

声场旋转器结构单元尺寸对其工作带宽的影响



忠果敦精
恕毅篤勤
任力勵求
事行志學



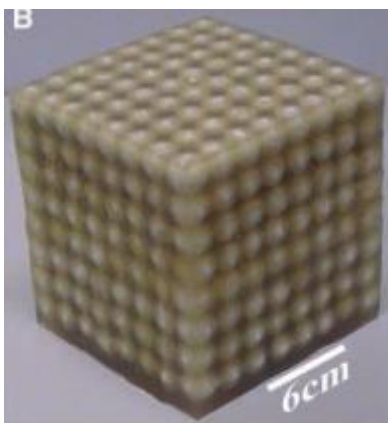
汇报人：张秀海

指导老师：屈治国 教授

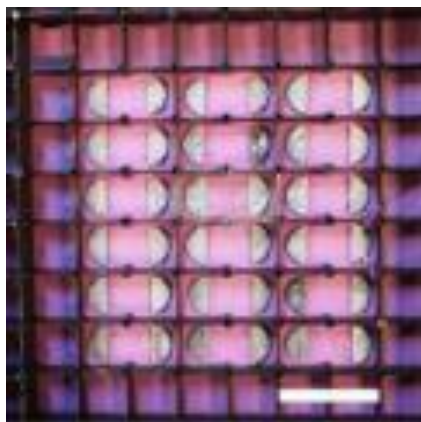
汇报内容

- ✓ 声学超材料
- ✓ 声场旋转器相关理论
- ✓ 声场旋转器结构单元尺寸对其工作带宽的影响
- ✓ 近期研究工作（连续梯度结构声子晶体）

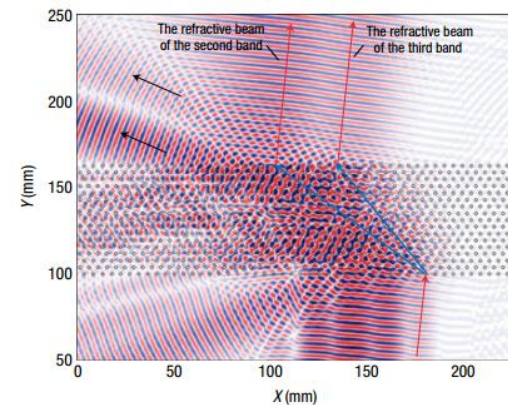
声学超材料



局域共振声子晶体



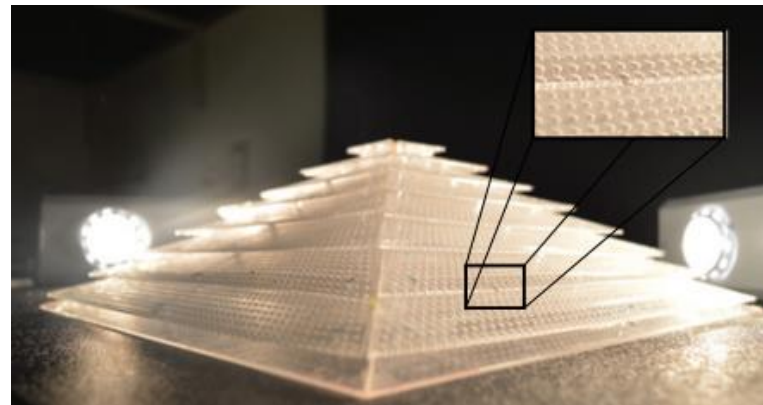
薄膜吸声超材料



双负折射



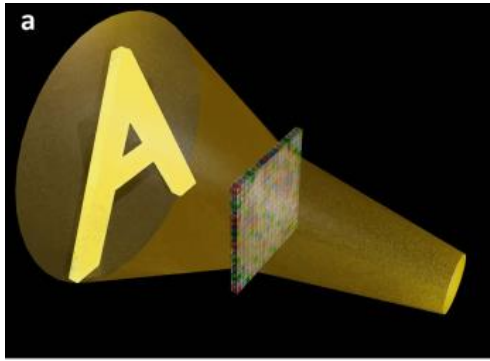
低频声波指向性超材料



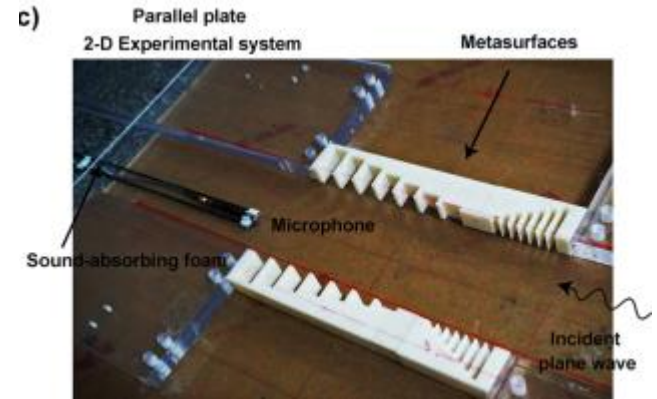
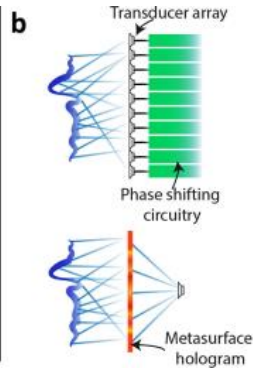
三维隐声结构

- Liu Z et al. Science, 2000, 289(5485): 1734-1736.
- Mei J et al. Nature communications, 2012, 3: 756.
- Lu M H et al. Nature materials, 2007, 6(10): 744-748.
- Quan L et al. Nature communications, 2014, 5.
- Zigoneanu L et al. Nat. Mater, 2014, 13(4): 352-355.

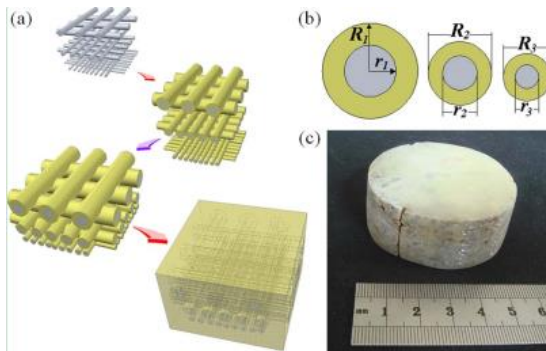
声学超材料



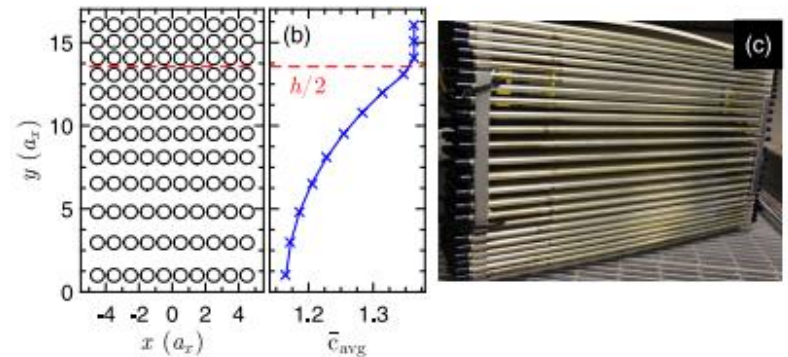
声学全息图



声单向通道



局域共振声子晶体



局域共振声子晶体

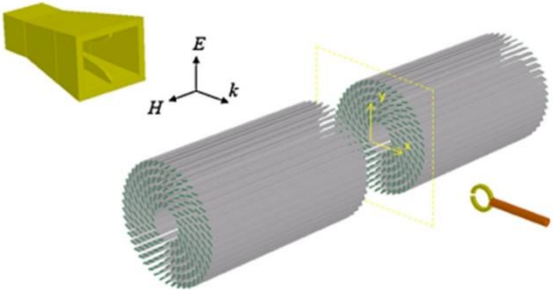
Xie Y et al. Scientific reports, 2016, 6: 35437.

Zhu Y F et al. Applied Physics Letters, 2015, 107(11): 113501.

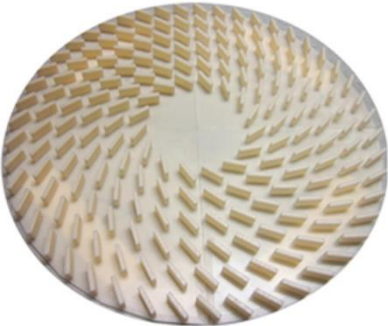
Jiang H et al. Applied Physics Letters, 2009, 95(10): 104101.

Martin T P et al. Physical Review Applied, 2015, 4(3): 034003.

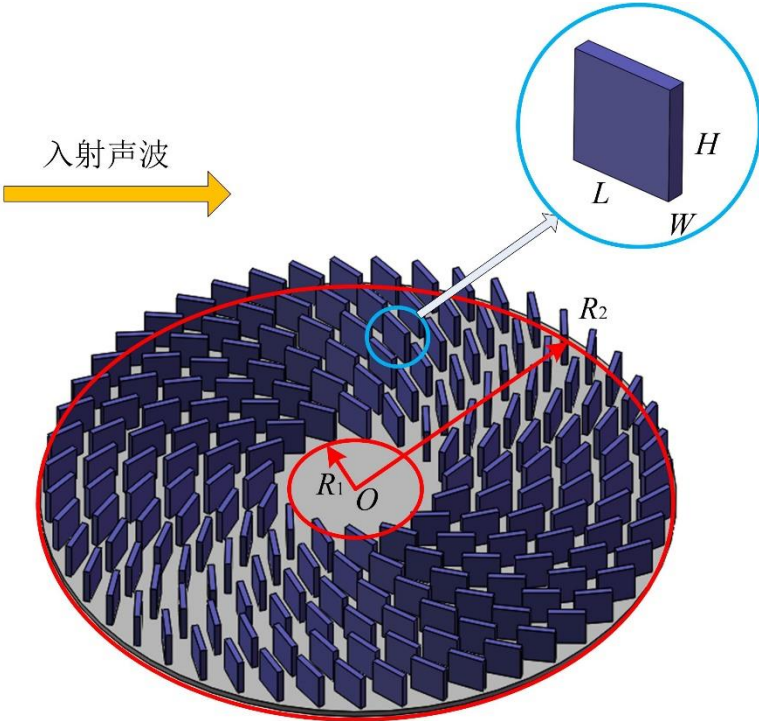
声学超材料



电磁场旋转器



声场旋转器



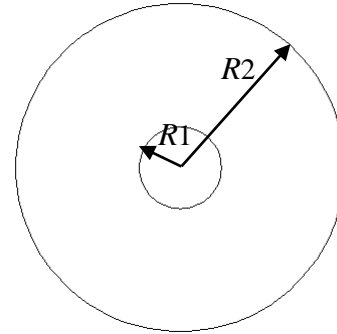
声场旋转器示意图

声场旋转器相关理论

$$r' = r, \quad \theta' = \theta + \theta_0 \quad (\text{for } r < R_1),$$

$$r' = r, \quad \theta' = \theta + \theta_0 \frac{f(R_2) - f(r)}{f(R_2) - f(R_1)} \quad (\text{for } R_1 < r < R_2),$$

$$r' = r, \quad \theta' = \theta \quad (\text{for } r > R_2).$$



$$\rho^{i'j'} = \left| \det(\Lambda_i^{i'}) \right|^{-1} \Lambda_i^{i'} \Lambda_j^{j'} \rho^{ij}$$

$$\Lambda = \begin{bmatrix} \Lambda_1^1 & \Lambda_2^1 \\ \Lambda_1^2 & \Lambda_2^2 \end{bmatrix} = \begin{bmatrix} \frac{\partial x'}{\partial x} & \frac{\partial x'}{\partial y} \\ \frac{\partial y'}{\partial x} & \frac{\partial y'}{\partial y} \end{bmatrix}$$

$$\vec{\rho}'^{-1} = \vec{\rho}_0^{-1} \begin{bmatrix} 1 + 2t \cos \theta' \sin \theta' + t^2 \sin^2 \theta' & -t^2 \cos \theta' \sin \theta' - t(\cos^2 \theta' - \sin^2 \theta') \\ -t^2 \cos \theta' \sin \theta' - t(\cos^2 \theta' - \sin^2 \theta') & 1 - 2t \cos \theta' \sin \theta' + t^2 \sin^2 \theta' \end{bmatrix}$$

$$t = \frac{\theta_0 r f'(r)}{f(R_2) - f(R_1)}$$

声场旋转器相关理论

$$\vec{p}'^{-1} = \vec{p}_0^{-1} \begin{bmatrix} 1 + 2t \cos \theta' \sin \theta' + t^2 \sin^2 \theta' & -t^2 \cos \theta' \sin \theta' - t(\cos^2 \theta' - \sin^2 \theta') \\ -t^2 \cos \theta' \sin \theta' - t(\cos^2 \theta' - \sin^2 \theta') & 1 - 2t \cos \theta' \sin \theta' + t^2 \sin^2 \theta' \end{bmatrix}$$



$$\vec{p}'^{-1} = \vec{p}_0^{-1} \begin{bmatrix} \cos(\tau/2) & -\sin(\tau/2) \\ \sin(\tau/2) & \cos(\tau/2) \end{bmatrix} \begin{bmatrix} \cos \theta' & -\sin \theta' \\ \sin \theta' & \cos \theta' \end{bmatrix} \begin{bmatrix} \varepsilon_u & 0 \\ 0 & \varepsilon_v \end{bmatrix}$$

$$\begin{bmatrix} \cos \theta' & \sin \theta' \\ -\sin \theta' & \cos \theta' \end{bmatrix} \begin{bmatrix} \cos(\tau/2) & \sin(\tau/2) \\ -\sin(\tau/2) & \cos(\tau/2) \end{bmatrix}$$

$$\cos \tau = \frac{t}{\sqrt{t^2 + 4}}$$

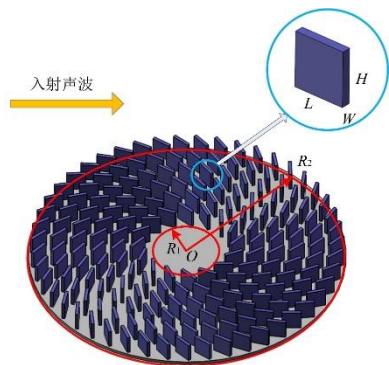
$$\varepsilon_u = 1 + \frac{1}{2}t^2 - \frac{1}{2}t\sqrt{t^2 + 4}$$

$$\sin \tau = \frac{4}{\sqrt{t^2 + 4}}$$

$$\varepsilon_v = 1 + \frac{1}{2}t^2 + \frac{1}{2}t\sqrt{t^2 + 4}$$

$$t = \frac{\theta_0 r f'(r)}{f(R_2) - f(R_1)} \quad \longrightarrow \quad \text{If } f(r) = \ln r, \text{ then } t = \frac{\theta_0}{\ln(R_2 / R_1)}$$

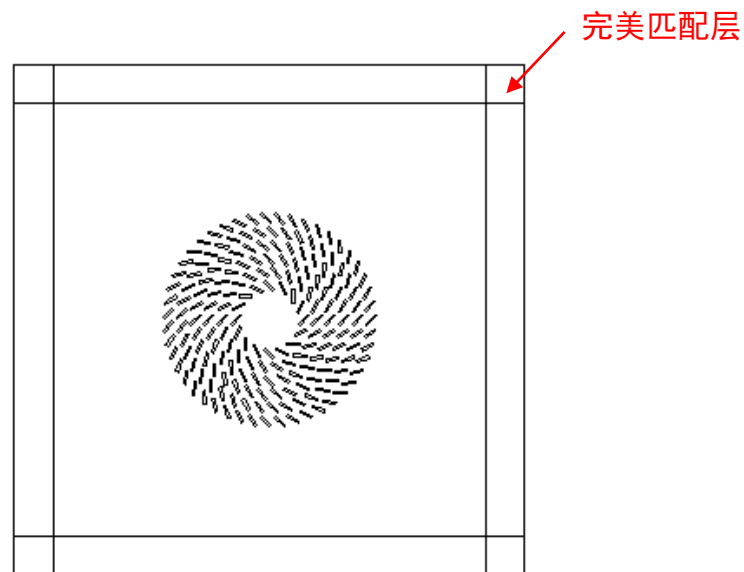
声场旋转器结构单元尺寸对其工作带宽的影响



| NO. | Length of building block (mm) | Width of building block (mm) | Ratio of length to width | Layers of building block |
|------|-------------------------------|------------------------------|--------------------------|--------------------------|
| R1-1 | 11.2 | 2.8 | 4: 1 | 9 |
| R1-2 | 14 | 2.8 | 5: 1 | 7 |
| R1-3 | 16.8 | 2.8 | 6: 1 | 6 |
| R1-4 | 19.6 | 2.8 | 7: 1 | 5 |
| R1-5 | 22.4 | 2.8 | 8: 1 | 4 |

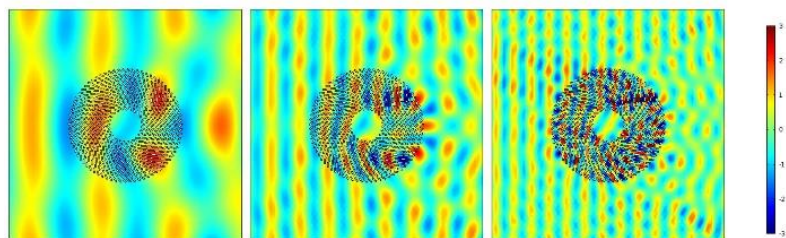
COMSOL

- 压力声学模块
- 固体力学模块



声场旋转器结构单元尺寸对其工作带宽的影响

R1-1

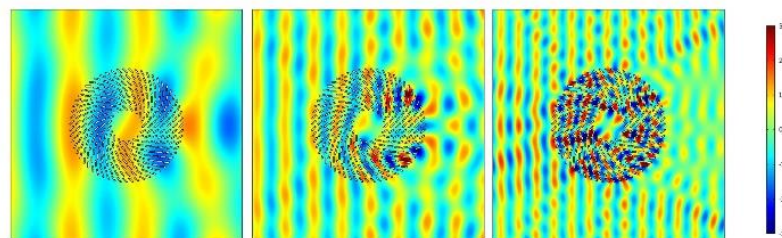


(a)

(b)

(c)

R1-2

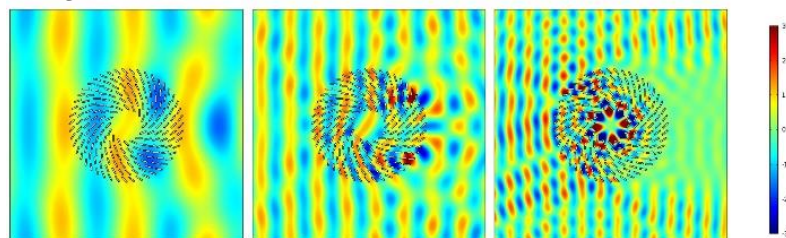


(a)

(b)

(c)

R1-3

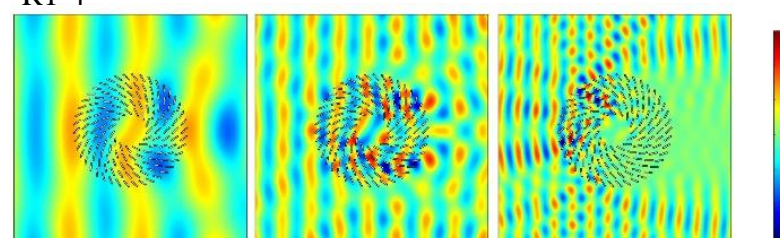


(a)

(b)

(c)

R1-4

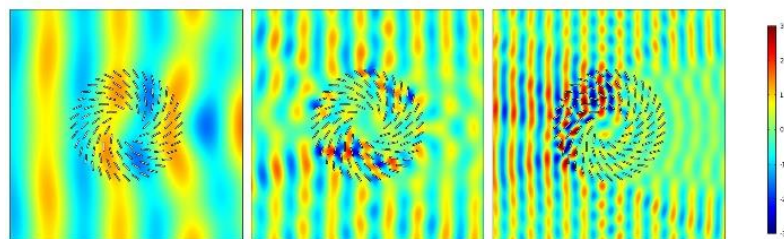


(a)

(b)

(c)

R1-5

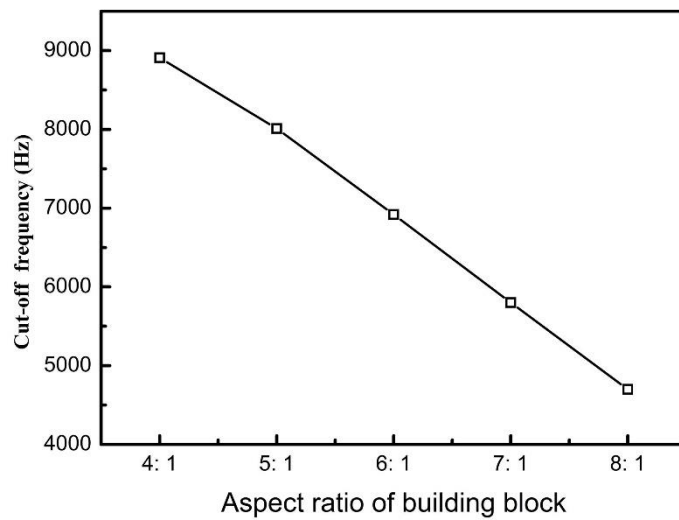
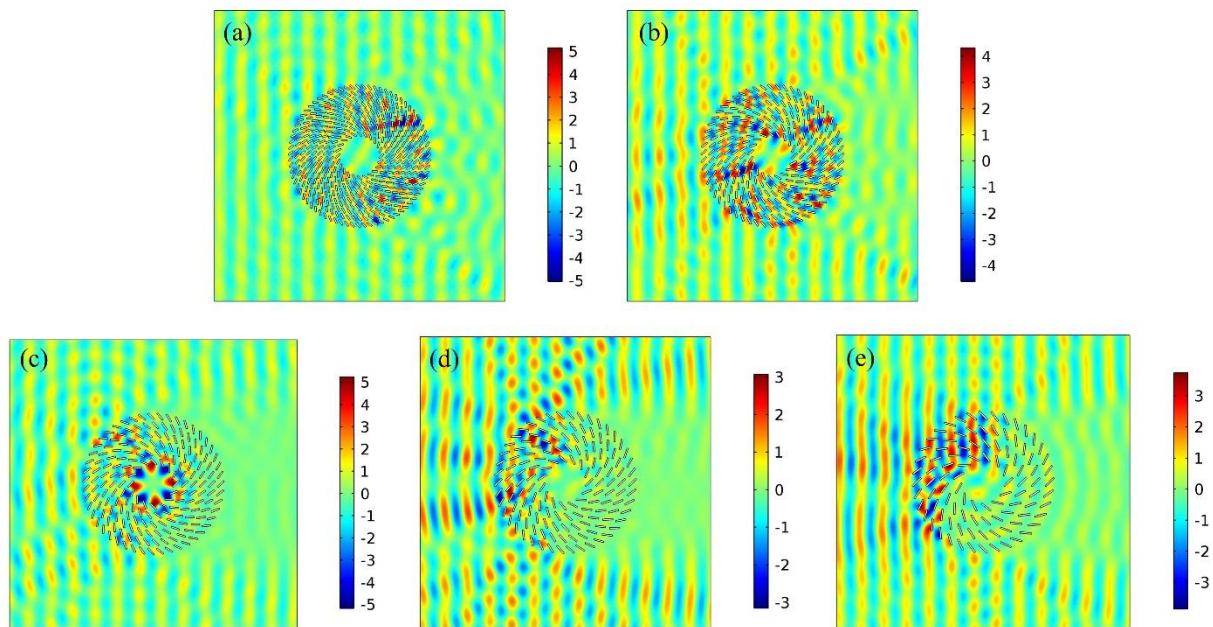


(a)

(b)

(c)

声场旋转器结构单元尺寸对其工作带宽的影响

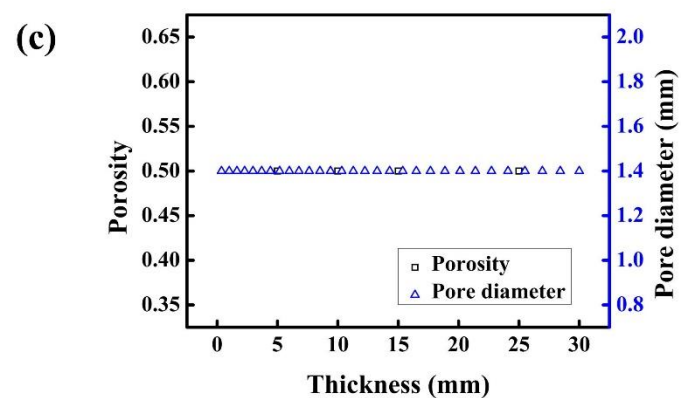
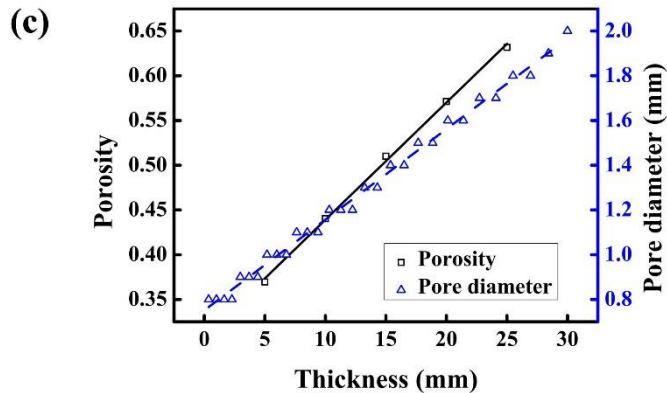
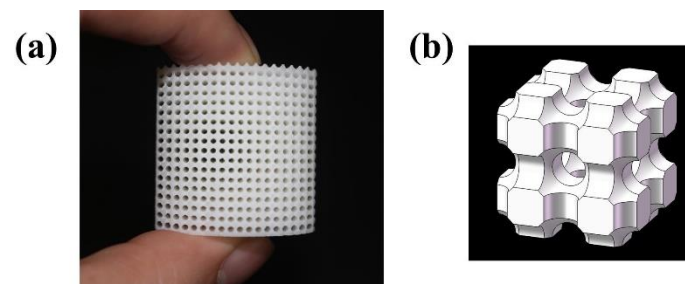
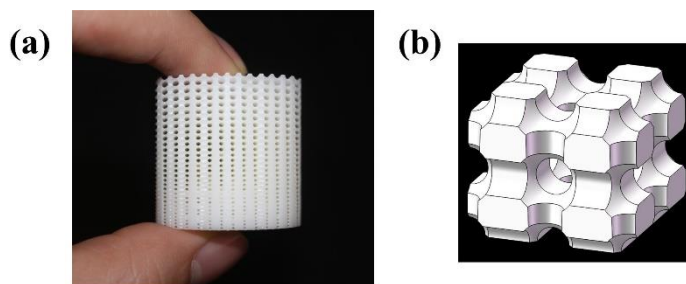


结论（声场旋转器部分）

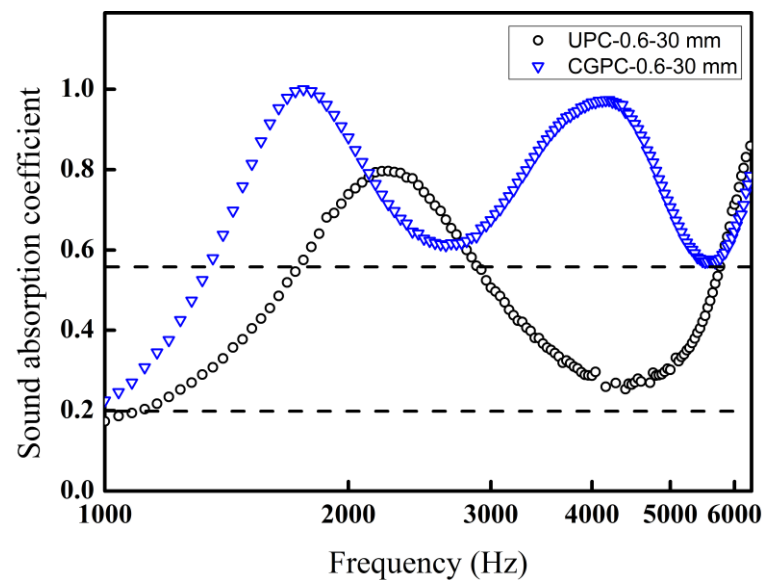
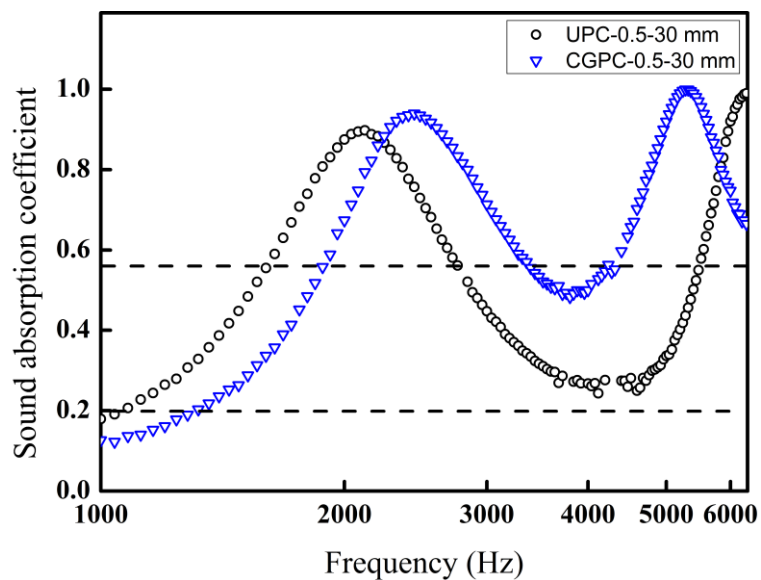
本文具体研究了声场旋转器结构尺寸对其工作带宽的影响，发现当结构单元为长方体时：

- 随着长方体结构单元长宽比的增加，尽管声场旋转器在低频仍能工作，但其可以工作的高频频率是下降的，即声场旋转器的工作带宽是变窄的，且声场旋转器的高频截止频率与长方体结构单元长宽比基本成线性关系；

近期研究工作-连续梯度结构声子晶体



近期研究工作-连续梯度结构声子晶体



近期研究工作-连续梯度结构声子晶体

设计了一种具有连续梯度结构的声子晶体，并实验研究了其吸声性能，实验结果表明，相比于均匀孔的声子晶体，该连续梯度结构声子晶体：

- 在更宽的频率范围内都具有高效的吸声性能；
- 在低频区的吸声性能也有所提高；
- 在测试频率范围内有更多的吸声峰值。

下一计划，利用 COMSOL Multiphysics® 模拟验证实验结果。

感谢各位专家批评指正!

更多建议与问题:

屈治国 zgqu@mail.xjtu.edu.cn

张秀海 zhangxiuhai000@stu.xjtu.edu.cn