Thermal Radiation in Microstructured Photonic Reservoirs

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The ability of microstructured photonic systems to significantly alter thermal radiation processes has recently received considerable attention [1, 2, 3] as it holds a tremendous potential for applications that range from thermophotovoltaic energy conversion devices [1], [4] to tunable infrared emitters [5].

We analyze the origin of thermal radiation enhancement and suppression inside photonic crystals and demonstrate that the central quantity that determines the thermal radiation characteristics such as intensity and emissive power is the area of the iso-frequency surfaces and not the density of states as is generally assumed [1], [2], [6], [7]. We show that for frequencies near photonic band-edges and other van Hove singularities, the thermal radiation flux exhibit profound departures from the conventional model of a blackbody in free space.

Our analysis shows that the directional behavior of the thermal radiation intensity is governed by the topology of the dispersion surface and can be expressed in terms of its gradient and curvature At long wavelengths, the departure of the iso-frequency contour from that of a homogeneous medium is minimal, and the directional spectral emissive power exhibits a Lambertian dependence. As the frequency increases, the thermal radiation becomes more and more anisotropic and the directional thermal radiation flux may become divergent along certain directions. In a manner similar to the phonon focusing in ordinary crystals [8], this behavior gives rise to "photonic caustics" and underscores that the spectral and angular redistribution of the photonic states play equally important roles in determining the thermal radiation flux.

We also discuss the fundamental physical mechanisms determining the thermal radiation emitted by microstructured photonic systems and use these insights to outline design principles that alow the maximization of the the radiation flux. We show that the increased isotropy of the effective Brillouin zone characterizing quasiperiodic photonic lattices make these systems ideal candidates for optimal design structures.

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