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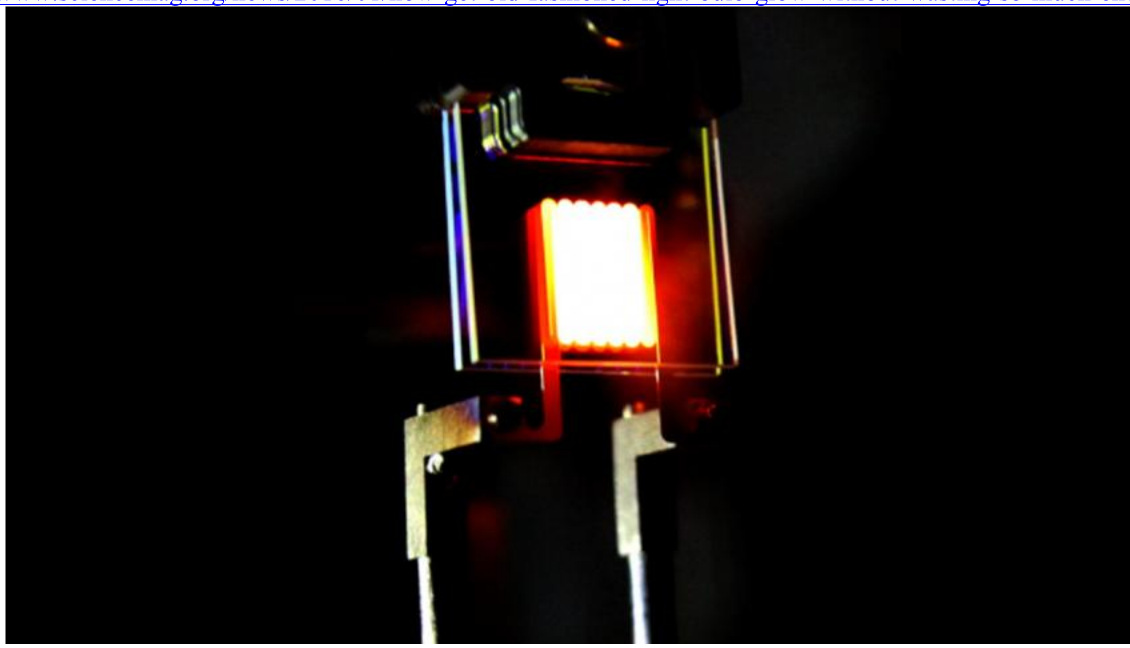

A new type of incandescent light bulb recycles infrared photons converting them to visible light.
O. Ilic *et al.*/MIT

How to get that old-fashioned light bulb glow without wasting so much energy

By Robert F. Service

Thomas Edison would be pleased. Researchers have come up with a way to dramatically improve the efficiency of his signature invention, the incandescent light bulb. The approach uses nanoengineered mirrors to recycle much of the heat produced by the filament and convert it into additional visible light. The new-age incandescents are still far from a commercial product, but their efficiency is already nearly as good as commercial LED bulbs, while still maintaining a warm old-fashioned glow.

"This is beautiful work," says Shawn-Yu Lin, an electrical engineer and optics expert at the Rensselaer Polytechnic Institute in Troy, New York. He and others note that there is plenty of room for further improving the mirrors, which could ultimately push the efficiency of the bulbs well beyond what is possible with today's lighting technologies. And because lighting consumes 11% of all electricity in the United States, any such improvement could dramatically lower energy use, and, by extension, the carbon dioxide emissions that contribute to climate change.

Incandescent lights have changed little since Edison first perfected them. The bulbs work by sending electricity through a curly tungsten filament. The long, twisting path increases the electrical resistance faced by traveling electrons, heating the filament to some 3000 K. At that temperature, the filament glows with the warm yellowish white light that we've come to expect from light bulbs.

Still, only about 2% of the energy fed into an incandescent is emitted at visible wavelengths. Most of its output is at longer infrared (IR) wavelengths and is wasted as heat. Other technologies do somewhat better. Compact fluorescent bulbs typically reach an efficiency between 7% and 13%; LEDs manage between 5% and 15%. But so far, these types of bulbs have had trouble producing the warm white light that most consumers prefer.

Researchers have tried to boost the efficiency of some light emitters by sculpting the surface of the emitting material with nanostructures designed to emit more energy as visible light. But with incandescent bulbs, the tungsten filament's scorching temperature quickly causes such nanostructures to fall apart.

Instead, researchers at the Massachusetts Institute of Technology (MIT) in Cambridge, led by physicists Ognjen Ilic, Marin Soljačić, and John Joannopoulos, set out to boost incandescent efficiencies with the help an intricately structured material, called a photonic crystal, that would sit apart from the filament and be more stable. Photonic crystals can act as both filters and mirrors, allowing some wavelengths of light to pass through while reflecting others. So the MIT team set out to create photonic crystals that would allow visible light to pass through while reflecting IR photons. The hope was that the filament would reabsorb the IR photons, which would then reemit some of that energy as visible light.

To create their photonic crystals, the researchers started with millimeter-thick sheets of glass and deposited 90 alternating layers of tantalum oxide and silicon dioxide. This mix was chosen because it reflects IR light but not visible photons. The team relied on extensive computer modeling to determine exactly how thick the layers had to be.

They also had to redesign the bulb's tungsten filament. In place of the curly wire, they folded a thin tungsten ribbon back and forth, creating what looks like a thin tungsten sheet. Electrons still follow a long, circuitous path, ensuring that they face a high electrical resistance, and thus heat up the metal so it will glow. But the larger surface area of the tungsten sheet now makes it easier for the metal to absorb more IR photons reflected by the photonic crystals.

The team flanked the sheetlike tungsten emitter with two sheets of the glass-coated photonic crystals and turned on the power. As they report today in *Nature Nanotechnology*, the crystals allowed virtually all the visible light to pass through but reflected the majority of IR photons back to the emitter, where they were reabsorbed. The energy recycling ultimately improved the efficiency of the bulb to 6.6%, triple that of conventional light bulbs.

That's still at the lower end of the efficiency range for compact fluorescents and LEDs. However, "I think they can do even better than this," says Alejandro Rodriguez, an electrical engineer and photonic crystal expert at Princeton University. Rodriguez notes that the MIT's photonic crystal mirrors would likely be even more efficient at reflecting IR light if they included additional types of materials and more complex structures. Nevertheless, he says, "this is a nice first step."

Ilic and Soljačić say with further engineering it may even be possible to reach efficiencies of 40%, far beyond what commercially available LEDs can muster today. They are looking at using a similar approach to improve the electrical conversion efficiency of devices called thermophotovoltaics, which use sunlight to heat tungsten so that it emits light at a wavelength that is efficiently converted to electricity by a solar cell. For either application to succeed, researchers must show that they can make and their photon recyclers cheaply enough to make them worth adding. If the approach lives up to its promise, cutting-edge photonics could give Edison's glowing filaments a new lease on life.

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Comment

The lifetime of the bulb is extremely important also, and a huge reason why LED and CFL is preferred over incandescent - it's not just electrical to optical efficiency. An incandescent bulb slowly vaporizes itself away due to the metal being close (relatively speaking) to the melting point. So, an incandescent that is equally efficient as an LED bulb is still not preferred unless the life can also achieve the tens of thousands of hours of mean time before failure.