Directional thermal radiation control based on ENZ materials

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Any object with a temperature above absolute zero (0 K) continuously emits thermal radiation. Thermal radiation is an omnidirectional natural phenomenon witch lacks polarization and wavelength characteristics[1]. To enhance our understanding and control of thermal radiation, we concentrate on the angular manipulation, which holds significant potential in the areas of thermal management[2], thermal camouflage[3], and radiative cooling[4].

In this paper, we investigate various methods for controlling directional thermal radiation using epsilon-near-zero (ENZ) materials, achieving ultra-high bandwidth directional thermal radiation through effective medium theory (EMT)[5]. We then integrate Fabry-Pérot bound states in the continuum (F-P BICs) with ENZ materials to enable simultaneous control over both the direction and wavelength of thermal radiation, while maintaining high quality factors[6]. Finally, we combine the non-reciprocal thermal radiation properties of magneto-optical ENZ materials with an anisotropic dielectric layer to realize broadband unidirectional thermal radiation[7]. Our research provides systematic approaches and guidance for the development of directional thermal radiation on thermal sources, sensors, and on-chip thermal information processing.

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