安徽理工大學
ANHUI UNIVERSITY OF SCIENCE & TECHNOLOGY

2023年人工微结构光声调控物理与应用学术研讨会

声学斯格明子模式调控研究

吴宏伟

2023. 10. 25 安徽 淮南

安徽理工大学 力学与光电物理学院

目录

背景:斯格明子

斯格明子，是一种具有准粒子特性并且受拓扑保护的自旋结构。由英国物理学家托尼·斯格明（Tony Hilton Royle Skyrme）于1962年首次发现，由他的名字而命名。

磁性材料中斯格明子的尺寸可以小到纳米级，有着受拓扑保护的稳定性。同时，驱动斯格明子状态改变的电流密度，比驱动传统磁畴所需的低5到6个量级。由于这些卓越的特性，斯格明子被普遍认为是高密度、高速度、低能耗的新一代磁存储器件的理想信息存储单元之一。

背景:光学斯格明子模式

Electric field skyrmion configuration

Science

RESEARCH ARTICLES

Cite as: S. Tsesses *et al.*, *Science* 10.1126/science.aau0227 (2018).

Optical skyrmion lattice in evanescent electromagnetic fields

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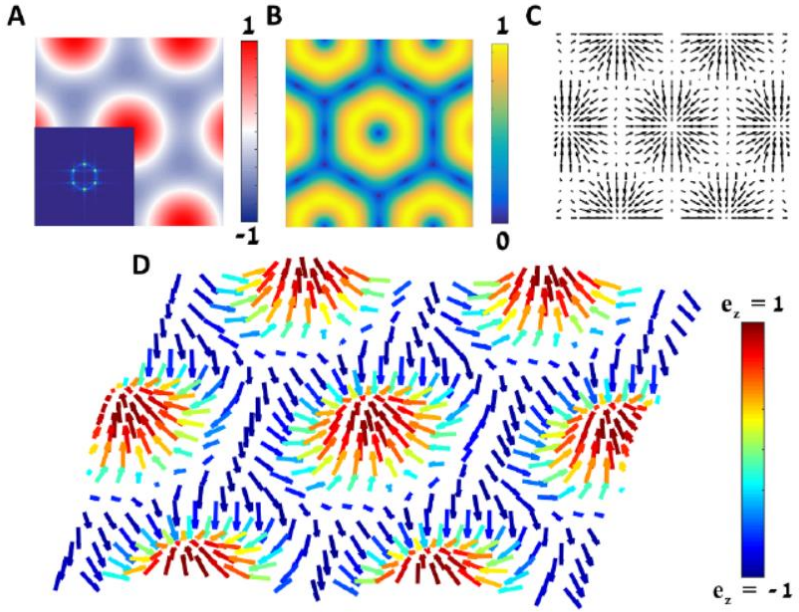
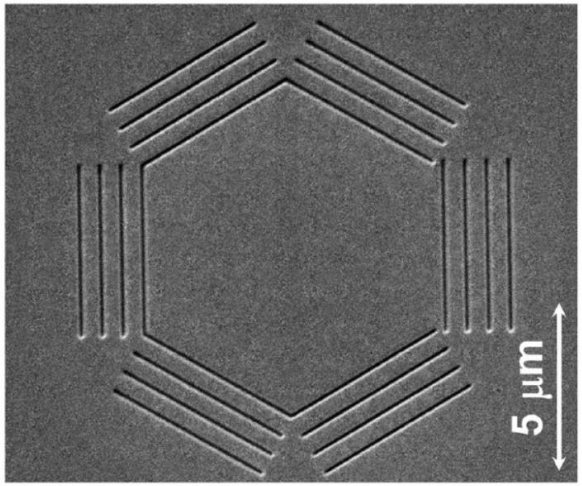
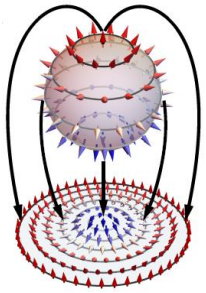
Topological defects play a key role in a variety of physical systems, ranging from high-energy to solid state physics. A skyrmion is a type of topological defect that has shown promise for applications in the fields of magnetic storage and spintronics. We show that optical skyrmion lattices can be generated using evanescent electromagnetic fields and demonstrate this using surface plasmon polaritons, imaged by phase-resolved near-field optical microscopy. We show how the optical skyrmion lattice exhibits robustness to imperfections while the topological domain walls in the lattice can be continuously tuned, changing the spatial structure of the skyrmions from bubble-type to Néel-type. Extending the generation of skyrmions to photonic systems provides various possibilities for applications in optical information processing, transfer and storage.





Why use the SPP to realize the optical skyrmion?

Answer: transferring the 3D vector field from the unit sphere to plane, SPP propagate in plane and evanescent in z direction to flip the electric field.



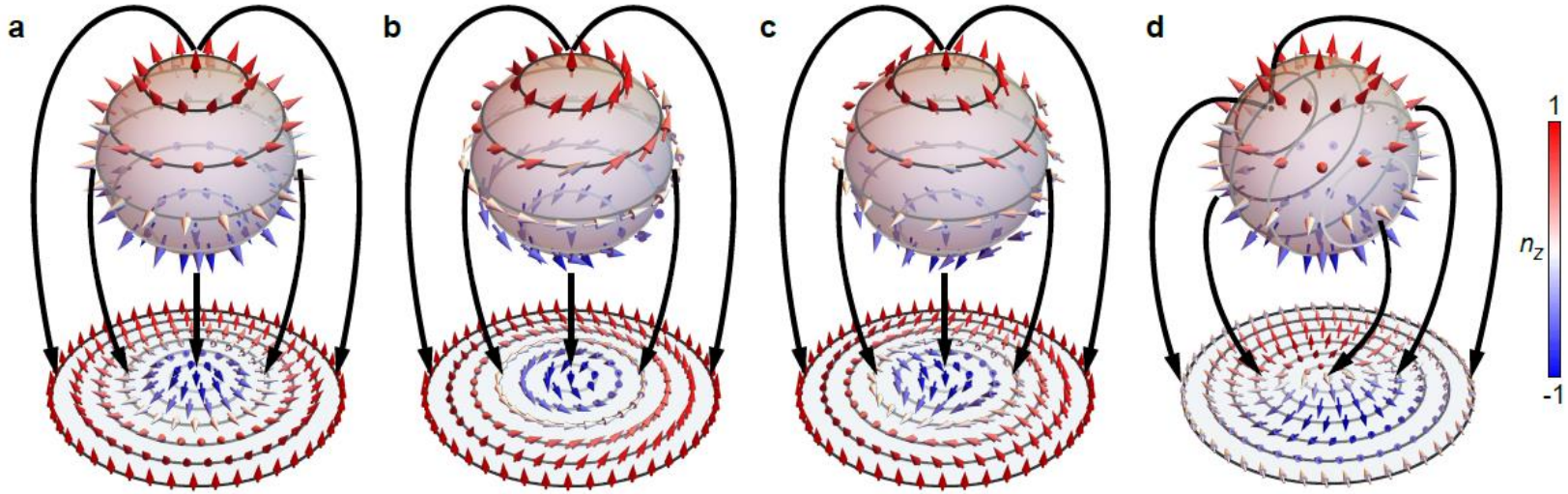
背景:光学斯格明子模式

3D vector sphere mapping to 2D vector configuration

Box 1 | Topological characteristics

The vector field to construct a 2D skyrmion, denoted as $\mathbf{n}(x,y) = [n_x(x,y), n_y(x,y), n_z(x,y)]$, can be represented as the vector distribution unwrapped from the vectors on a sphere parametrized by longitude, α, and latitude, β, angles (Fig. 1). The topological property of a skyrmionic configuration can be characterized by the skyrmion number defined as [23, 24]

$$s = \frac{1}{4\pi}\iint_{\sigma} \mathbf{n}\cdot\left(\frac{\partial \mathbf{n}}{\partial x}\times\frac{\partial \mathbf{n}}{\partial y}\right)\mathrm{d}x\mathrm{d}y \tag{1}$$

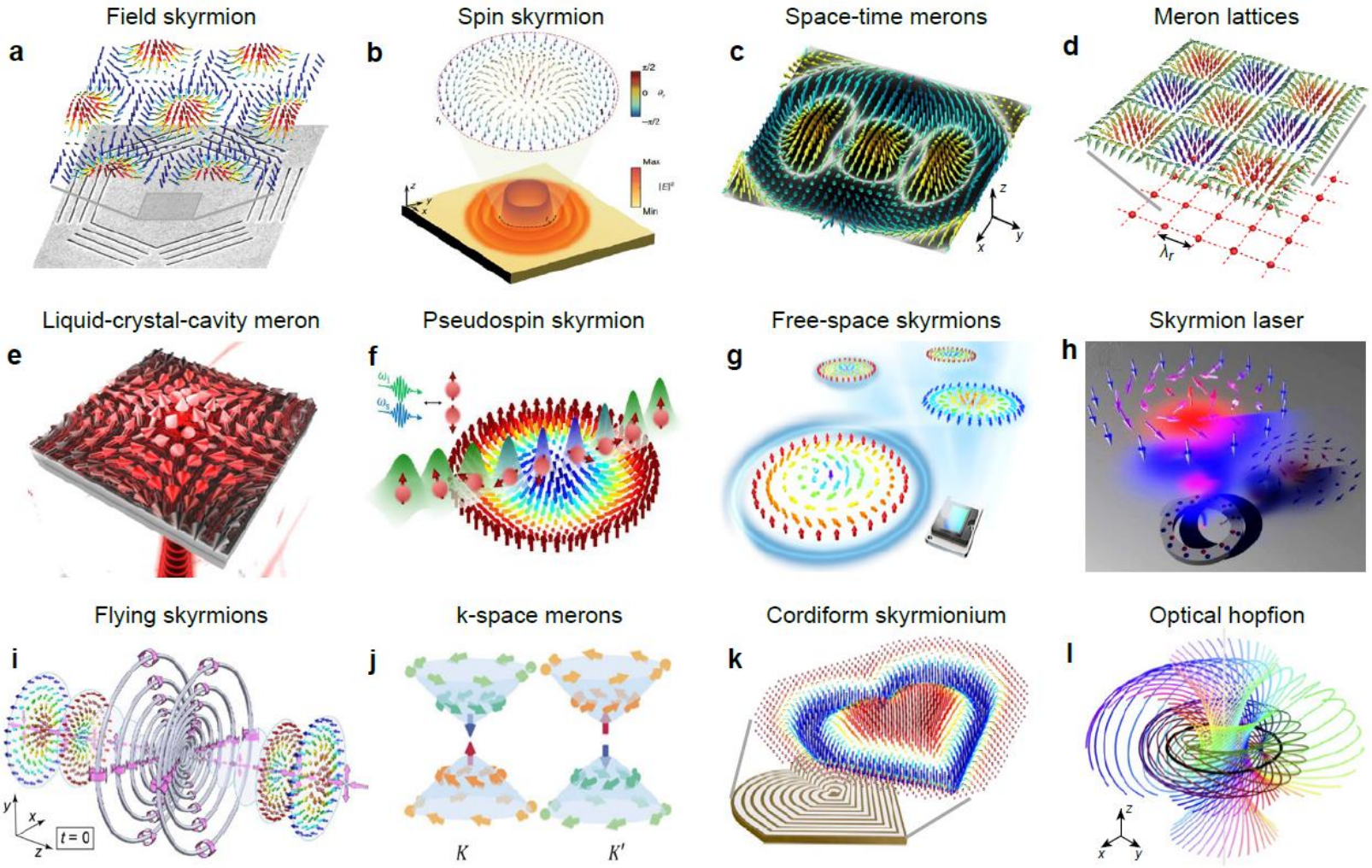


Neel-style Bloch-style Anti-style Bi-meron

Nat. Photonics in press,(2024) doi: 10.1038/s41566-023-01325-7

背景:光学斯格明子模式

Various optical skyrmion configuration

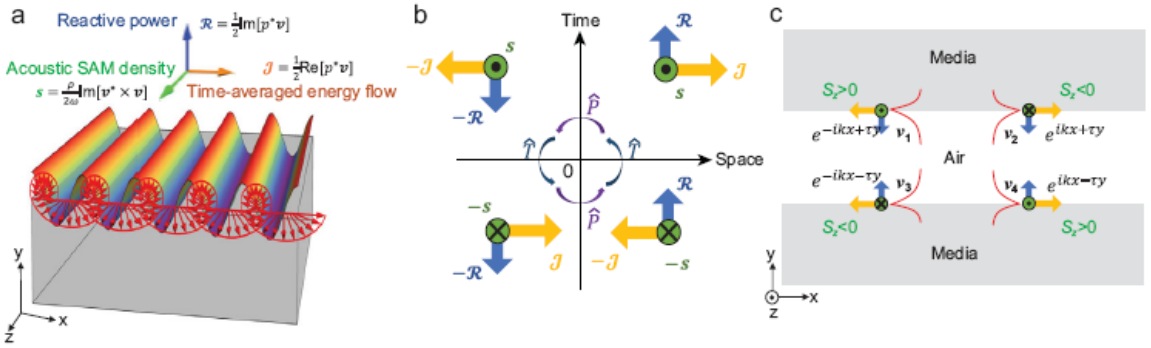


Nat. Photonics in press,(2024) doi: 10.1038/s41566-023-01325-7

背景:声学场的矢量性质

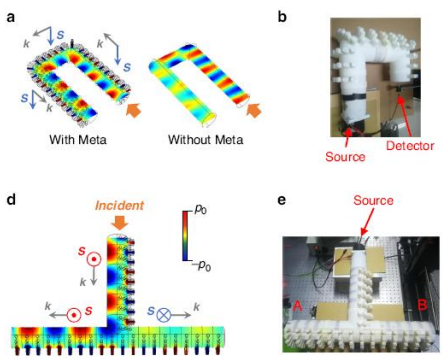
- 声学场
  - 标量压力场
  - 矢量速度场

Acoustic transverse spin in evanescent surface wave

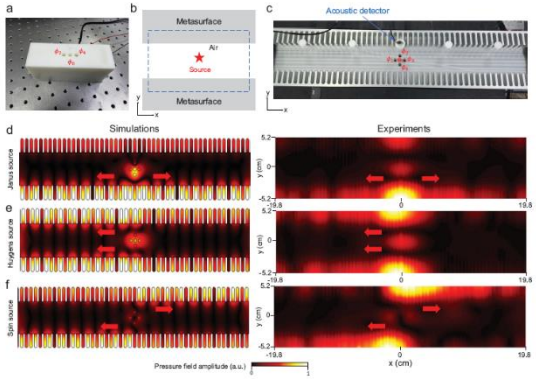


National Science Review 7, 1024 (2020)

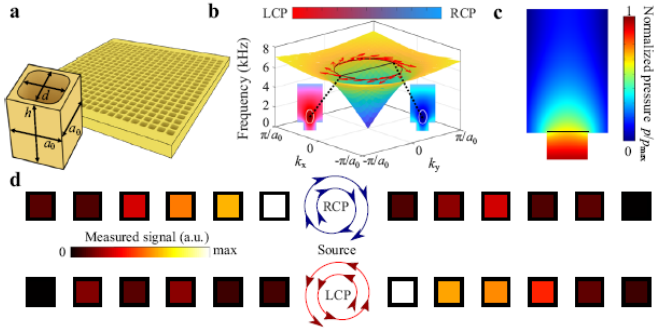
Acoustic spin-momentum lock



Nat. Commun. **11**, 4716 (2020)



National Science Review 7, 1024 (2020)



Nat. Commun. **13**, 6332 (2022)

背景:声学斯格明子模式

Acoustic vector velocity field skyrmion

PHYSICAL REVIEW LETTERS **127,** 144502 (2021)

Editors' Suggestion | Featured in Physics

Observation of Acoustic Skyrmions

Hao Ge,[1,*] Xiang-Yuan Xu,[2,1,*] Le Liu,[1] Rui Xu,[1] Zhi-Kang Lin,[3] Si-Yuan Yu,[1,5] Ming Bao,[2] Jian-Hua Jiang,[3,†] Ming-Hui Lu,[1,4,5,‡] and Yan-Feng Chen[1,5,§]

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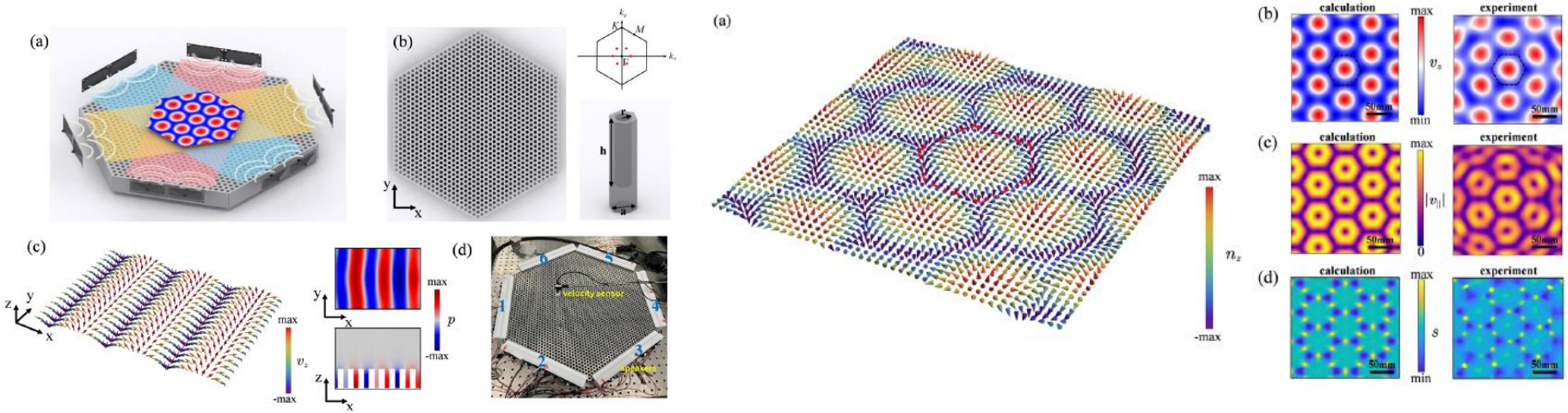
[2]*Key Laboratory of Noise and Vibration Research, Institute of Acoustics, Chinese Academy of Sciences, Beijing 100190, China*

[3]*School of Physical Science and Technology, Soochow University, Suzhou 215006, China*

[4]*Jiangsu Key Laboratory of Artificial Functional Materials, Nanjing, Jiangsu 210093, China*

[5]*Collaborative Innovation Center of Advanced Microstructures, Nanjing University, Nanjing 210093, China*



However, based on the surface wave interference approach, the acoustic skyrmions not only have stringent requirement for external excitation conditions and lattice structure symmetry but also have the limitations of single-mode skyrmions at a given frequency.

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亚波长局域结构实现多频斯格明子模式

Applied Physics Letters ARTICLE scitation.org/journal/apl

Observation of localized acoustic skyrmions

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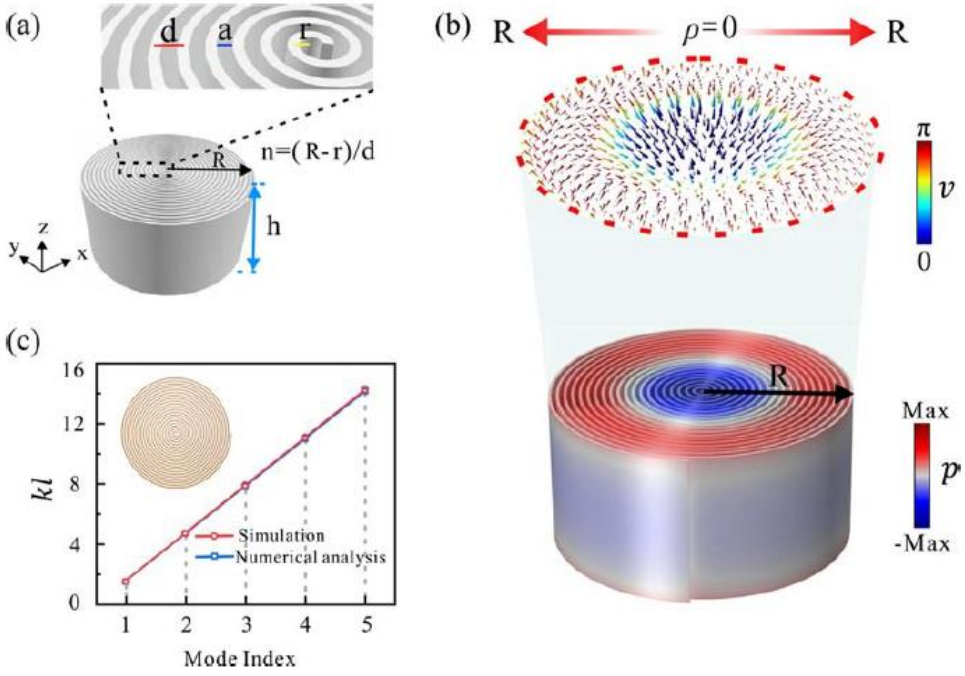
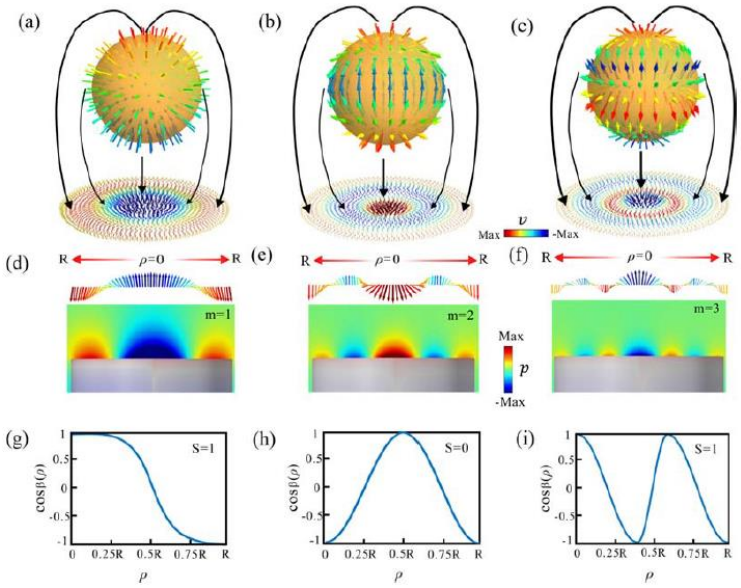
Published Online: 9 January 2023

Ping Hu,[1] Hong-Wei Wu,[1,2,a)] Wen-Jun Sun,[1] Nong Zhou,[1] Xue Chen,[1] Yong-Qiang Yang,[1] and Zong-Qiang Sheng[1]

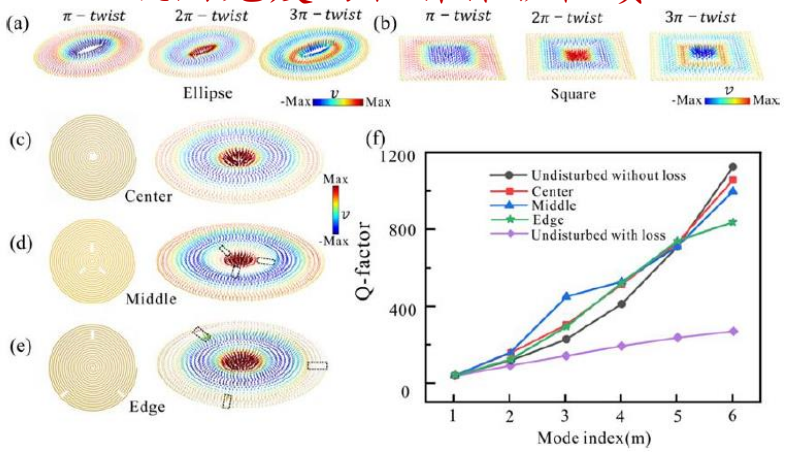
阿基米德螺旋结构与速度场斯格明子模式



多阶斯格明子模式

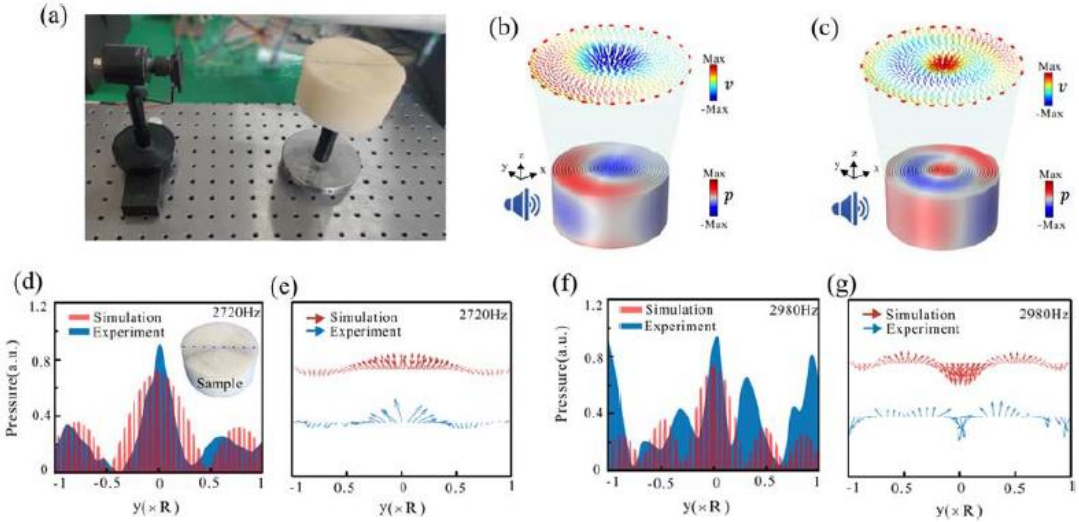


缺陷免疫的拓扑保护性质

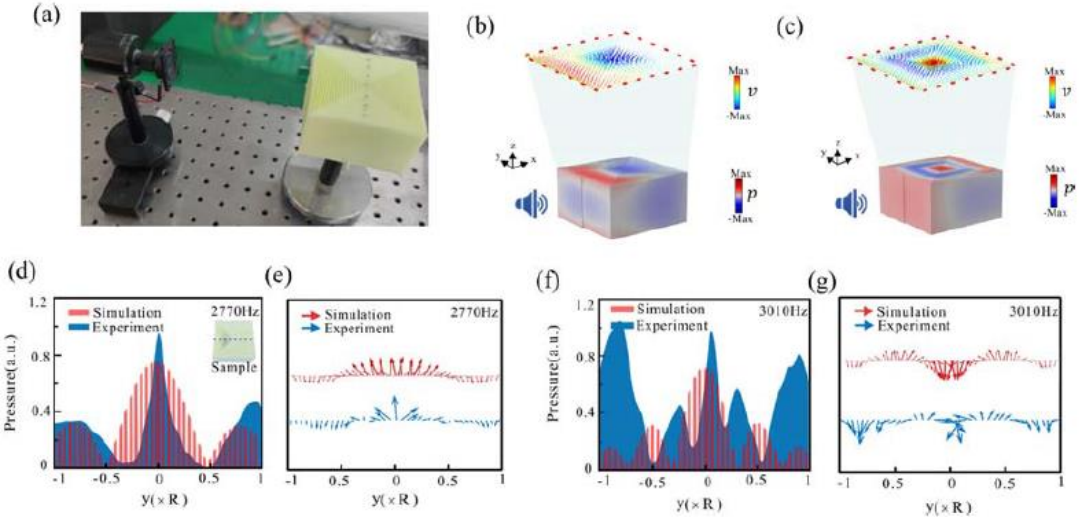


亚波长局域结构实现多频斯格明子模式

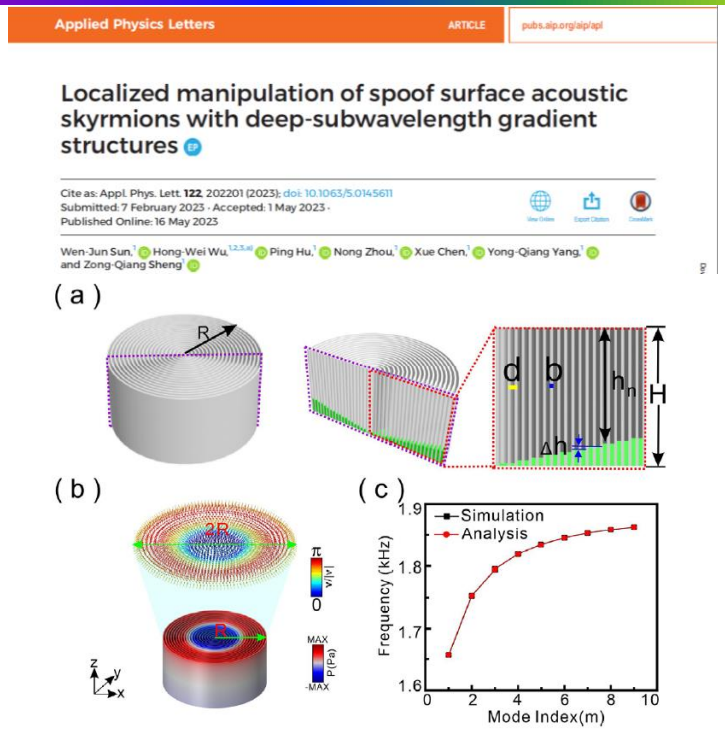
圆形结构的斯格明子模式实验测量



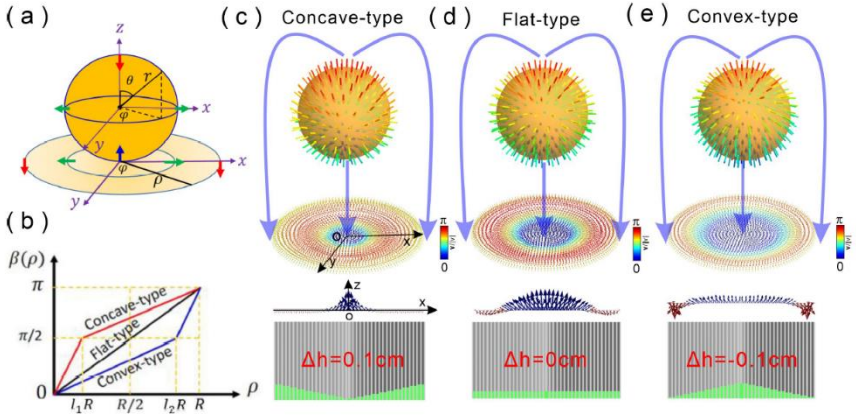
方形结构的斯格明子模式实验测量



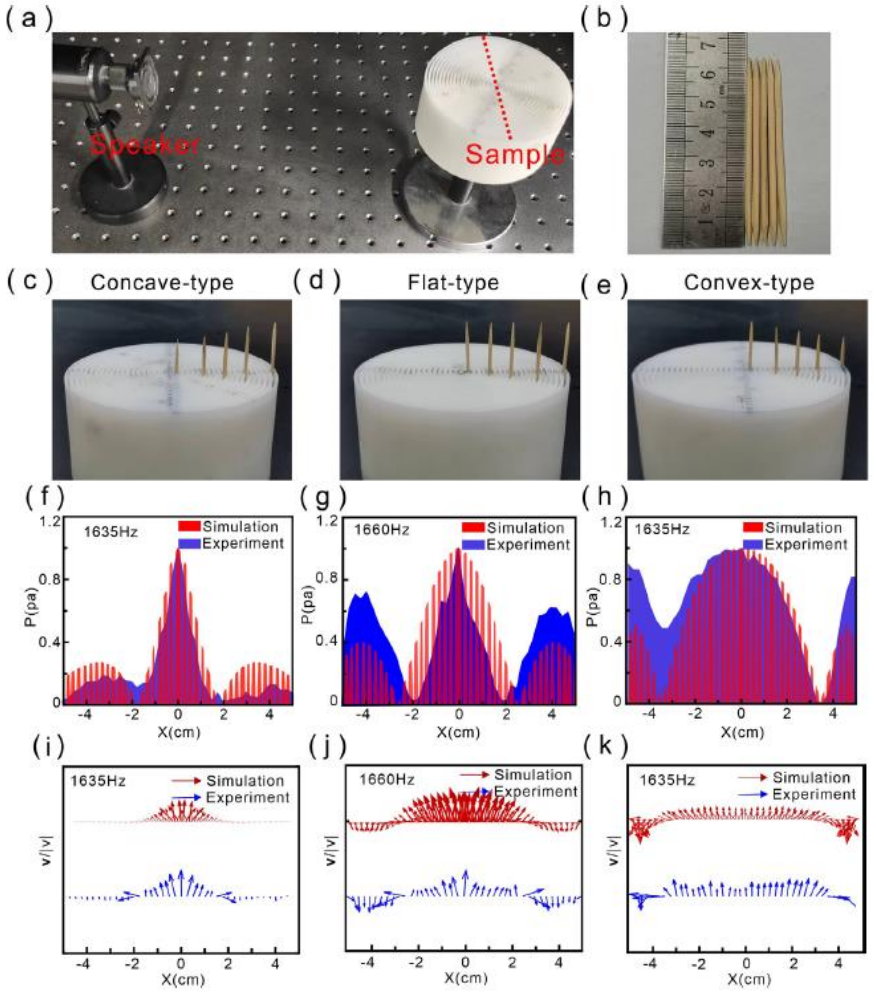
梯度型局域结构调控模式分布



梯度结构操控斯格明子模式分布

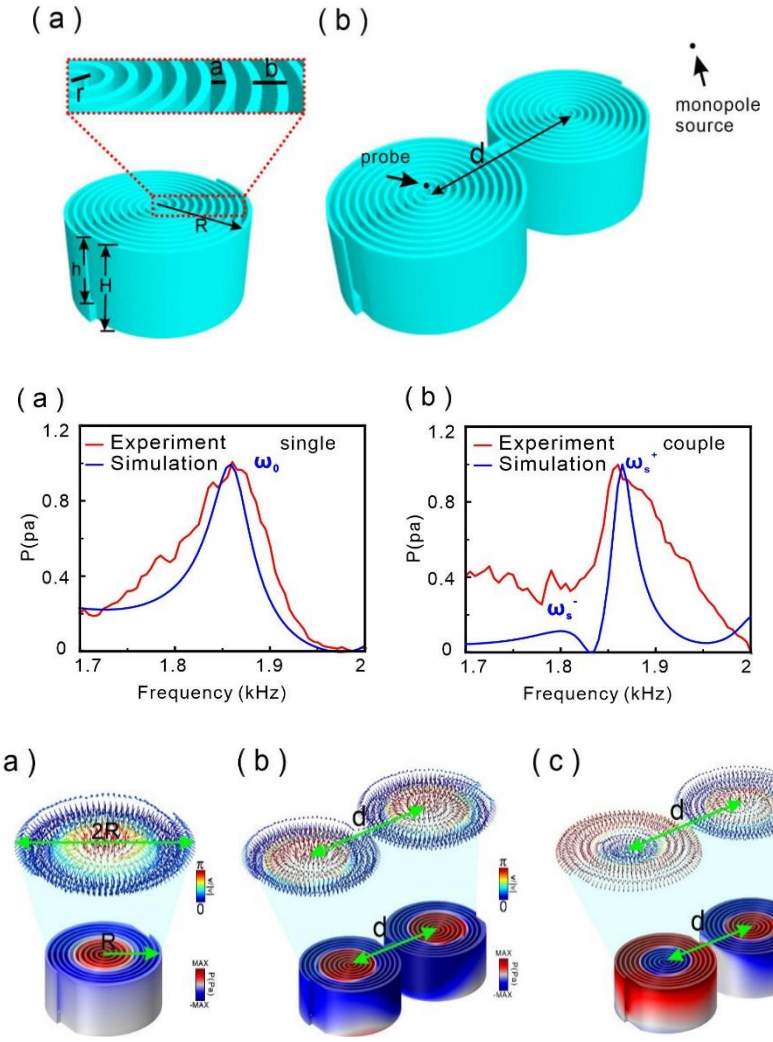


实验观测斯格明子模式分布

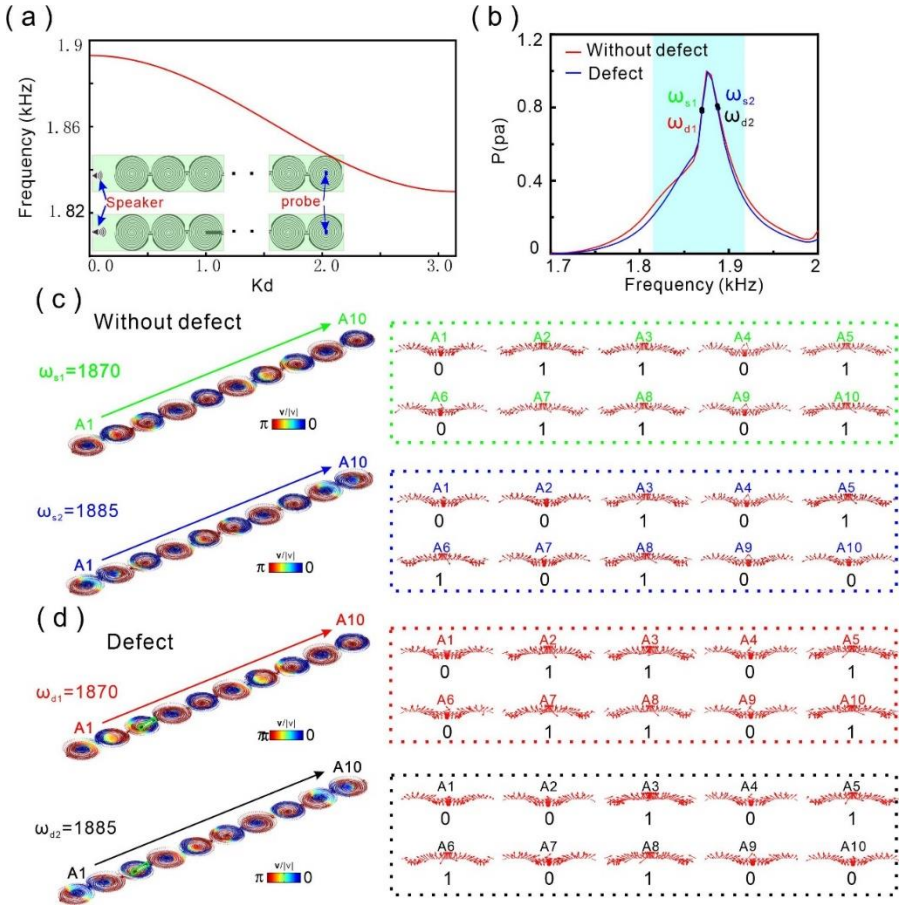


耦合局域结构实现斯格明子模式传输

局域共振结构的斯格明子模式耦合



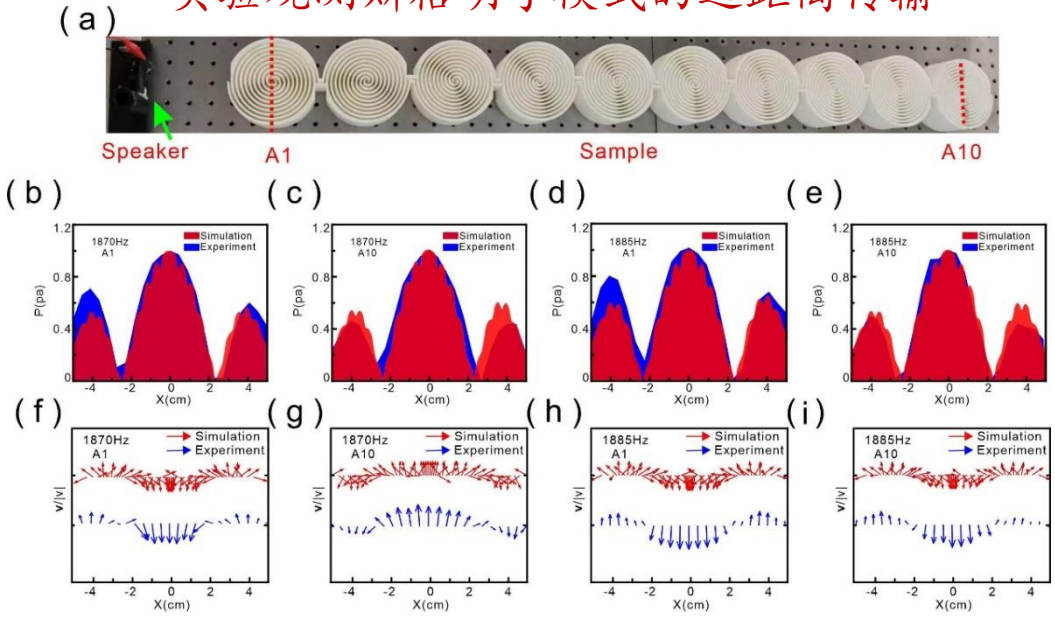
斯格明子模式的耦合与传输



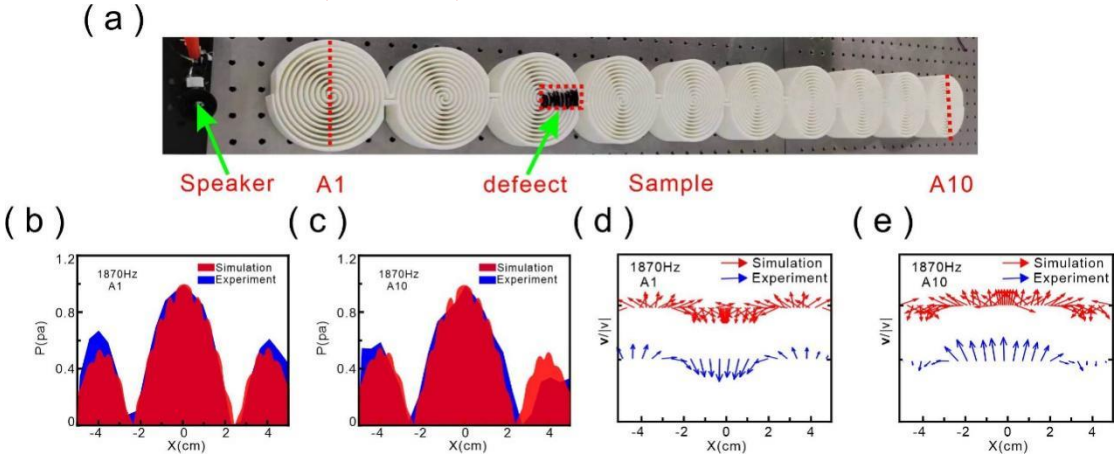
Manuscript preparation

耦合局域结构实现斯格明子模式传输

实验观测斯格明子模式的远距离传输



实验观测斯格明子模式传输的缺陷免疫性质



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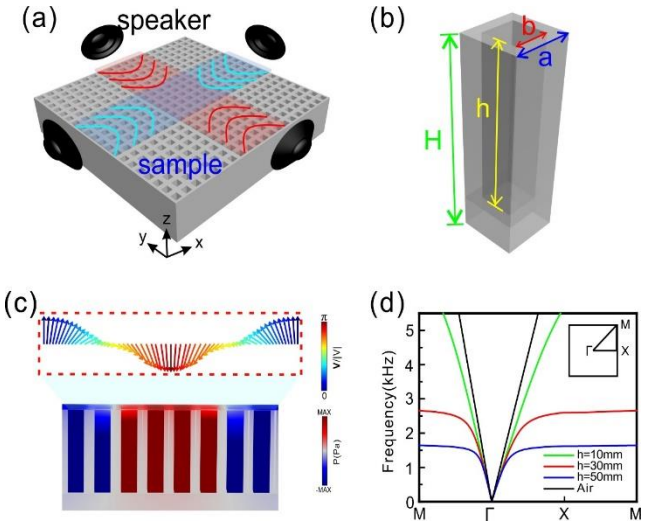
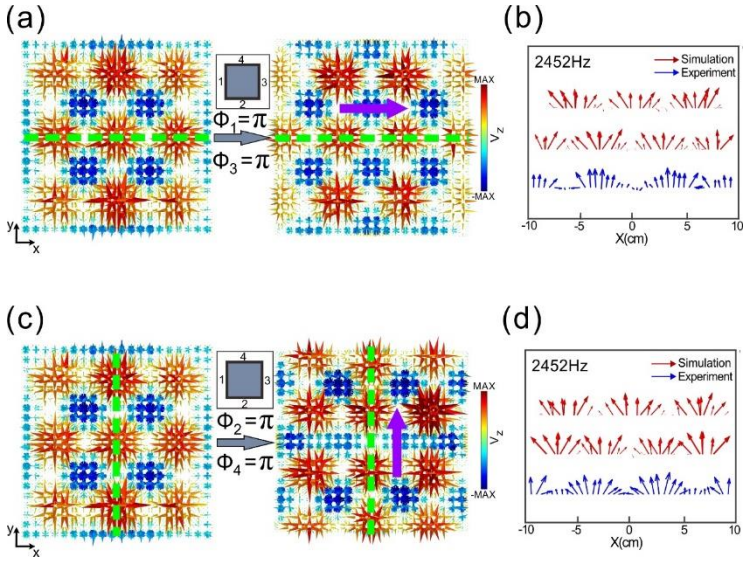
晶格型声学半子模式的实现与调控

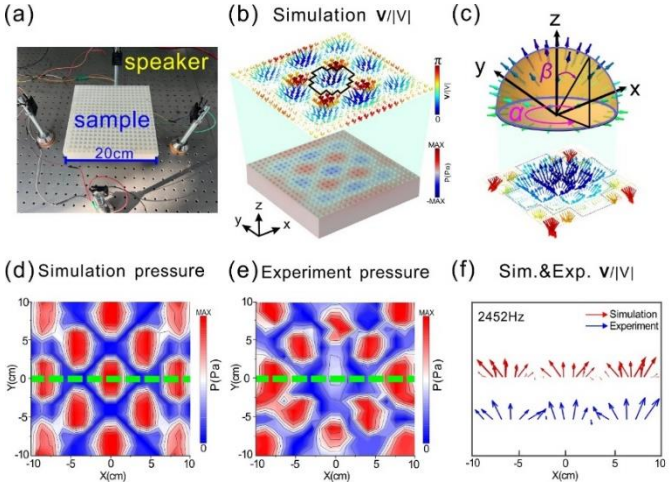
声学半子结构



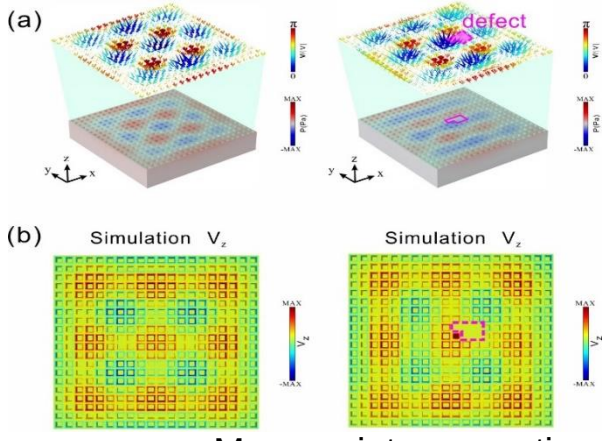
激发相位操控半子模式移动



实验观测声学半子模式



拓扑保护的半子模式对缺陷免疫



Manuscript preparation

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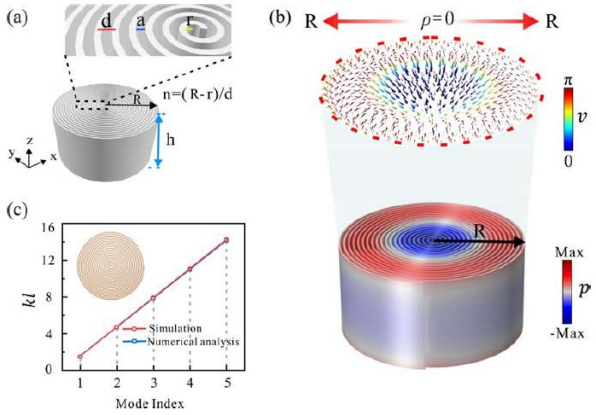
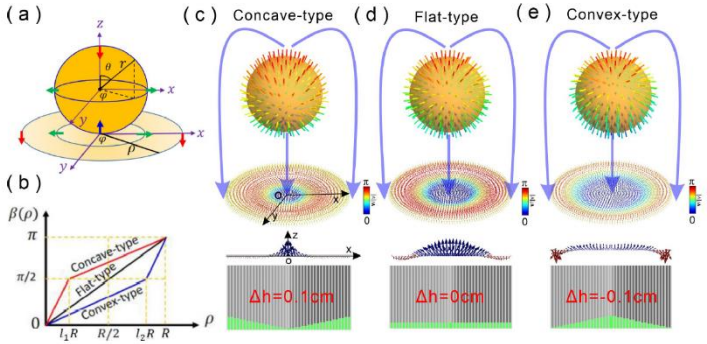
总结与展望

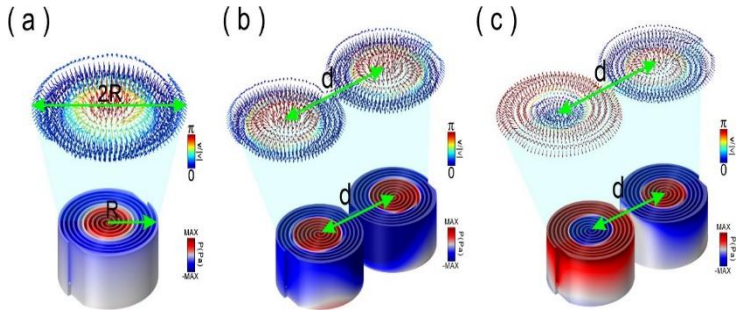
速度场斯格明子模式的实现



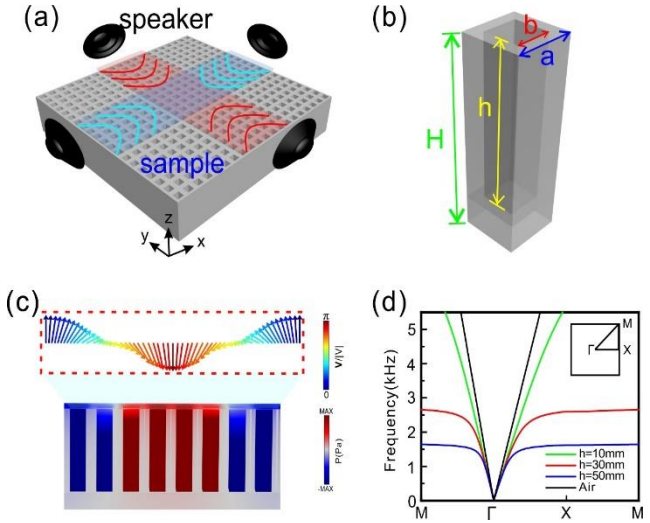
速度场斯格明子模式的局部操控



耦合结构实现斯格明子模式传输



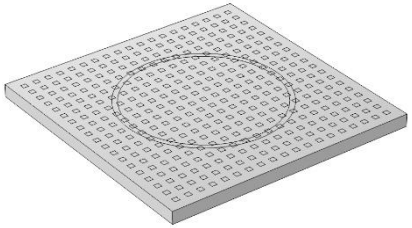
声学半子模式的观测

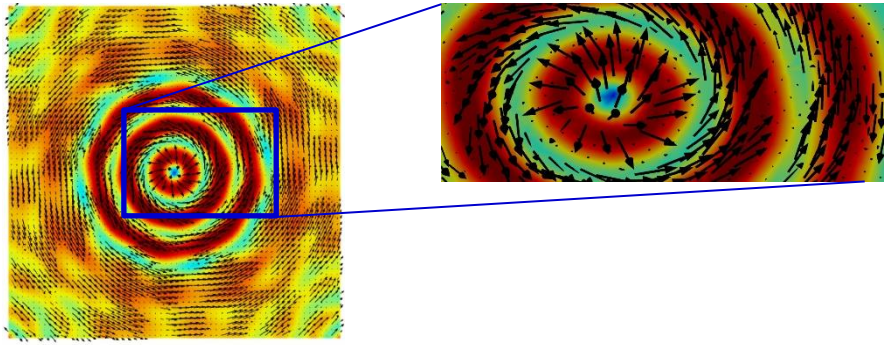


总结与展望

通过贝塞尔声学表面波实现声自旋矢量的 Néel 型斯格明子模式

Spin source





基于不同对称性源选择性激发不同位置的斯格明子模式

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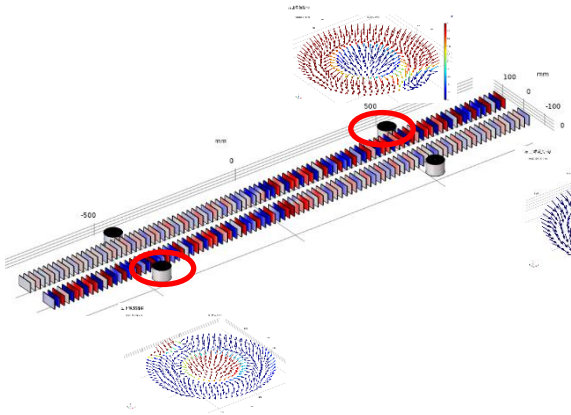

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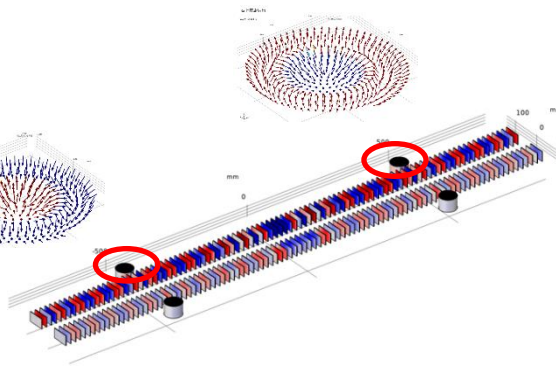
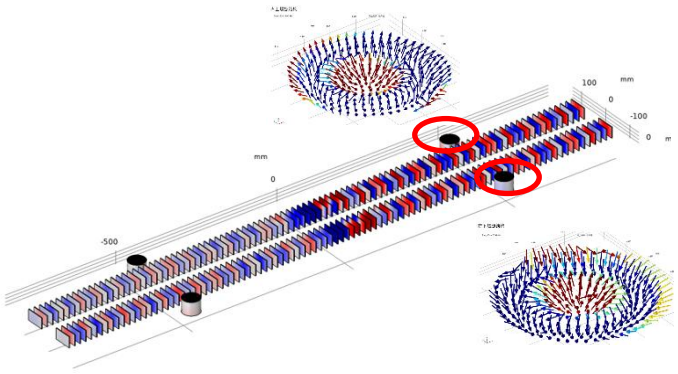


Huygens source



Thank you!