Blackhole-Inspired Thermal Trapping with Graded Heat-Conduction Metadevices

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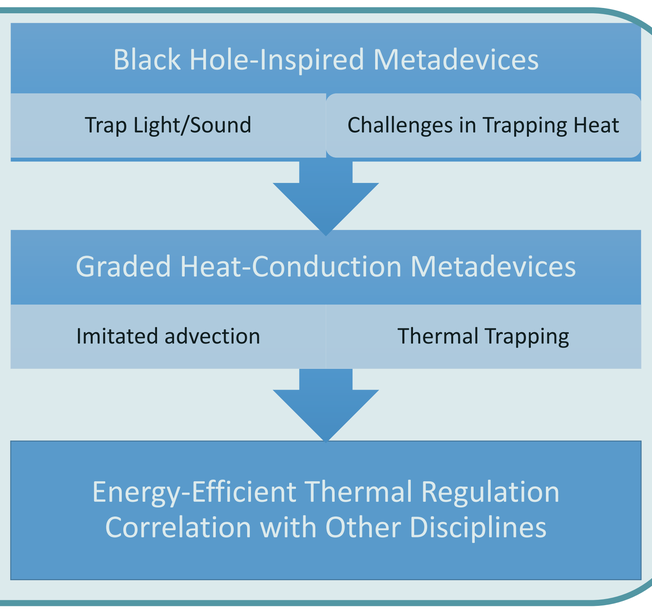
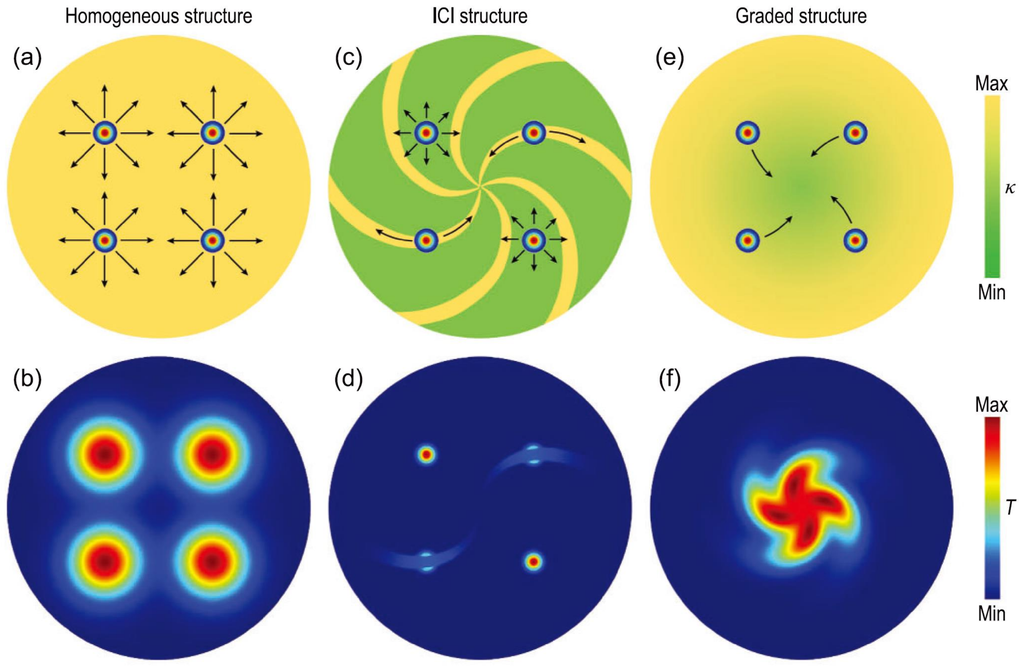
Ⅰ Background

Black hole-inspired metadevices have been used to trap light and sound.

However, there are challenges in trapping heat due to its diffusive, directionless behavior.

Graded heat-conduction metadevices can achieve thermal trapping, guiding hot spots to diffuse towards the center and leads to energy-efficient thermal regulation.





Thermal diffusion in different structures

Ⅱ Methods

The imitated advection

Heat conduction in one dimension is

$$\rho c(x)\partial_t T - \partial_x(\kappa(x)\partial_x T) = 0$$

When the thermal conductivity κ, mass density ρ and heat capacity C satisfy

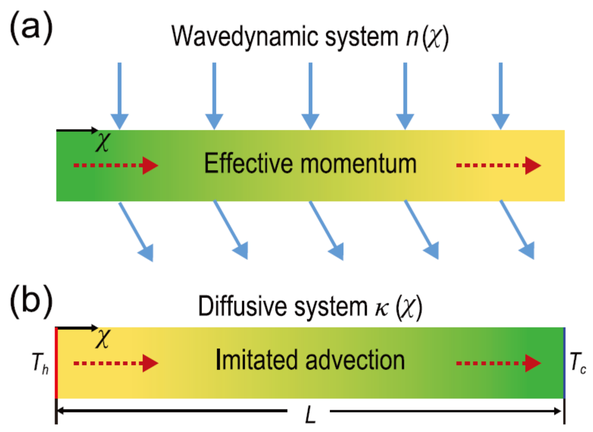
$$\kappa \sim \kappa_0 e^{\alpha x}, \rho C \sim \rho_0 C_0 e^{\alpha x}$$

Equation is equivalent to diffusion-advection equation

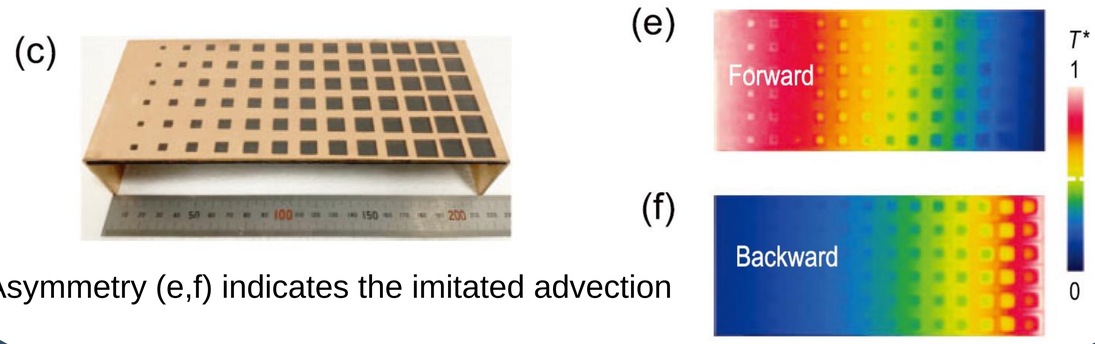
$$\rho_0 C_0 \partial_t T + \rho_0 C_0 v_0 \partial_x T - \partial_x(\kappa_0 \partial_x T) = 0$$

yields a constant velocity of v_0

$$v_0 = -\alpha(\kappa_0/\rho_0 C_0)$$



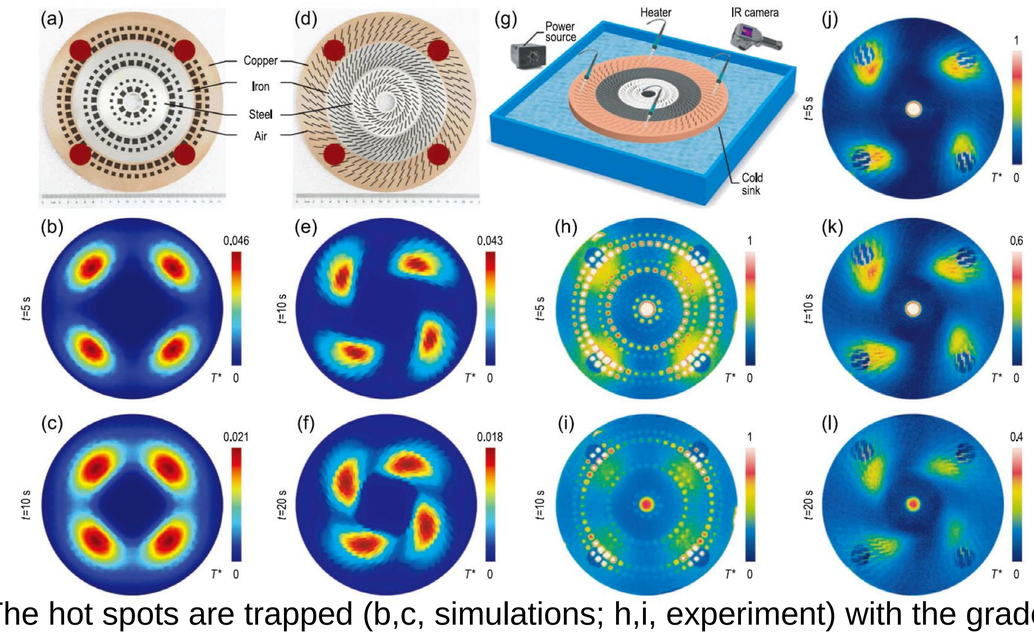
Experimental demonstration



Asymmetry (e,f) indicates the imitated advection

Ⅲ Results

Experiments of thermal trapping



The hot spots are trapped (b,c, simulations; h,i, experiment) with the graded metadevice. Under the rotational transformation, the hot spots are trapped and rotated (e,f, simulations; j-k, experiment) with anisotropic metadevice.

Simulations of thermal trapping

Inspired by black holes, we guide the imitated advection to point towards the center to realize thermal trapping. Hot spots are almost stationary (a-c, homogeneous medium), centrally trapping (e-f, normal graded) and rotational trapping (g-i, graded and anisotropic)

Ⅳ Conclusions

We reveal blackhole-inspired thermal trapping with graded heat-conduction metadevices. The underlying mechanism lies in the imitated advection induced by graded thermal conductivities as a counterpart to graded refractive indexes responsible for the effective momentum in photonics.

Reference
Liujun Xu†, Jinrong Liu†, Peng Jin, Guoqiang Xu, Jiaxin Li, Xiaoping Ouyang, Ying Li , Cheng-Wei Qiu and Jiping Huang
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