Strategies for Electrical Tuning of Thermal Emissivity in Metamaterials

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Achieving tunable control over the thermal emission spectrum of materials is expected to enable new possibilities in applications including thermophotovoltaics, waste heat recycling, and infrared communication and sensing. In recent work, we have introduced several strategies for achieving electrical control over thermal emission based on resonant coupling and symmetry breaking in infrared metamaterials.

In one thrust of our work, we consider control over emissivity amplitude. We employ metamaterials comprised of several, coupled resonators in each unit cell. By tuning the dimensions of each resonator, we can arrange for either a bright mode (one that couples to normally incident light) or a dark mode (one that does not) to fall within a specified region of the spectrum. This leads to several possibilities for spectral control. In an exemplar strategy, we consider two, initially bright modes that couple to form a dark mode. At zero applied voltage, the system is mirror symmetric, and the dark mode does not produce any observable feature in the emission spectrum. When a voltage is applied to tune the refractive index in a portion of the unit cell, mirror symmetry is broken. The formerly dark mode becomes bright, switching on an emissive peak. We present design strategies for implementing this concept within both graphene and III-V semiconductor platforms.

In a second thrust, we consider control over directionality of thermal emission. In this case, we consider a metamaterial based on weakly coupled resonators, which give rise to a nearly flat photonic band. We then consider the effect of a small index perturbation of the refractive index of the structure. We show that for fixed wavelength, the flatness of the photonic band magnifies the change in angle for emitted radiation. We present several practical designs for realizing this effect in a III-V semiconductor platform.