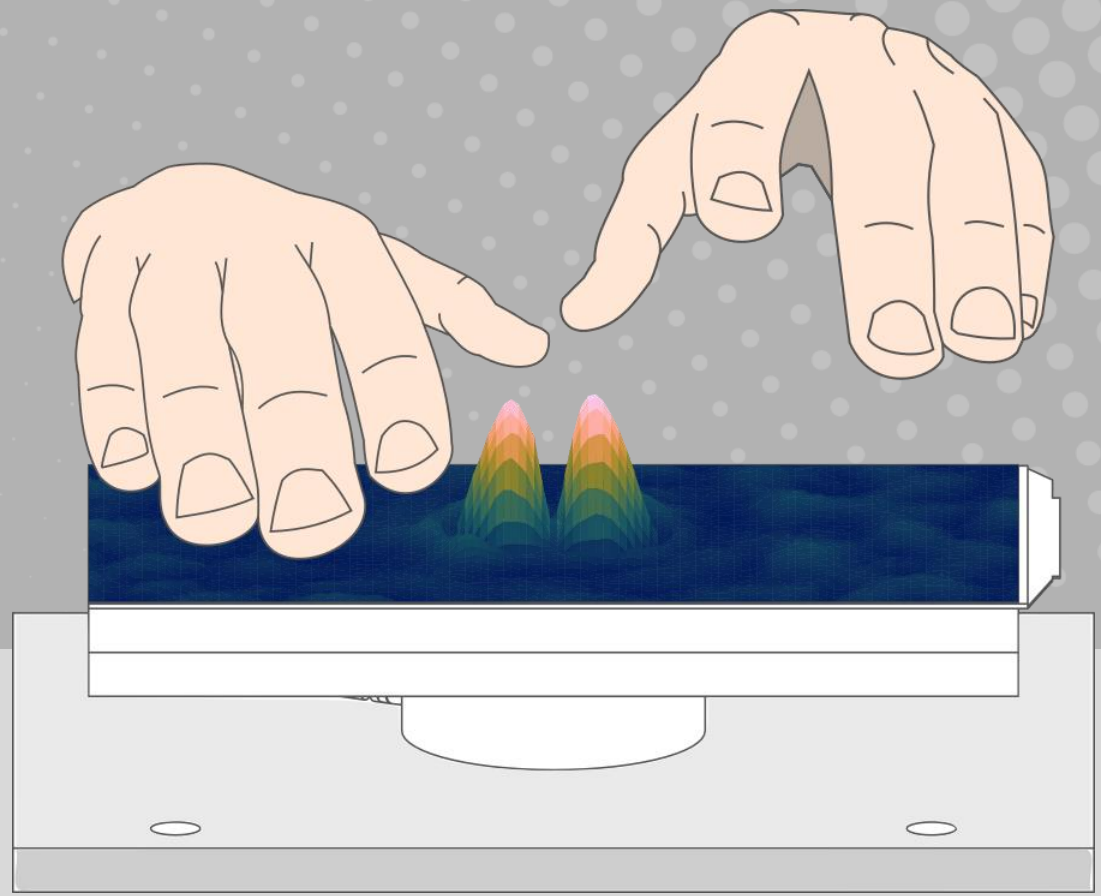
(a) Non propagation

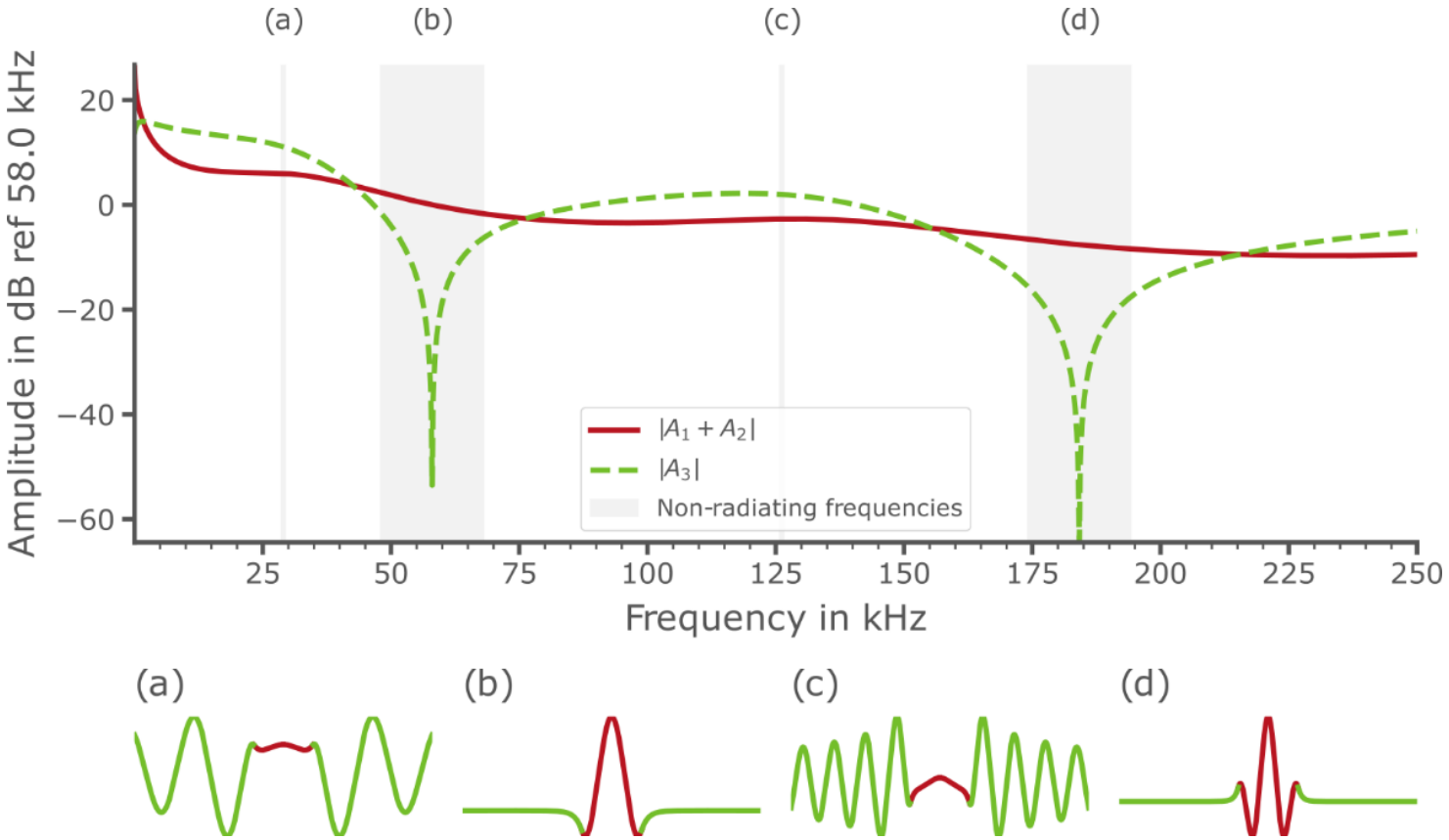
(b) Propagation

(c) Attenuation

(d) Non-rayonnement

Fréquences Non-Rayonnantes et Modulation de Friction Localisée





$$f_n = \frac{1}{2\pi}\sqrt{\frac{D}{\rho h}}\left(\frac{\alpha_n}{R}\right)^2$$

$$avec : J_1(\alpha_n) = 0$$
$$soit : \alpha_n = 3.83, 7.02, 10.17, \ldots$$

- Si R ↘ → f_n ↗

Perspectives

CONCEPTION

RECHERCHE

AUDIO

ASSEMBLAGE

SUPPORT

USAGES

MULTI-TOUCH

COLLAGE

PIEZOELECTRIQUE

MATERIAU MOU

COQUE

ELECTRONIQUE

SOUDAGE

CODEC

ACCESSIBILITE

MATRICE

PSYCHOPHYSIQUE

API