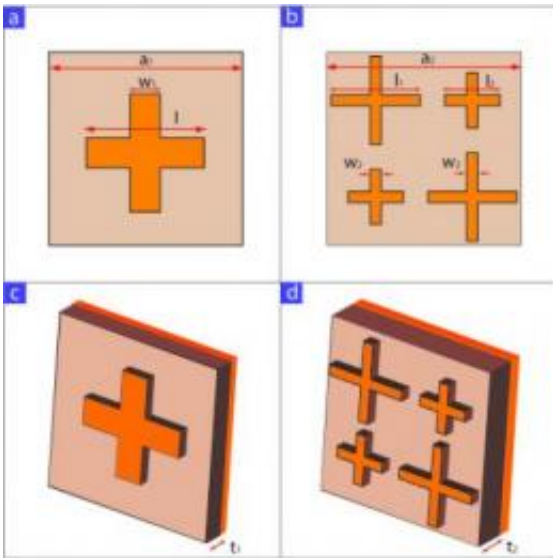


Shining a light on the elusive 'blackbody' of energy research

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A designer metamaterial has shown it can engineer emitted "blackbody" radiation with an efficiency beyond the natural limits imposed by the material's temperature, a team of researchers report in *Physical Review Letters*. Illustration shows design of the infrared metamaterial absorber. (a) Top view of a single band metamaterial absorber unit cell. (b) Schematic of a dual-band metamaterial absorber. (c & d) Perspective view for single and dual-band metamaterial absorbers. Credit: Physical Review Letters

A designer metamaterial has shown it can engineer emitted "blackbody" radiation with an efficiency beyond the natural limits imposed by the material's temperature, a team of researchers led by Boston College physicist Willie Padilla report in the current edition of *Physical Review*

Letters.

A "blackbody" object represents a theorized ideal of performance for a material that perfectly absorbs all radiation to strike it and also emits energy based on the material's temperature. According to this blackbody law, the energy absorbed is equal to the energy emitted in equilibrium.

The breakthrough reported by Padilla and colleagues from Duke University and SensorMetrix, Inc., could lead to [innovative technologies](#) used to cull energy from [waste heat](#) produced by numerous [industrial processes](#). Furthermore, the man-made metamaterial offers the ability to control emissivity, which could further enhance energy conversion efficiency.

"For the first time, metamaterials are shown to be able to engineer blackbody radiation and that opens the door for a number of energy harvesting applications," said Padilla. "The energy a natural surface emits is based on its temperature and nothing more. You don't have a lot of choice. Metamaterials, on the other hand, allow you to tailor that radiation coming off in any desirable manner, so you have great control over the emitted energy."

Researchers have long sought to find the ideal "blackbody" material for use in solar or thermoelectric [energy generation](#). So far, the hunt for such a class of thermal emitters has proved elusive. Certain rare earth oxides are in limited supply and expensive, in addition to being almost impossible to control. [Photonic crystals](#) proved to be inferior emitters that failed to yield significant efficiencies.

Constructed from artificial composites, metamaterials are designed to give them new properties that exceed the performance limits of their actual physical components and allow them to produce "tailored" responses to radiation. Metamaterials have exhibited effects such as a

negative index of refraction and researchers have combined metamaterials with artificial optical devices to demonstrate the "invisibility cloak" effect, essentially directing light around a space and masking its existence.

Three years ago, the team developed a "perfect" metamaterial absorber capable of absorbing all of the light that strikes it thanks to its nano-scale geometric surface features. Knowing that, the researches sought to exploit Kirchoff's law of thermal radiation, which holds that the ability of a material to emit radiation equals its ability to absorb radiation.

Working in the mid-infrared range, the thermal emitter achieved experimental emissivity of 98 percent. A dual-band emitter delivered emission peaks of 85 percent and 89 percent. The results confirmed achieving performance consistent with Kirchoff's law, the researchers report.

"We also show by performing both emissivity and absorptivity measurements that emissivity and absorptivity agree very well," said Padilla. "Even though the agreement is predicted by Kirchoff's law, this is the first time that Kirchoff's law has been demonstrated for metamaterials."

The researchers said altering the composition of the metamaterial can results in single-, dual-band and broadband [metamaterials](#), which could allow greater control of emitted photons in order to improve [energy conversion efficiency](#).

"Potential applications could lie in [energy](#) harvesting area such as using this metamaterial as the selective thermal emitter for thermophotovoltaic (TPV) cells," said Padilla. "Since this metamaterial has the ability to engineer the thermal [radiation](#) so that the emitted photons match the band gap of the semiconductor – part of the TPV cell – the converting

efficiency could be greatly enhanced.

Provided by Boston College

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