COMSOL CONFERENCE 2018 SHANGHAI

基于耦合单负超材料单元的多带双负声学超材料

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双负声超材料简介

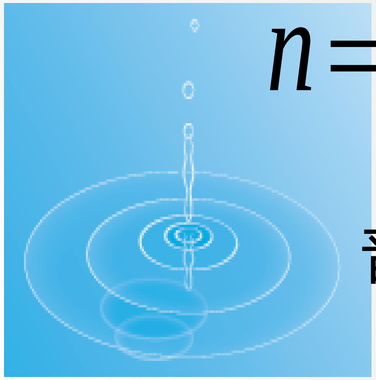
K

ρ

$K>0, \rho<0$

$n = i\sqrt{\rho/|K|}$

倏逝波



$K>0, \rho>0$

$n = \sqrt{\rho/K} > 0$

普通材料

$K<0, \rho<0$

$n = -\sqrt{|\rho|/|K|} < 0$

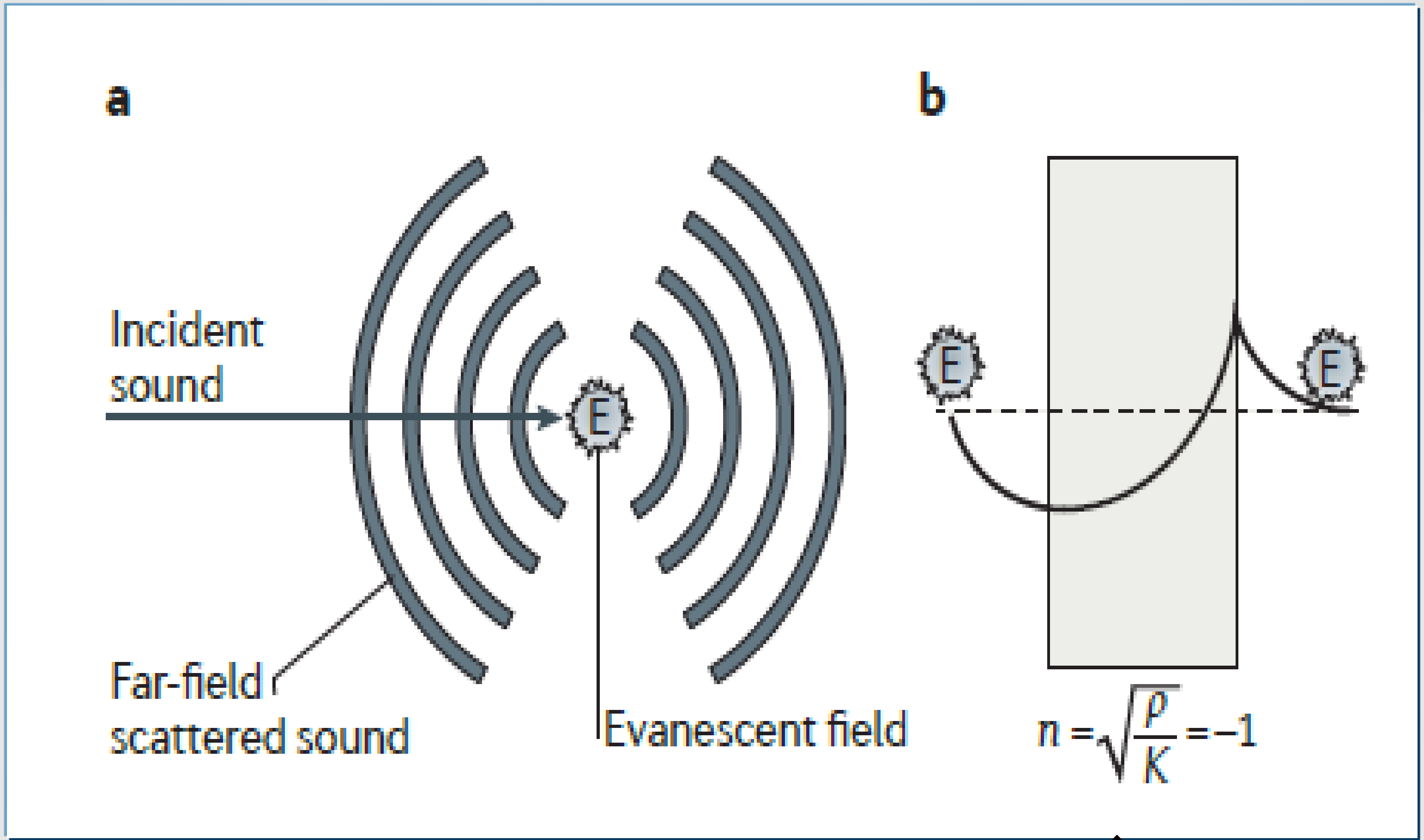
双负超材料

$K<0, \rho>0$

$n = i\sqrt{|\rho|/K}$

倏逝波

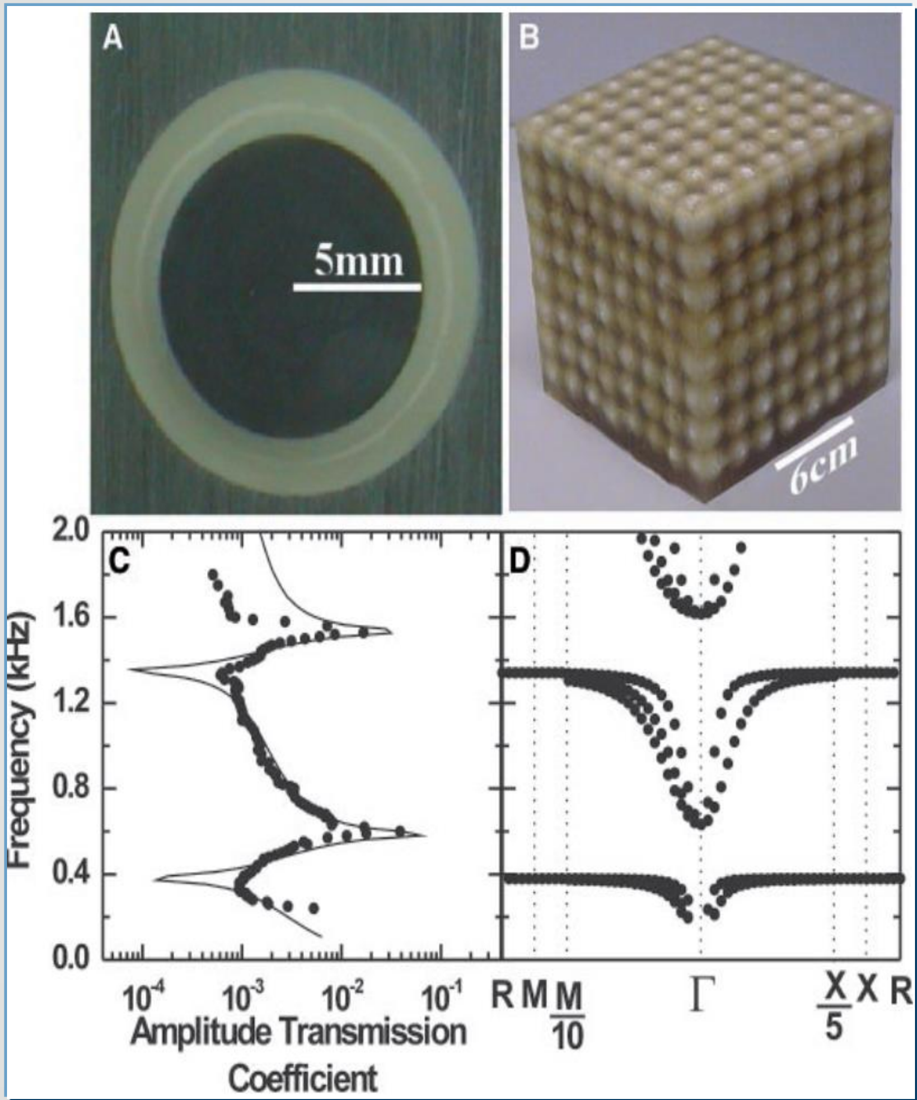
双负声超材料应用



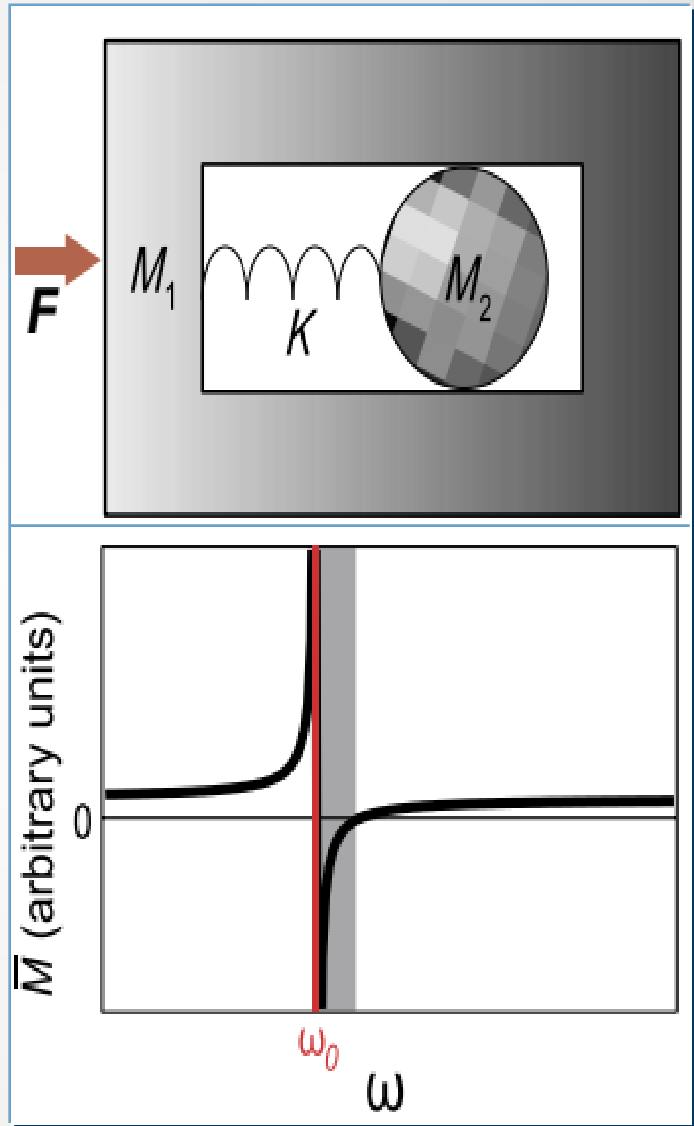
Cummer S A, Christensen J, Alù A.
Nature Reviews Materials, 2016, 1: 16001

倏逝波放大实现远场汇聚

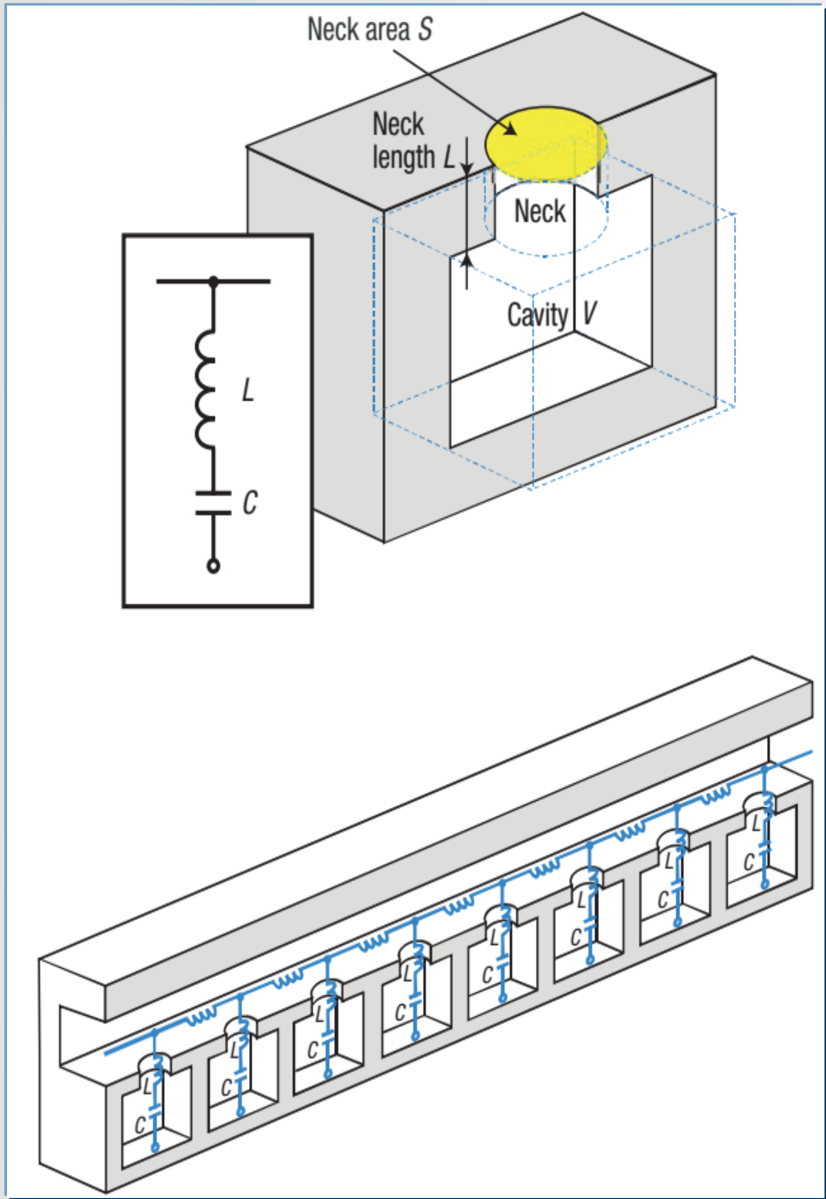
常见声超材料

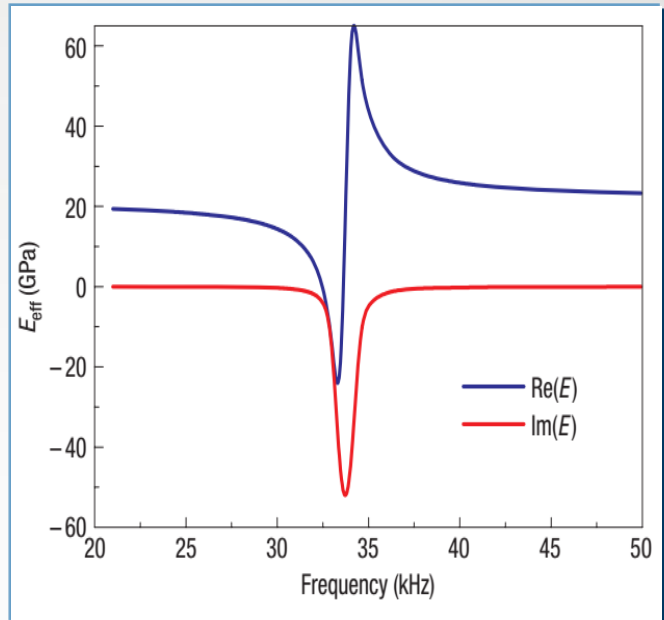


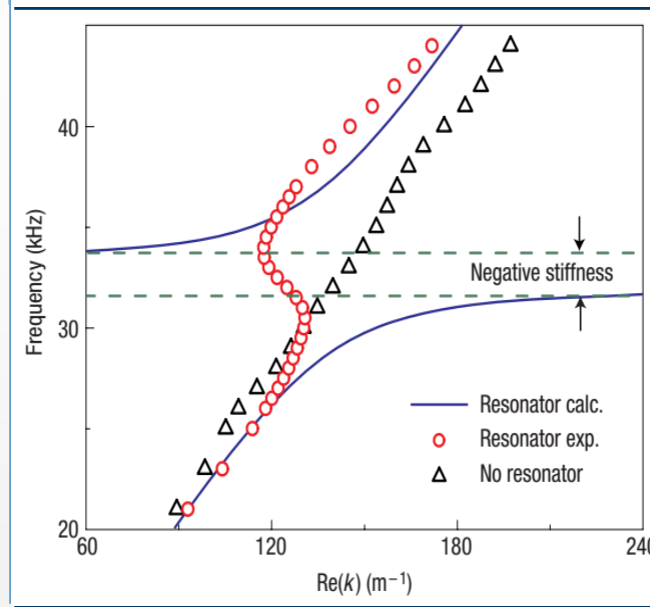
Z. Liu et al.,Science .289, 1734–1736 (2000)



$\bar{\rho}<0$ 负有效密度







Fang, N. et al.,Nat. Mater. 5, 452–456 (2006)

$\bar{K}<0$ 负有效模量

负参数机理解释

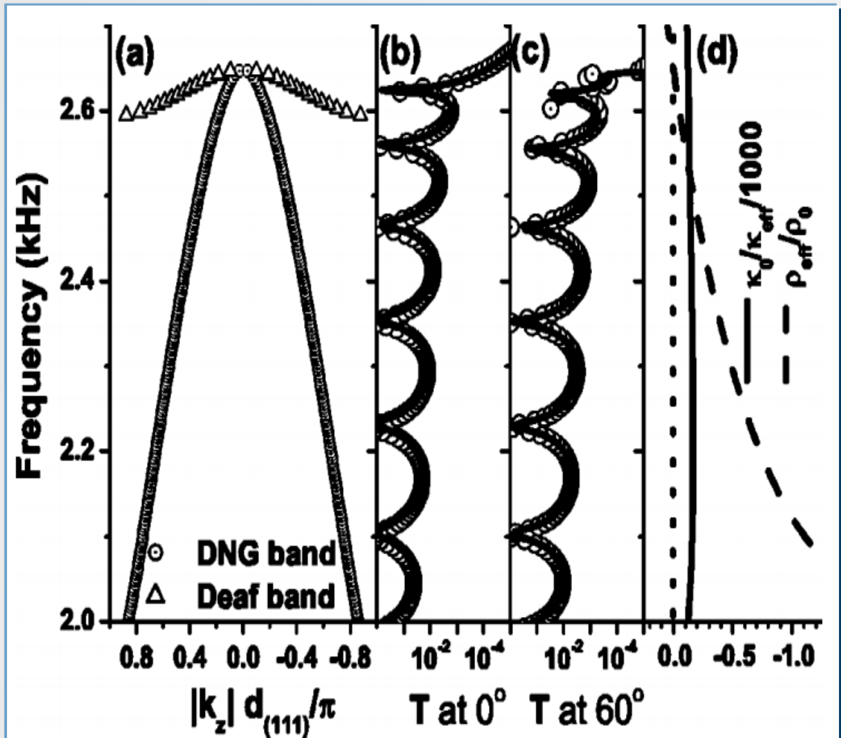
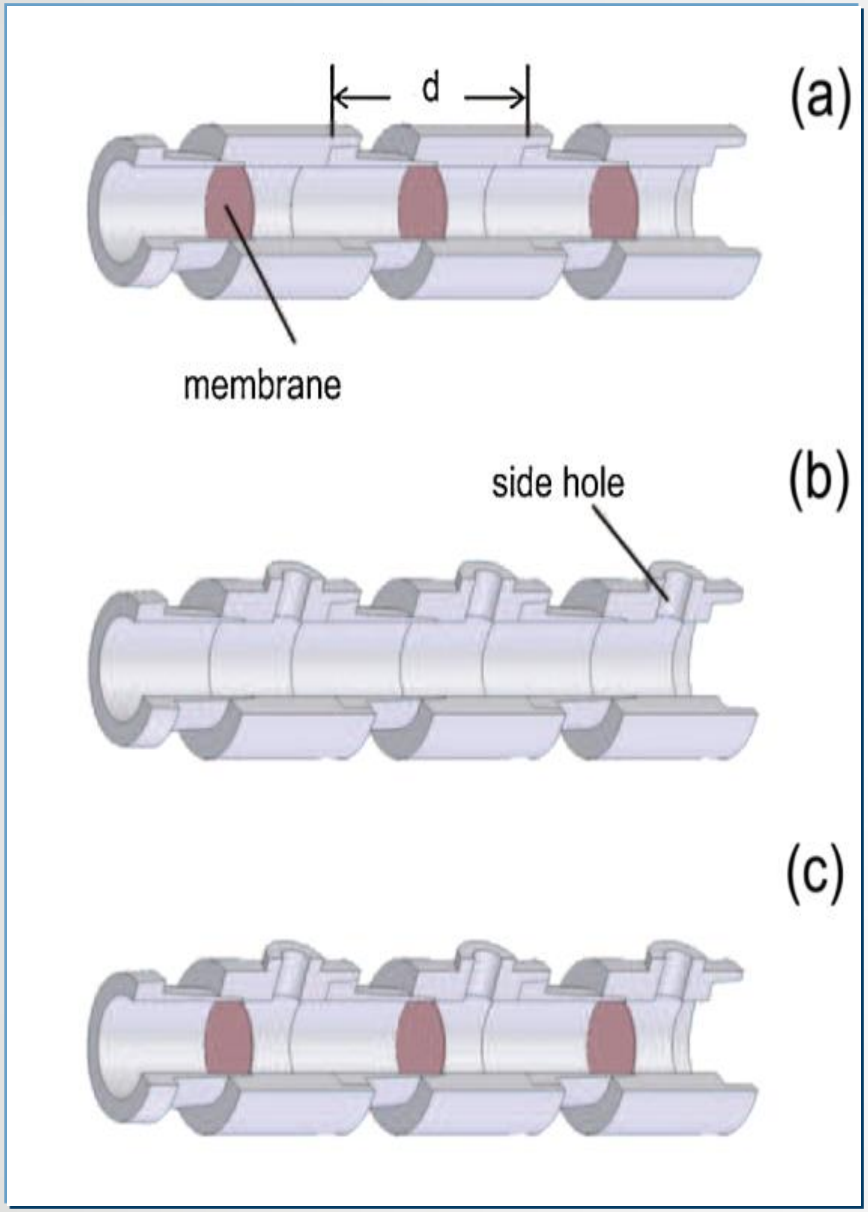


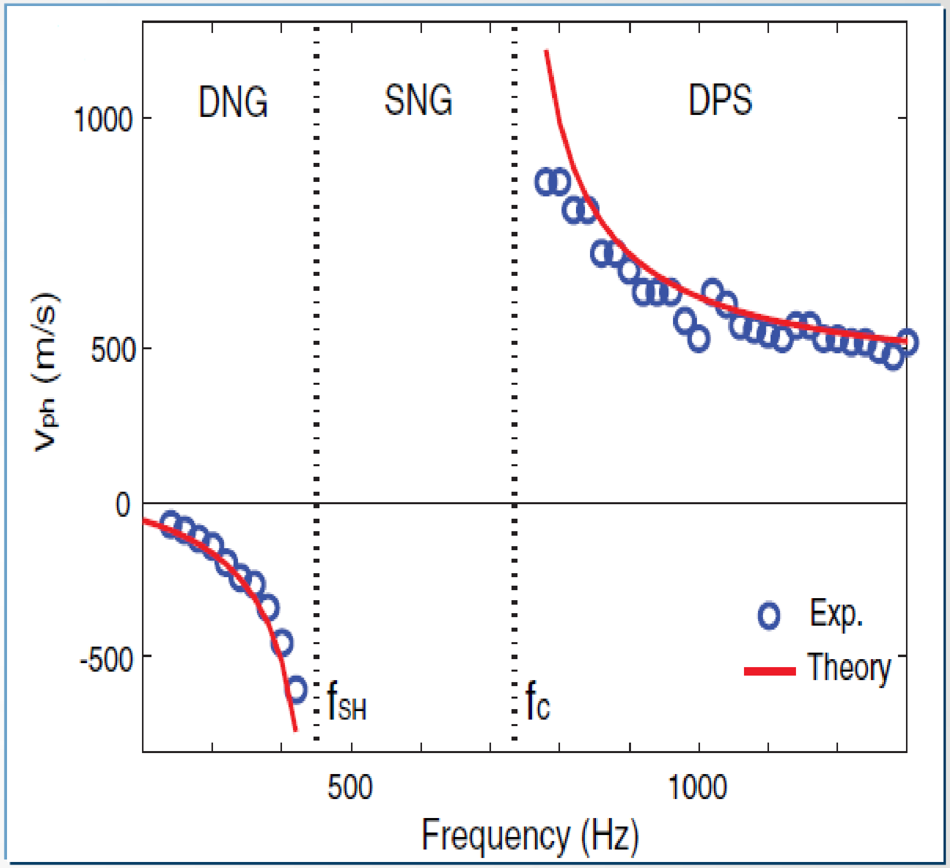
FIG. 2. Double acoustic negativity and negative refractive index of rubber spheres in water, fcc arrangement with a filling ratio of 40%. (a) Dispersion; (b) and (c) The transmittance through eight layers of the (111) planes at normal and 60° incidence. The open circles are calculated by the multiple-scattering method and the solid line is the approximation using homogeneous media with effective bulk modulus and density [as shown in panel (d)] extracted from the dispersion.

单极子共振时质量中心不随时间变化，产生等效负模量

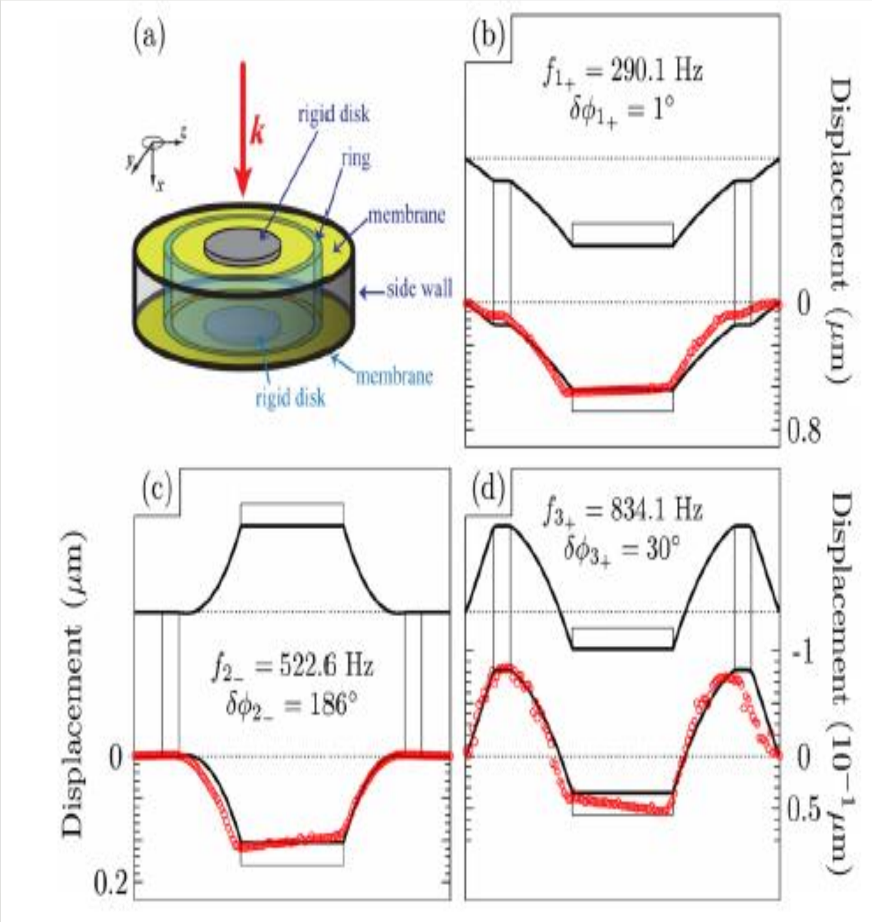
偶极子共振时质量中心随时间变化产生负的等效密度

Jensen Li, and CT Chan, Physical Review E, 70 (2004),055602.

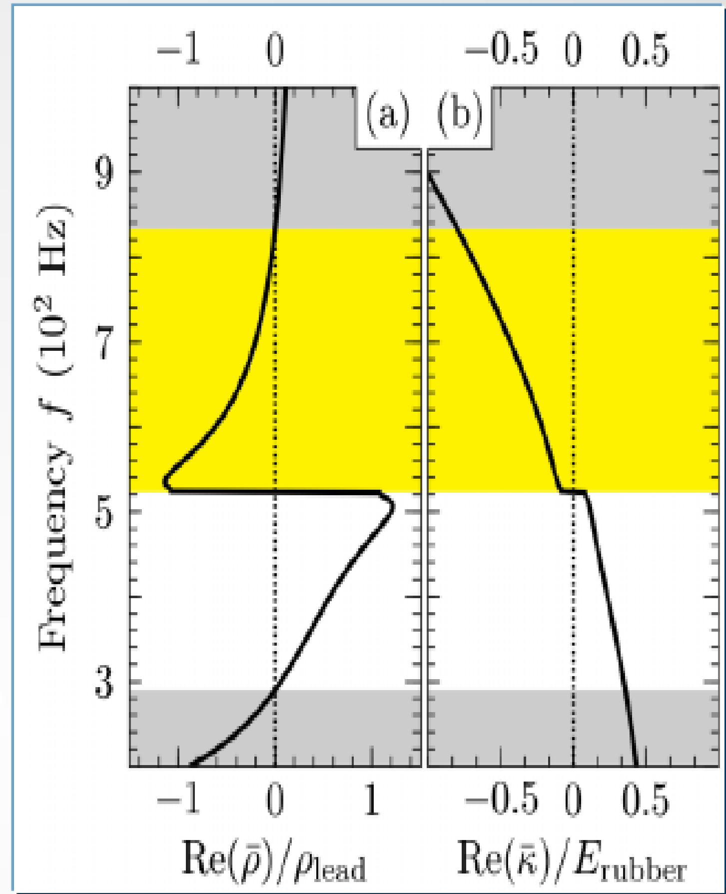




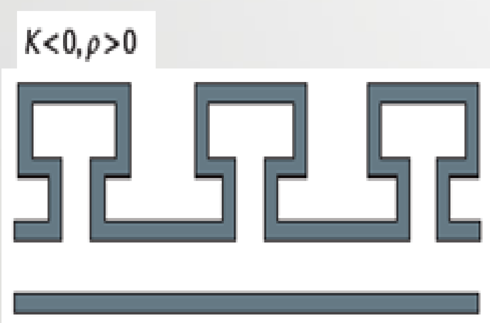
***Sam Hyeon Lee et al., Physical review letters*, 104 (2010), 054301.**



Yang M, Ma G, Yang Z, et al.. Physical review letters, 2013, 110(13): 134301.

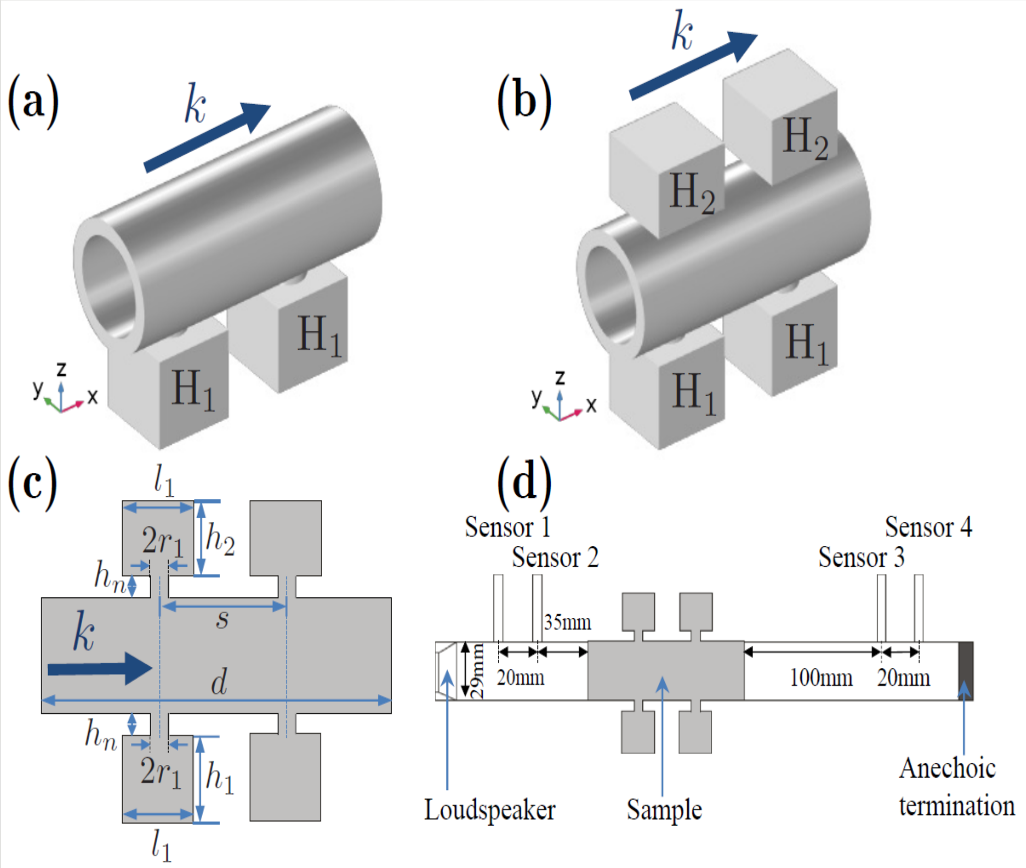


优点：单负材料耦合实现双负
缺点：结构损耗大，可调控性差



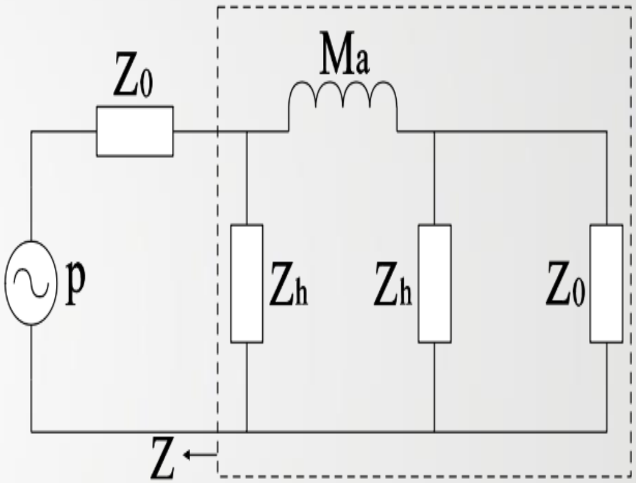
单负Helmholtz共鸣器耦合实现双负

研究方法



耦合结构和测量方法：(a)单带双负超材料单元。(b)双带双负超材料单元。(c)双带结构的截面图 (d)实验测量示意图

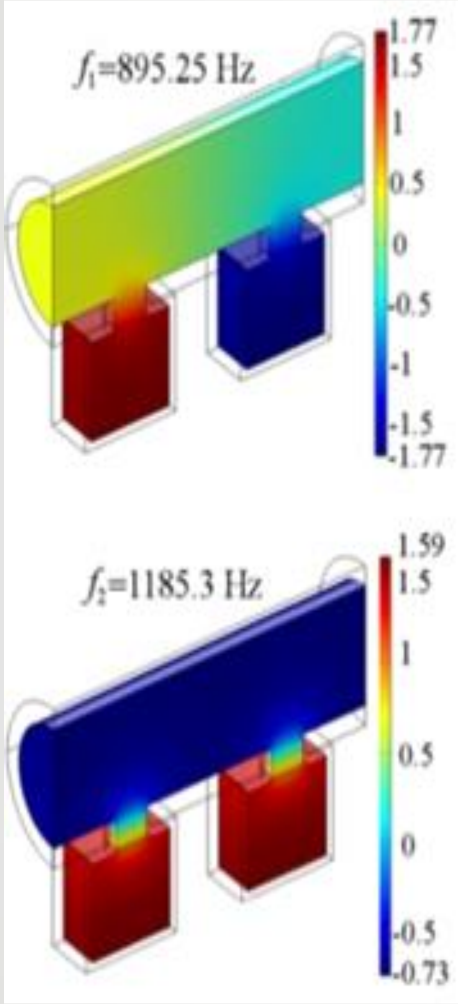
单带双负结构的等效电路

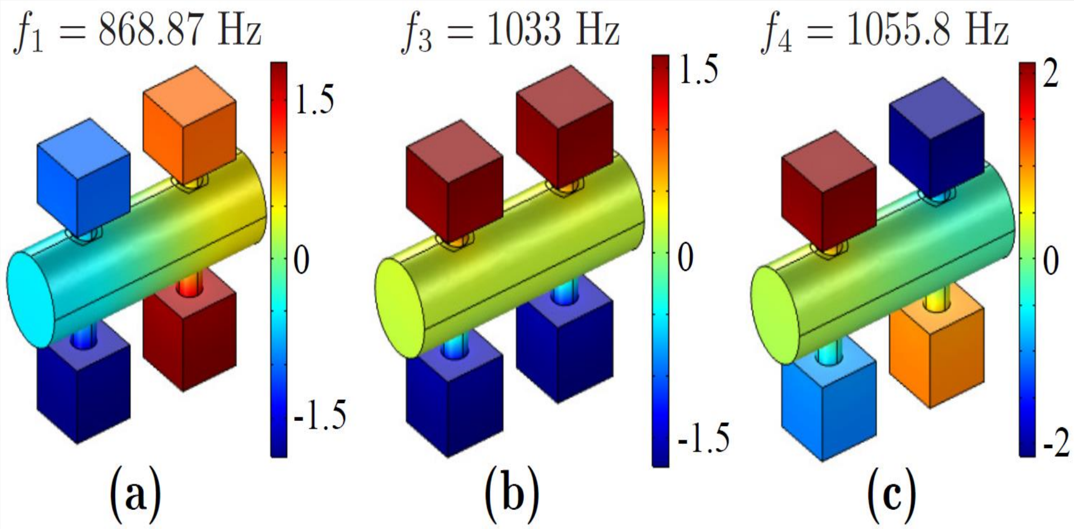


耦合声质量 $M_a = \rho_0 s / A$

s耦合距离，A 波导截面积

基于COMSOL求解结构本征频率





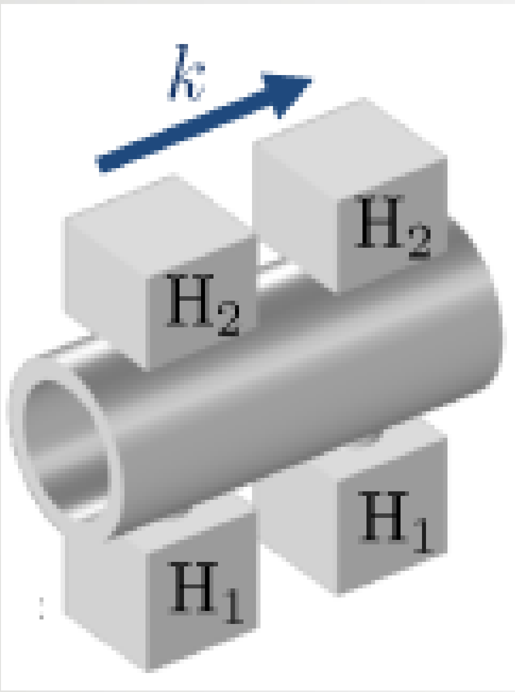
H1和H2双负带结构声压场分布(a)H1耦合反相共振。(b)H1-H2耦合同相共振。(c)H2耦合反相共振

同频率H1耦合结构声压场分布

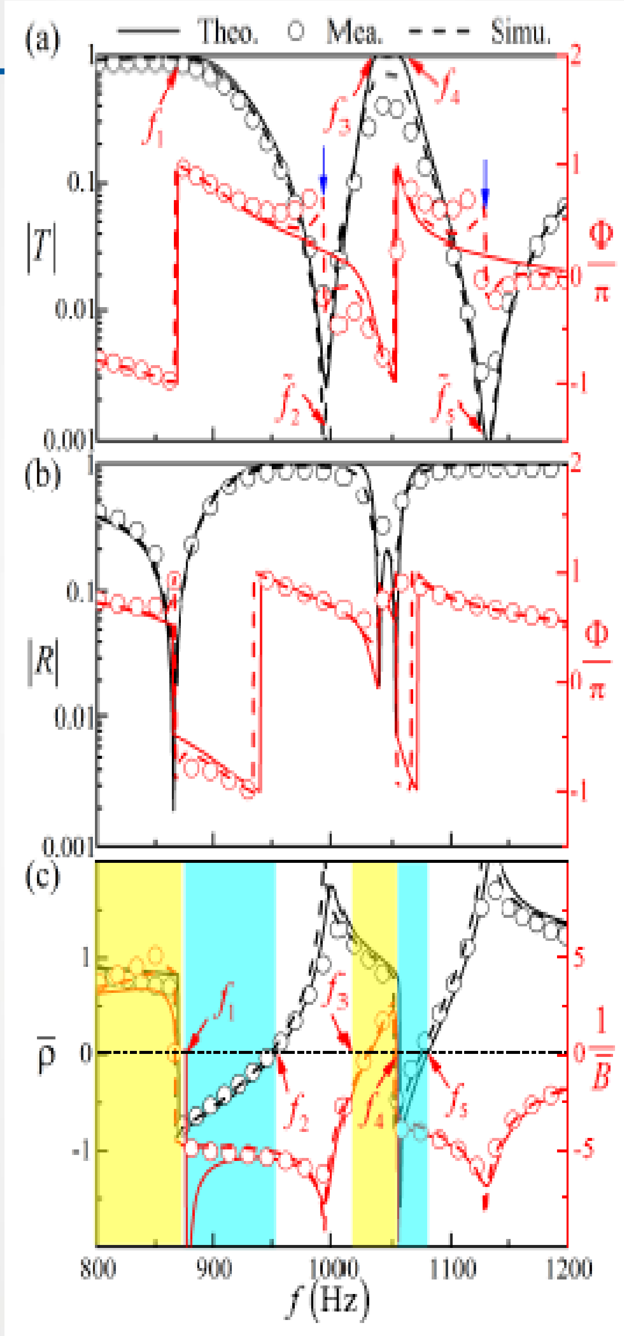
基于COMSOL频域分析

H1共振频率1000Hz

H2共振频率1130Hz

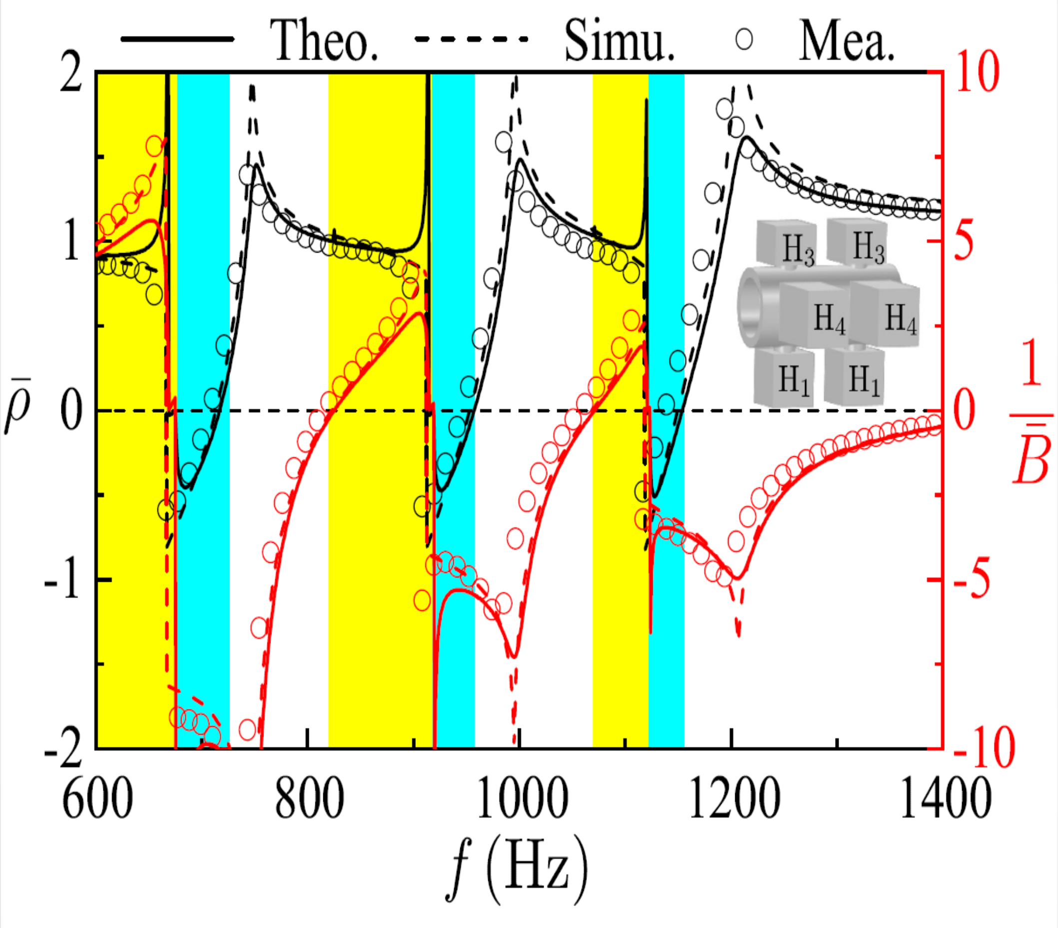


双带双负超材料单元分析



实验、仿真和理论分析结果：(a)透射谱和相位。(b)反射谱和相位。(c)有效密度和有效压缩系数

多带双负结构分析



H1共振频率1000Hz

H3共振频率752Hz

H4共振频率1214Hz

实验、仿真和理论分析提取三带双负单元有效参数

研究结论

◆基于单负双Helmholtz共鸣器耦合实现了双负超材料。
◆基于多Helmholtz共鸣器两两耦合实现了多带双负超材料。

◆研究成果可用于调控双负材料带宽和双负带区间。

◆相关研究已经发表:

Zhou, Yukun, et al. "Acoustic Multiband Double Negativity from Coupled Single-Negative Resonators." *Physical Review Applied* 10.4 (2018): 044006.

Thank you for your attention！

UIS课题组：周玉坤