智能超表面实现超高性能辐射制冷

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选择性热辐射器由于能够抑制来自大气窗口之外的大气辐射的吸收，从而能够实现更低的稳态温度。然后现有的基于多层介质薄膜、玻璃/聚合物超材料、等离激元超表面/纳米粒子等光子结构的选择性辐射制冷器的光谱不能完美匹配大气透明窗口并且热辐射率较低。

上海理工大学光子芯片研究院顾敏院士、张轶楠教授借助人工智能逆向设计了介质超表面热辐射器，实现了大气透明窗口（8~13 μm）0.92 的平均热辐射率，1.8 的大光谱选择性和高达 80°的宽发射角。这种选择性和全向性热辐射特性使得辐射器在 800 W/m^2 的强太阳辐射下，温度降低到了环境温度 15.4 ℃ 以下，显著超过了目前最先进的结果。

为了测试选择性和全向热辐射器的降温性能，研究人员在中国上海进行了连续的室外温度测量。测试结果表明，在夏季 800~850 W/m^2 强烈的太阳照射下，与环境温度相比，辐射制冷器平均降温高达 12.7 ℃，最大降温 15.4 ℃。为了进一步阐明该热辐射器的冷却性能，他们还利用实验测量的太阳和发射光谱计算了冷却功率与温度的关系。结果表明，实验的最高降温接近理论最大值 16.5 ℃，证明了选择性全向热辐射器优异的降温性能。

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Intelligent metasurfaces enable ultra-high performance passive radiative cooling

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The past decade has witnessed many photonic structure designs for achieving selective thermal emission spectra that match the atmospheric transparency window, including multilayer dielectric thin films, silica sphere/polymer metamaterials, plasmonic metasurfaces/nanoparticle. However, the emission profiles of these structures are still highly dispersive with either low emissivity or mismatched with the transparency window.

Academician Gu Min and Prof. Zhang Yinan from the Photonics Chip Research Institute of Shanghai University of Technology proposed machine learning inverse designed hybrid metasurface thermal emitters consisting of polar dielectric materials for highly selective, strongly emissive, and omnidirectional thermal emission. By designing and optimizing the geometry-dependent multiple Mie resonances in the hybrid polar dielectric resonators, the group demonstrated thermal emitters with an emissivity of ~0.92 across the atmospheric transparency window, ultra-high spectral selectivity of ~1.8 and emission angle up to 80 degrees simultaneously, leading to a new record of equilibrium temperature reduction as large as ~15.4 ℃ in rooftop test, significantly surpassing the state-of-the-art radiative coolers under non-vacuum conditions.

The demonstrated radiative cooler also holds great promise for the urban heat island effect mitigation with modeling results suggesting a more than 50% deployment area reduction compared with the current radiative coolers.

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