

# Pseudoconformal mapping: Unifying insulating and zero-index carpet cloaks for thermal-wave manipulation



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## Introduction

Controlling thermal waves is crucial for dynamic thermal management, yet inherently challenging due to their rapid attenuation and complex convection-diffusion coupling. Conventional transformation theories either struggle with these transient waves or require unachievable anisotropic materials. Here, we propose a **diffusive pseudoconformal mapping theory** to manipulate **thermal waves** using purely **isotropic materials**. Within this unified framework, we simultaneously realize **insulating and zero-index carpet cloaks**, revealing a fundamental **geometric duality** between **invisibility and environmental sensing**.

## Thermal waves with diffusive pseudoconformal mapping

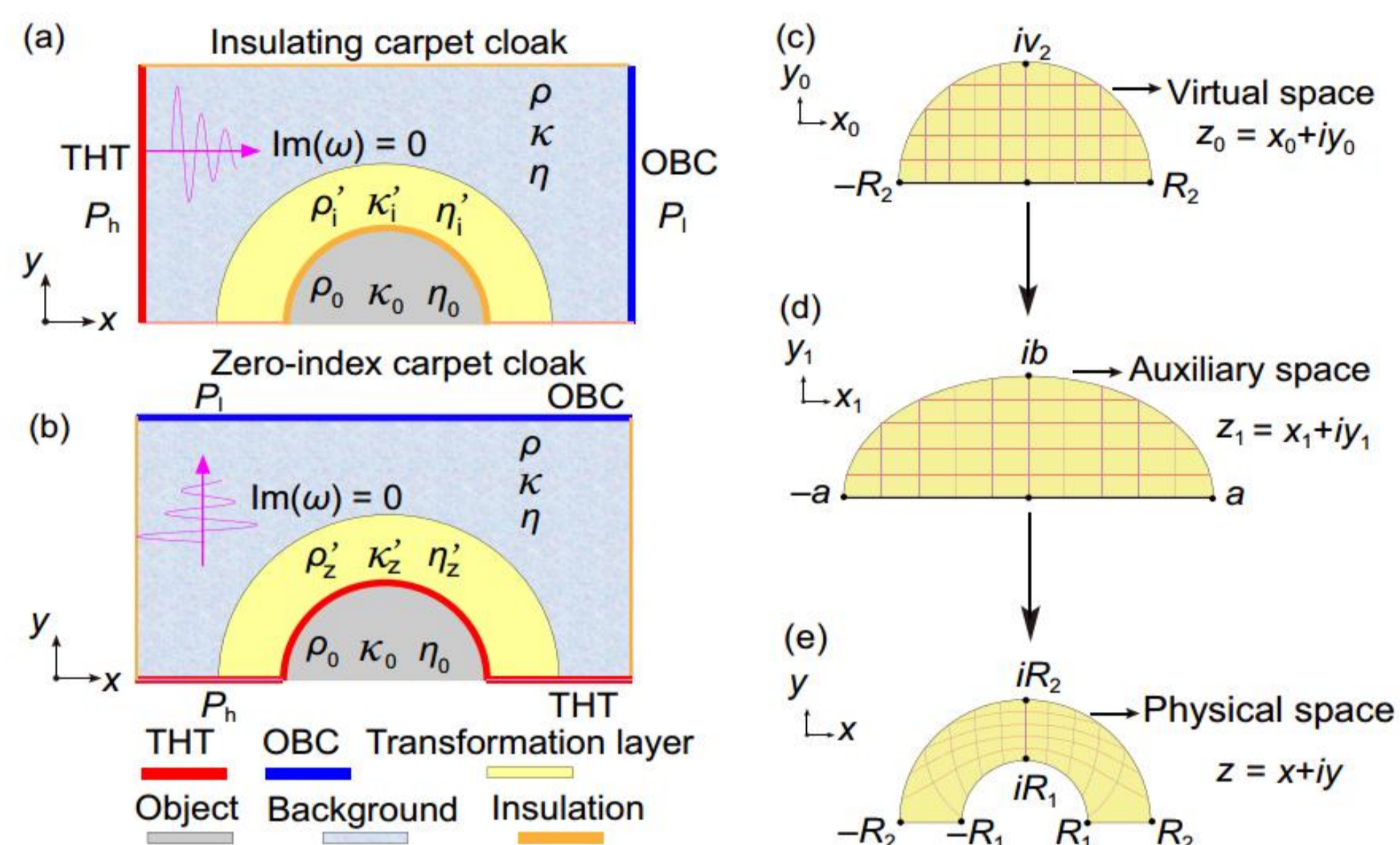


Fig. 1. Design of thermal-wave carpet cloaks via pseudoconformal mapping. (a, b) Schematics of the insulating and zero-index cloaks under harmonic thermal-wave excitation. (c-e) The spatial transformation process revealing a fundamental geometric duality: isotherms/isobars (purple) and streamlines (red) perfectly swap roles between the two cloaks.

## Insulating carpet cloak: shielding thermal waves

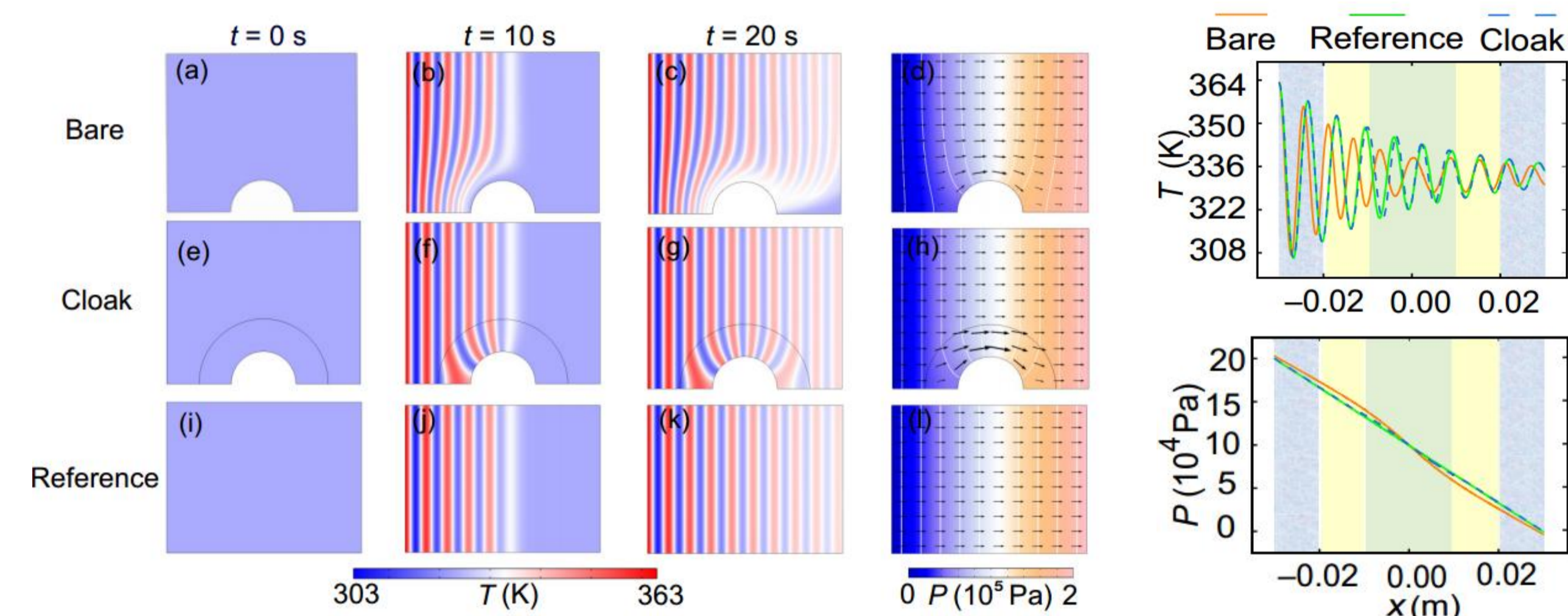


Fig. 2. Thermal shielding by the insulating cloak. The cloak effectively eliminates temperature and pressure distortions caused by the object, keeping the background wave field perfectly undisturbed (matching the reference).

## Zero-index carpet cloak: invisibility with sensing

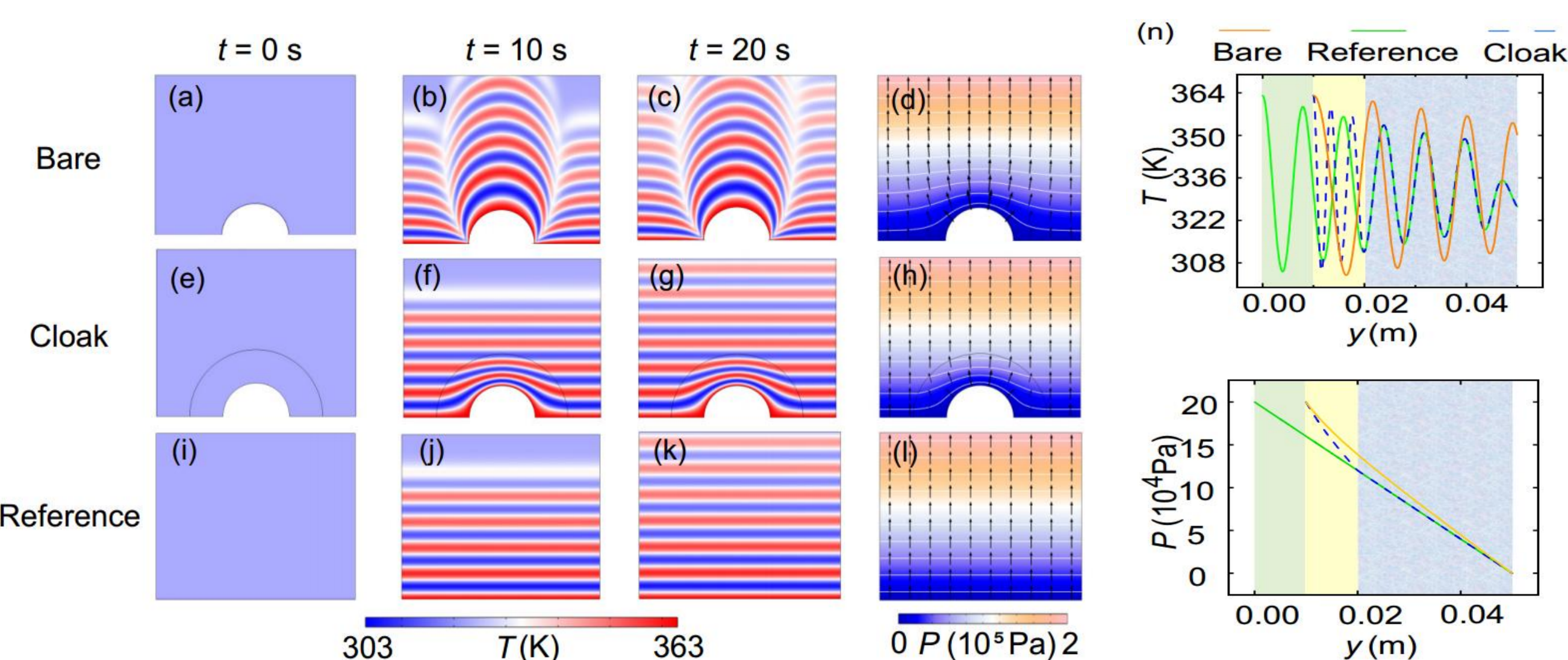


Fig. 3. Invisibility and sensing via the zero-index cloak. While maintaining thermal-wave invisibility in the background, the inner boundary responds to ambient temperature fluctuations, functioning as a real-time sensor.

## Experimental suggestions

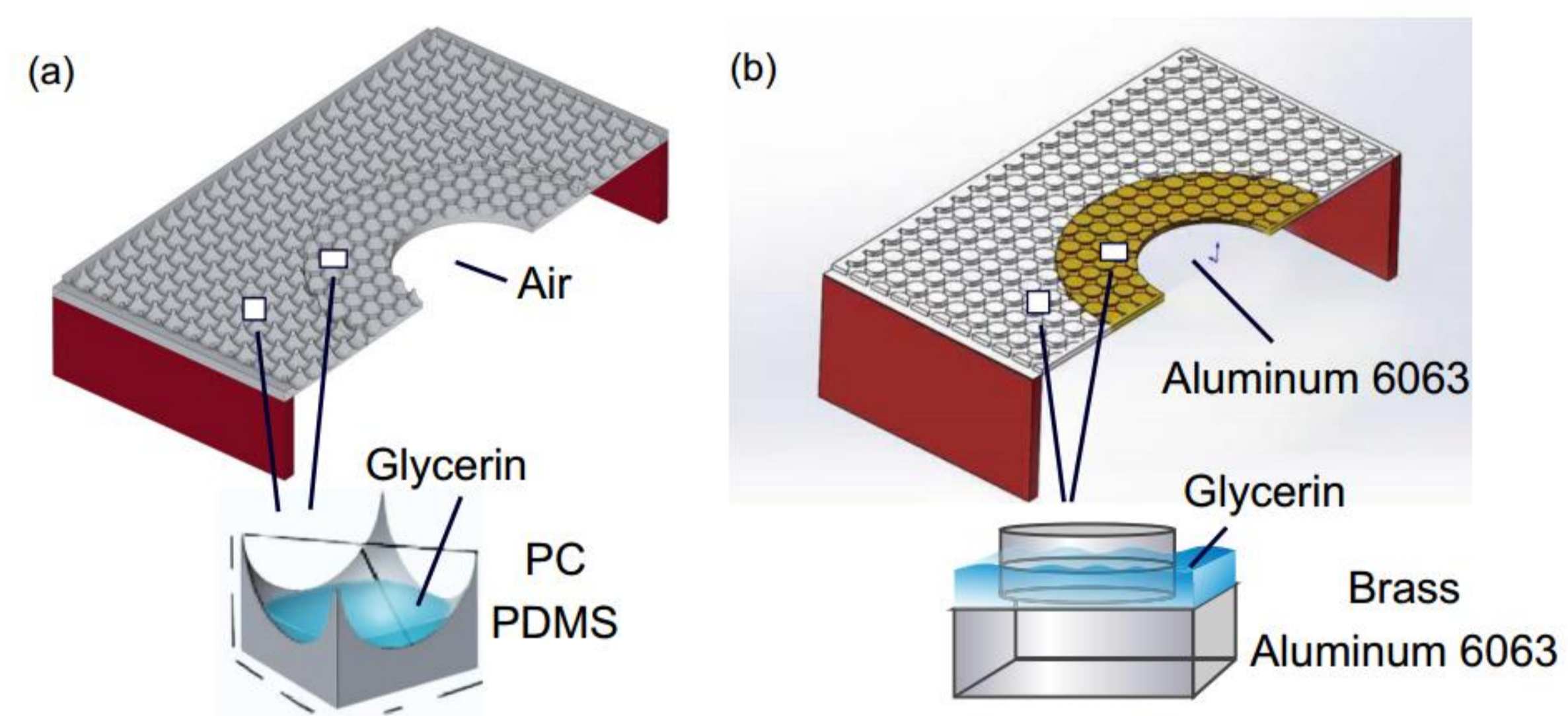


Fig. 4. Proposed experimental structure. (a) Insulating cloak. It is composed of PDMS (gray), PC (gray), Glycerin and air (white). (b) Zero-index cloak. It is composed of brass (yellow), Glycerin and Aluminum 6063 (silver).

## Conclusion.

- ◆ We establish a unified framework using **diffusive pseudoconformal mapping** to manipulate complex **thermal waves** with purely **isotropic materials**.
- ◆ We simultaneously realize **insulating and zero-index carpet cloaks**, revealing a fundamental **geometric duality** between **thermal shielding and environmental sensing**.
- ◆ Numerical simulations and a proposed **segmented experimental design** (using common materials like PDMS, PC, and Glycerin) validate the practical feasibility of these metadevices.
- ◆ This framework provides a new route for transient thermal management, with promising applications ranging from **aerospace thermal protection** to **noninvasive biomedical hyperthermia**.

## Reference.

1. **Y. Q. Zhao**, H. L. Feng, Z. X. Li, P. Jin, G. L. Dai, L. J. Xu, J. P. Huang, Phys. Rev. Appl. 24, 044033 (2025).
2. H. H. Tan, **Y. Q. Zhao**, P. Jin, X. Xu, X. C. Zhou, F. Marchesoni, J. P. Huang, Proc. Natl. Acad. Sci. USA 122, e2424421122 (2025).
3. **Y. Q. Zhao**, Y. H. Zhou, P. Jin, J. P. Huang, Phys. Rev. E, 113, 044134 (2026).
4. H. H. Tan, **Y. Q. Zhao**, J. P. Huang, Phys. Rev. E, 109, 044124 (2024).