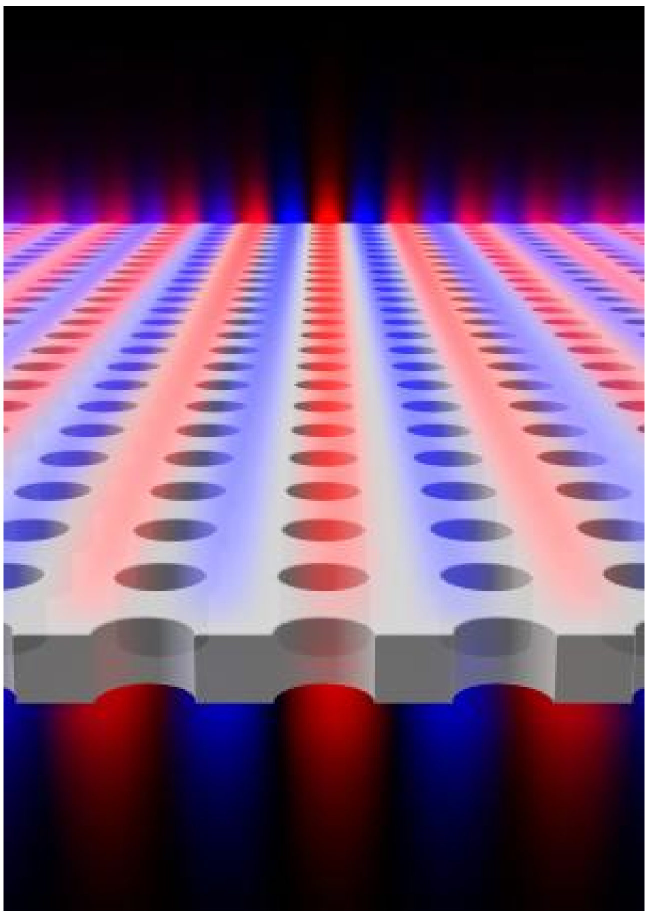
New phenomenon could lead to novel types of lasers and sensors

July 10 2013, by David Chandler



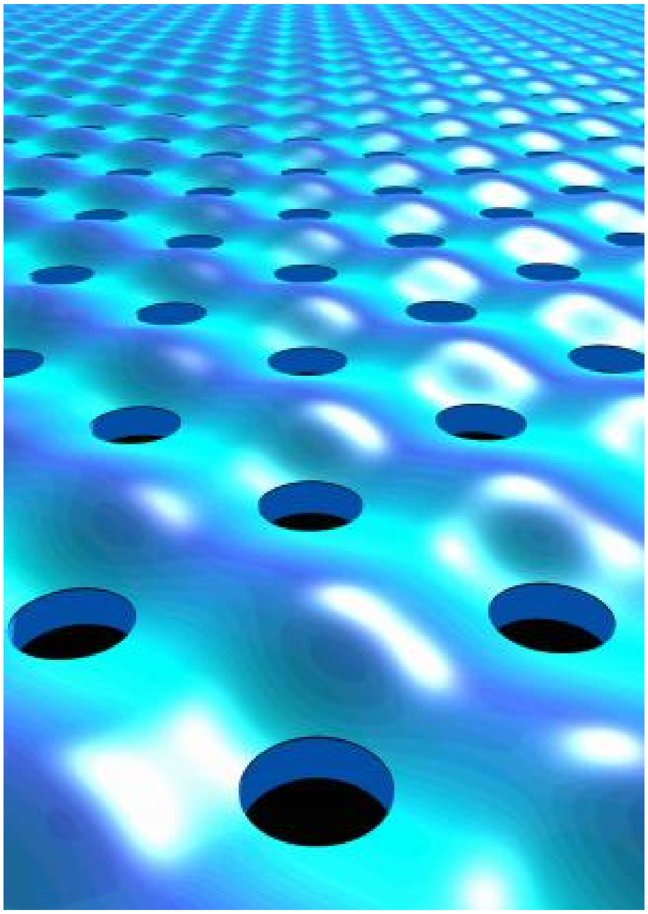
Light is found to be confined within a planar dielectric photonic crystal slab even though the state exists within the radiation continuum. The photonic crystal slab is shown in grey, and the red and blue colors indicate the density of the out-of-plane electric field for this trapped state of light. Credit: Chia Wei Hsu

There are several ways to "trap" a beam of light—usually with mirrors, other reflective surfaces, or high-tech materials such as photonic crystals. But now researchers at MIT have discovered a new method to trap light that could find a wide variety of applications.

The new system, devised through computer modeling and then demonstrated experimentally, pits light waves against light waves: It sets up two waves that have the same wavelength, but exactly opposite phases—where one wave has a peak, the other has a trough—so that the waves cancel each other out. Meanwhile, light of other wavelengths (or colors) can pass through freely.

The researchers say that this phenomenon could apply to any type of wave: sound waves, radio waves, electrons (whose behavior can be described by wave equations), and even waves in water.

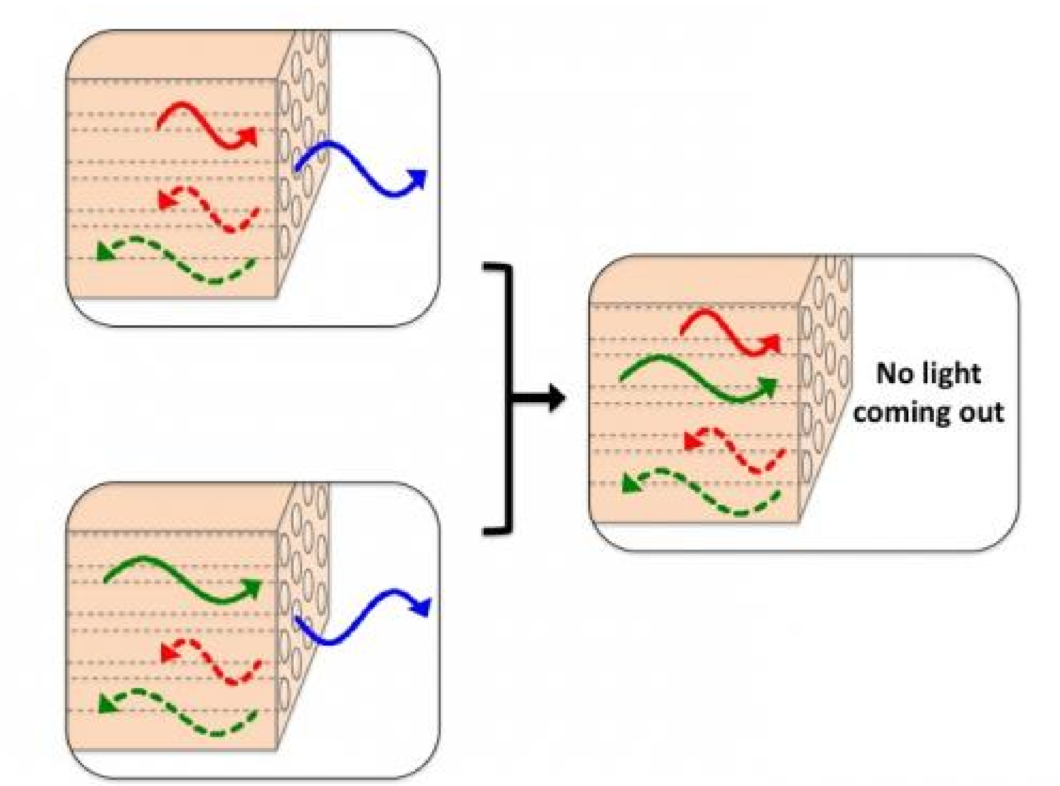
The discovery is reported this week in the journal *Nature* by professors of physics Marin Solja?i? and John Joannopoulos, associate professor of applied mathematics Steven Johnson, and graduate students Chia Wei Hsu, Bo Zhen, Jeongwon Lee and Song-Liang Chua.



Light is found to be confined within a planar dielectric photonic crystal slab even though the state exists within the radiation continuum. The photonic crystal slab is shown in light blue, and the dark blue surface represents the electromagnetic energy density for this trapped state of light. Credit: Bo Zhen

"For many optical devices you want to build," Solja?i? says—including lasers, solar cells and fiber optics—"you need a way to confine light." This has most often been accomplished using mirrors of various kinds, including both traditional mirrors and more advanced dielectric mirrors, as well as exotic photonic crystals and devices that rely on a phenomenon called Anderson localization. In all of these cases, light's passage is blocked: In physics terminology, there are no "permitted" states for the light to continue on its path, so it is forced into a reflection.

In the new system, however, that is not the case. Instead, light of a particular wavelength is blocked by destructive interference from other waves that are precisely out of phase. "It's a very different way of confining light," Solja?i? says.



Light can escape the photonic crystal slab using different channels, but waves in these channels can destructively interfere such that nothing escapes and light remains trapped. Credit: Chia Wei Hsu

While there may ultimately be practical applications, at this point the team is focused on its discovery of a new, unexpected phenomenon. "New physical phenomena often enable new applications," Hsu says. Possible applications, he suggests, could include large-area lasers and chemical or biological sensors.

The researchers first saw the possibility of this phenomenon through numerical simulations; the prediction was then verified experimentally.

In mathematical terms, the new phenomenon—where one frequency of light is trapped while other nearby frequencies are not—is an example of an "embedded eigenvalue." This had been described as a theoretical possibility by the mathematician and computational pioneer John von Neumann in 1929. While physicists have since been interested in the possibility of such an effect, nobody had previously seen this phenomenon in practice, except for special cases involving symmetry.

More information: dx.doi.org/10.1038/nature12289

Provided by Massachusetts Institute of Technology