Supplemental Material: Ultra-Broadband Thermal Emitter for Daytime Radiative Cooling with Metal-Insulator-Metal Metamaterials

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To obtain the temperature difference, a steady heat balance system is illustrated in Fig S1. The system consists of radiative cooling thin film and it places high above the ground in an ideal atmospheric environment. The sun shines directly on the air-filled box. To calculate the cooling ability of the system, it is simplified as a three-layer system in the right panel, namely, the atmospheric layer, the radiative cooling thin film and the internal air layer. Heat exchange between the system and the outside is indicated as P_{net}. Owing to the radiative cooling capability of the thin film, the temperature inside the box intends to be lower than the outside [1].

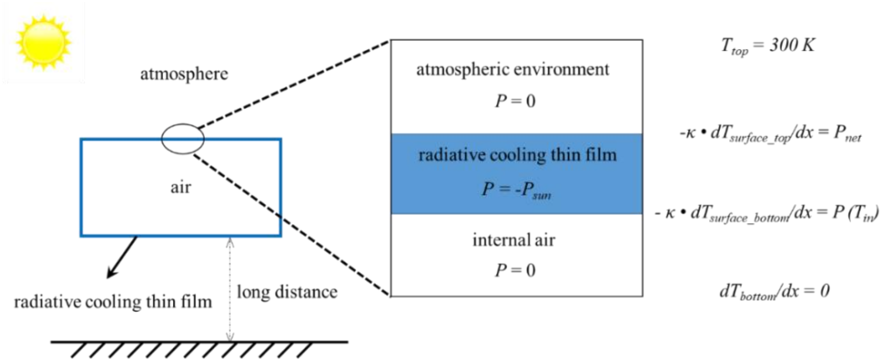

Fig. S1 Schematic diagram of the cooling system. The heat conduction equation and boundary conditions are presented in the simplified three-layer construction.

Under the assumption of a steady state, the heat conduction equation is written as,

$$\kappa\nabla^2 T = P \tag{1}$$

κ is the thermal diffusivity. The thickness of the air layer is taken as 20 cm, and the designed thin cooling films is simplified as one layer ignoring surface grooves. The thickness of the internal structure of the surface area is taken as 20 microns, and the thickness of the device is far less than the thickness of the air layer. For the top and bottom air layer, the power P is taken as 0. For the active intermediate radiative cooling film, it is set as,

$$P = -P_{\mathrm{sun}} \tag{2}$$

Namely, it equals to the heating power form the sun (P_{sun}). An infinite extension layer is considered in the longitudinal direction. To solve the conduction equations, the temperature of top air layer is assumed to be the average atmospheric temperature, and it is fixed at 300 K. The boundary condition of bottom layer follows the temperature derivative.

$$dT_{bottom}/d\mathrm{y} = 0 \tag{3}$$

y is set as the vertical direction. For the intermediate medium, the top surface radiates heat outward, and the temperature gradient follows the relationship as,

$$-\kappa\, dT_{\mathrm{surface\_top}}/dy = P_{\mathrm{net}} \tag{4}$$

The inner surface only convects heat with the air cavity and it observes the following equation.

$$-\kappa\, dT_{\mathrm{surface\_bottom}}/dy = P_{non}\,(\Delta T_{\mathrm{in}}) \tag{5}$$

The thickness of the air layer is large enough compared with the cooling film and it can be calculated evenly by taking points with large intervals inside the air layer [2]. To obtain accurate results, the above two boundary conditions should be the temperature gradient between the device surface and the inside film, otherwise it may lead to iteration divergence. The solution of the above equations is programmed by using Visual studio software with the Jacobi iteration method and ended up with a temperature distribution at all locations. The temperature difference between the device surface and the atmosphere is finally obtained.

References

[1] Yin H Y and Fan C Z 2023 Results Phys. **45** 106216
[2] Jia Y L, Ren P W, and Fan C Z 2020 Chin. Phys. B **29** 104210