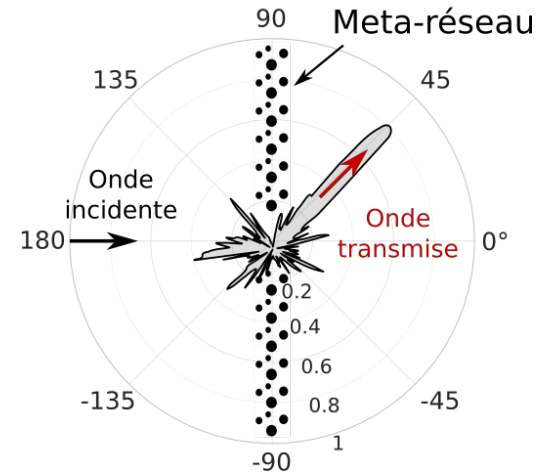
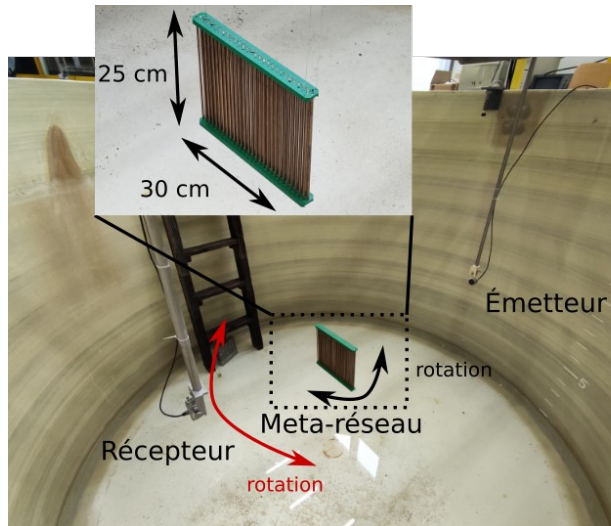


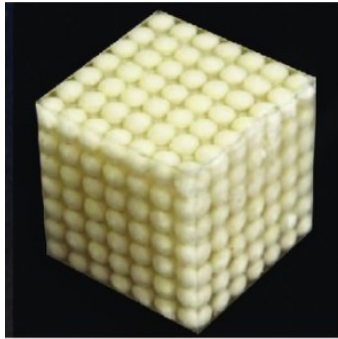
Mesure en cuve du diagramme de rayonnement d'un objet immergé : métaréseau asymétrique

Simon Bernard



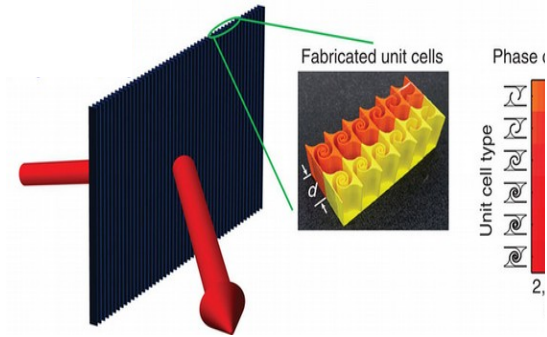
Les metasurfaces sont l'analogue plat des métamatériaux

3D



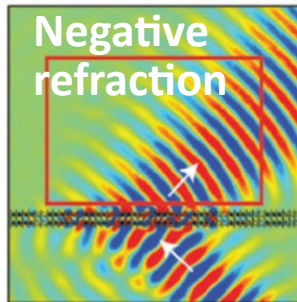
Locally resonant acoustic metamaterial
(Liu et al., **Science**, 2000)

2D

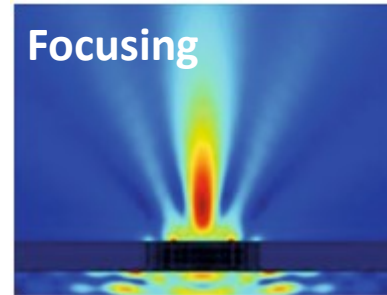


Acoustic metasurface
(Xie et al., **Nature communications**, 2014)

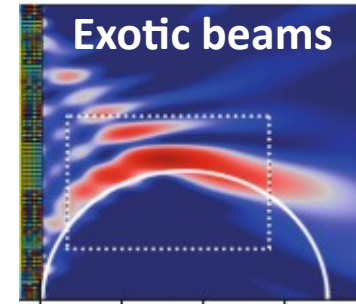
Quelques applications :



Xie et al., 2014



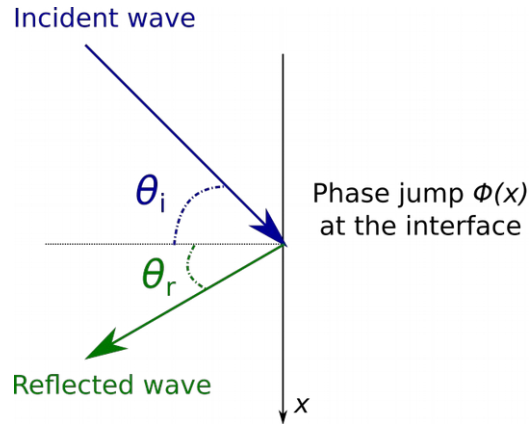
Jahdali et al., 2016



Li et al., 2015

Les metasurfaces reposent sur le concept de gradient de phase

- Un **saut de phase local et variable** modifie la direction de l'onde (*Yu et al., Science, 2011*)

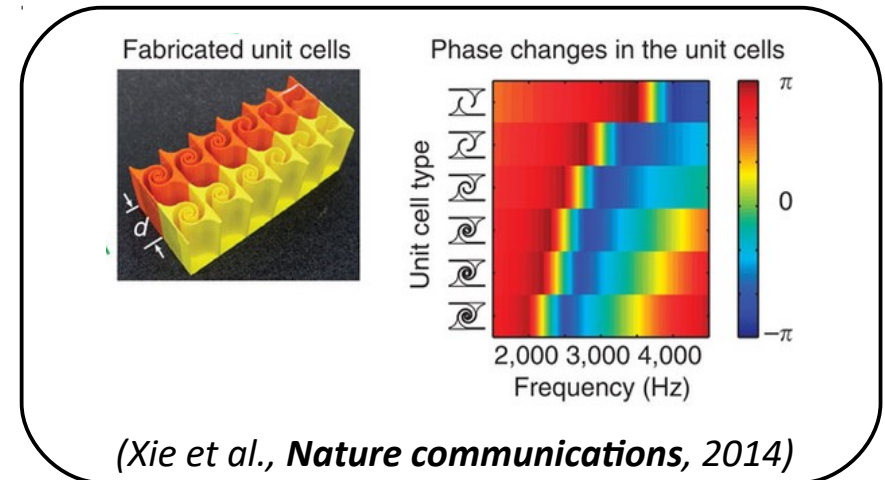


Generalized Snell-Descartes's law

$$\sin(\theta_r) - \sin(\theta_i) = \frac{\lambda}{2\pi} \frac{d\phi}{dx}$$

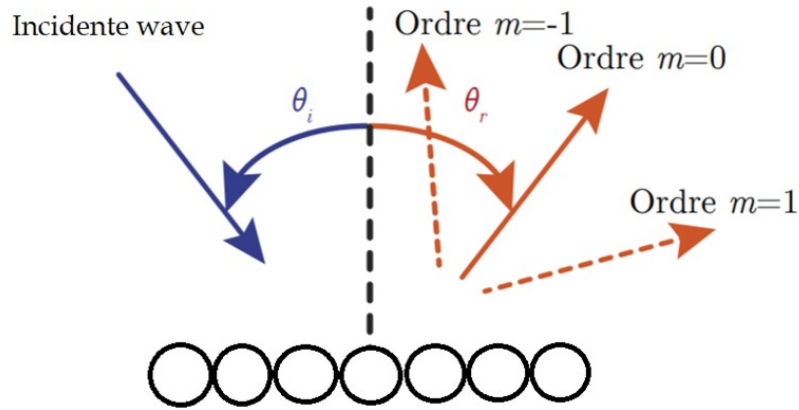
- **Plusieurs limites en pratique :**

- Impression 3D → pas en acoustique sous-marine
- Efficacité limitée pour des angles importants (*Diaz-Rubio et al., Phys. Rev. B, 2017*)



Un concept plus simple : le metaréseau

- **Un unique atome répété périodiquement**
- Les directions possibles sont données par l'équation de Bragg :



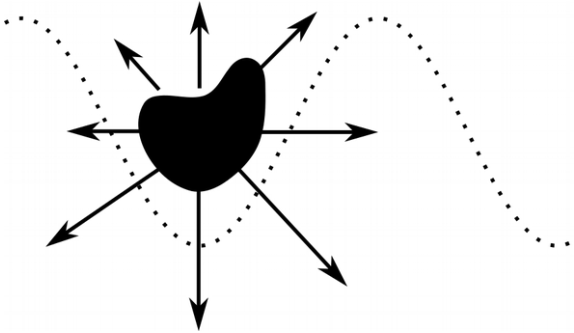
$$\theta_{out}^m = \arcsin(\sin \theta_{inc} - m \cdot \lambda / p)$$

- La part d'énergie envoyée vers chaque mode dépend des propriétés de diffusion acoustique de l'atome (Ra'di et al., 2017; Epstein & Rabinovitch, 2017; Torrent, 2018)

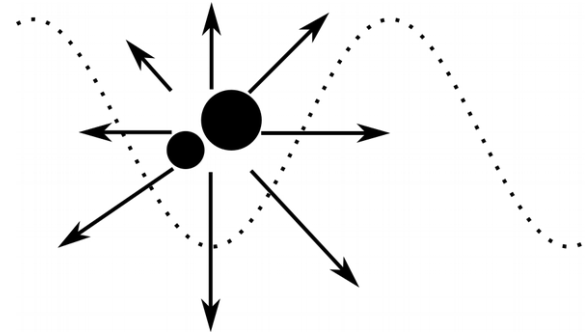
➡ **Il faut concevoir l'atome de sorte que toute l'énergie soit renvoyée vers un mode choisi**

Diffusion multipolaire : ..., A_{-1} , A_0 , A_1 , ...

Objet de forme complexe :
difficile à paramétriser, à fabriquer

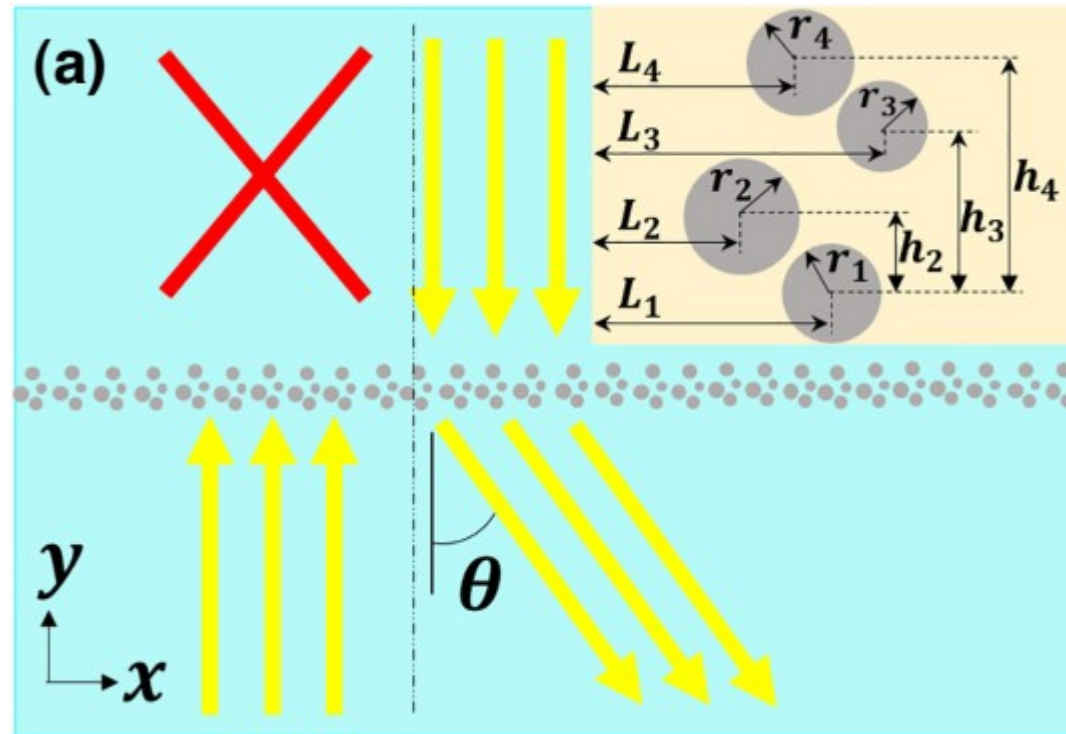


Objet « composite » de forme simple :
Plus facile à paramétriser, à fabriquer

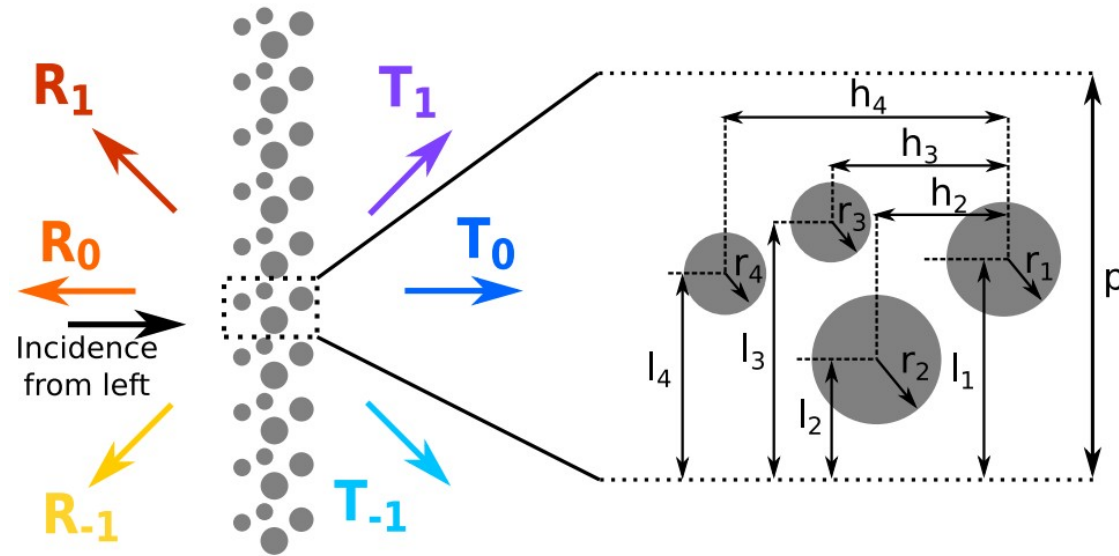


- Plus de degrés de liberté -> possibilité de supprimer plusieurs modes de Bragg

Transmission asymétrique



L. Fan and J. Mei, Physical Review Applied, 2020.

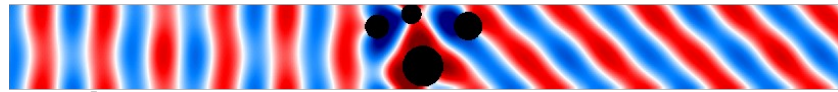
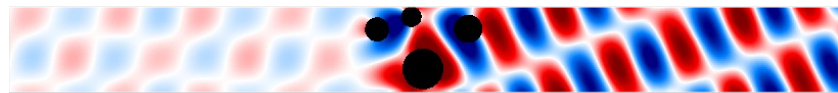
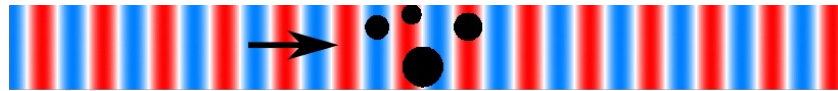


$$F = 1/T_1^{\text{left}} + (T_{-1}^{\text{right}} + T_0^{\text{right}} + T_1^{\text{right}})$$

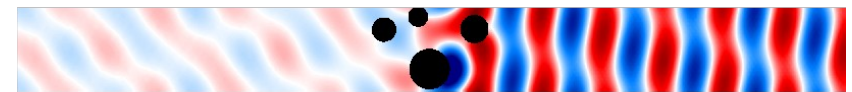
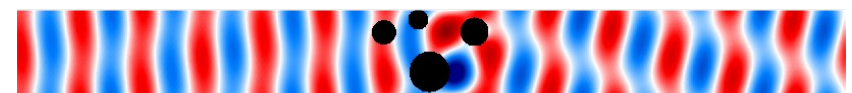
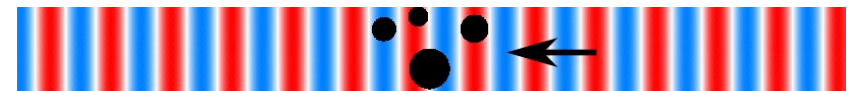
- On ajuste numériquement (FEM) les paramètres géométriques pour minimiser F
 - Maximise transmission pour incidence de la gauche
 - Minimise transmission pour incidence de la droite

200 kHz

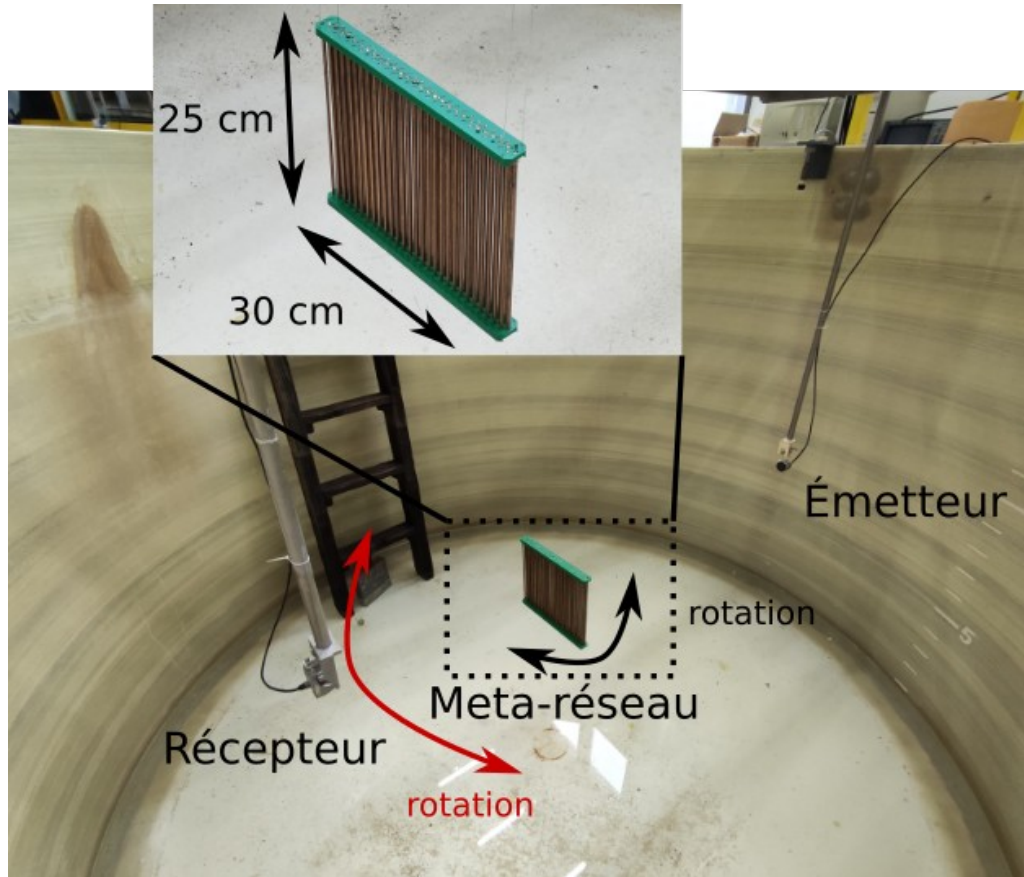
Incidence de la gauche



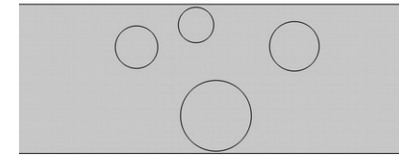
Incidence de la droite



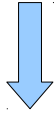
Dispositif expérimental



Géométrie optimisée dans Comsol



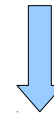
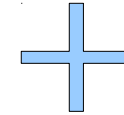
Modèle 3D . stl



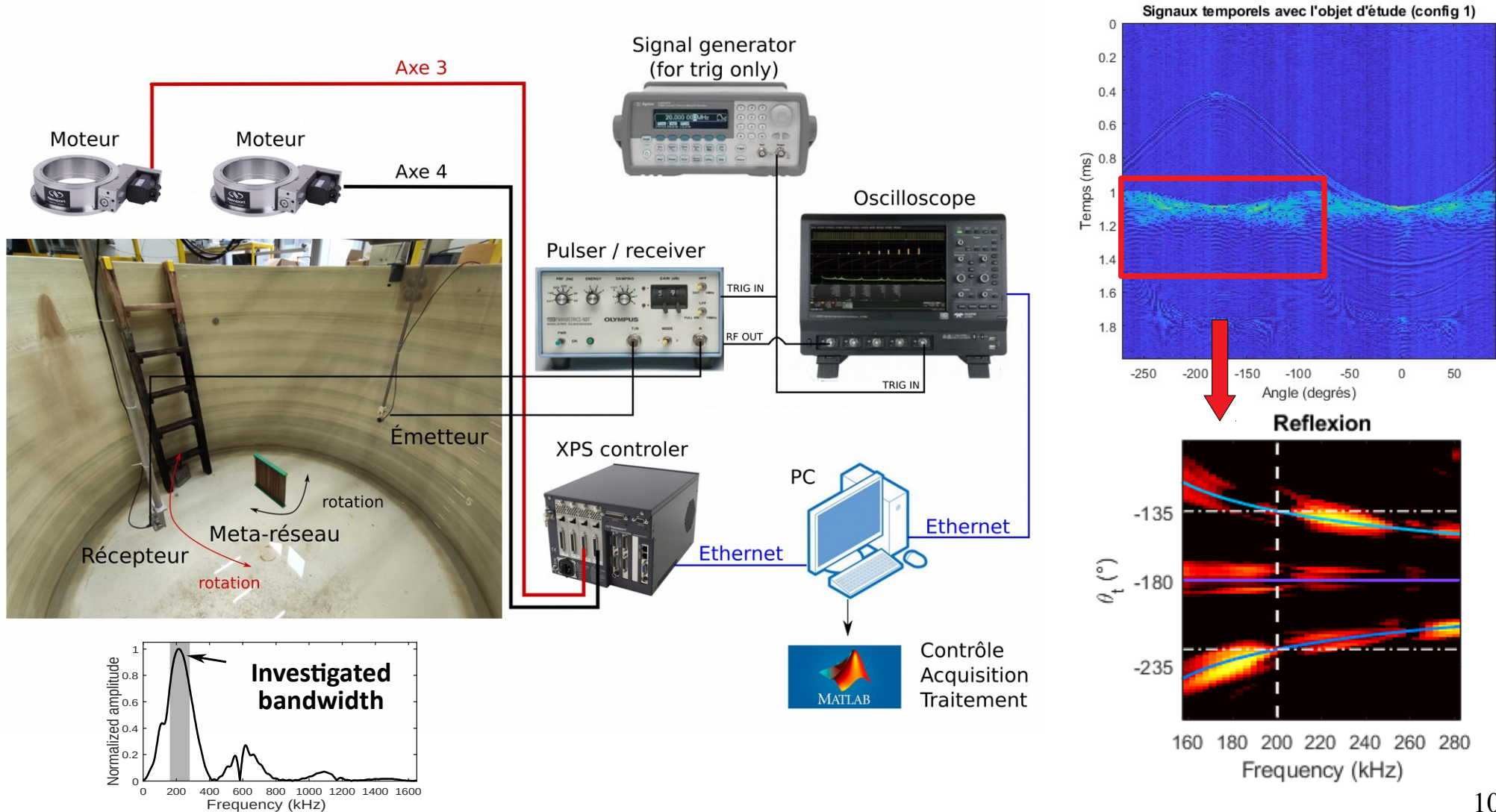
Impression 3D



Cylindres en laiton

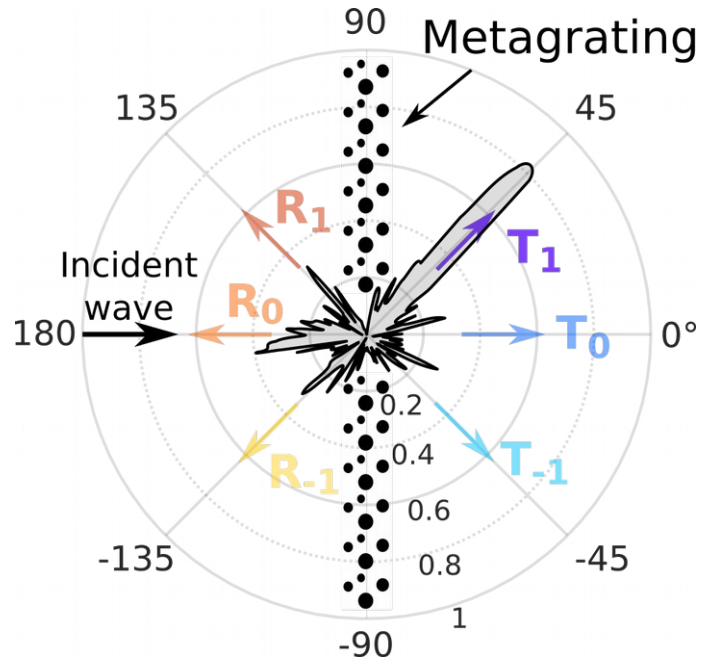


Dispositif expérimental

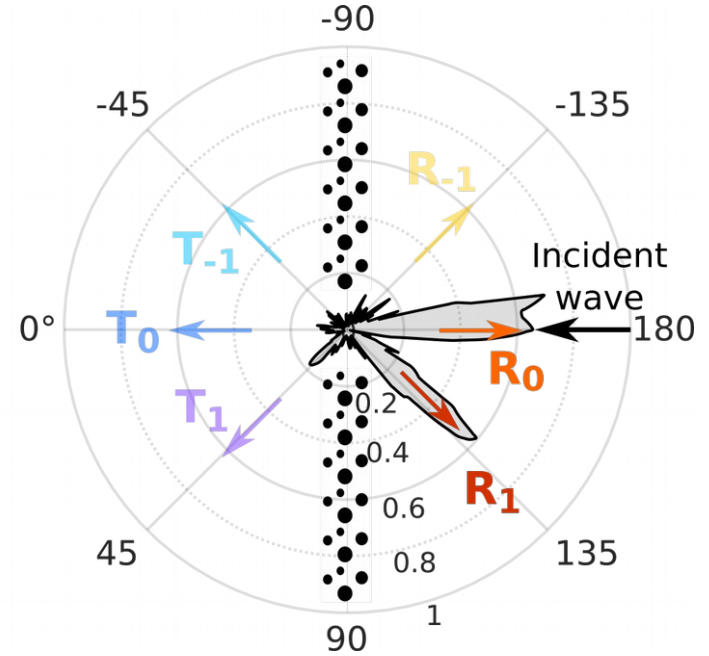


200 kHz

Incidence de la gauche

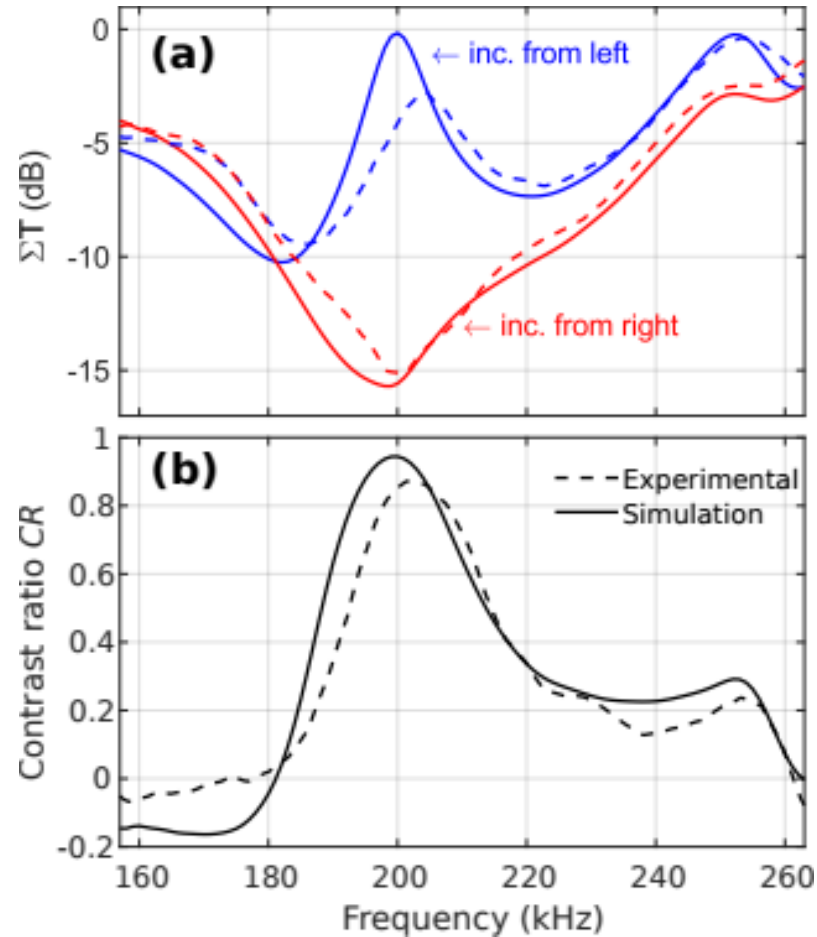


Incidence de la droite



H Kourchi, S Bernard, F Chati, and F Léon., *Efficient asymmetrical transmission through a metagrating for underwater acoustic waves*. Applied Physics Letters, **2023**

Réseau à quatre cylindres : résultats expérimentaux



H Kourchi, S Bernard, F Chati, and F Léon., *Efficient asymmetrical transmission through a metagrating for underwater acoustic waves*. Applied Physics Letters, **2023**

A quoi ça sert ?

