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NEWS

Antilaser Invented

Device acts like a laser in reverse, could become a silicon photonics component

By NEIL SAVAGE / FEBRUARY 2011

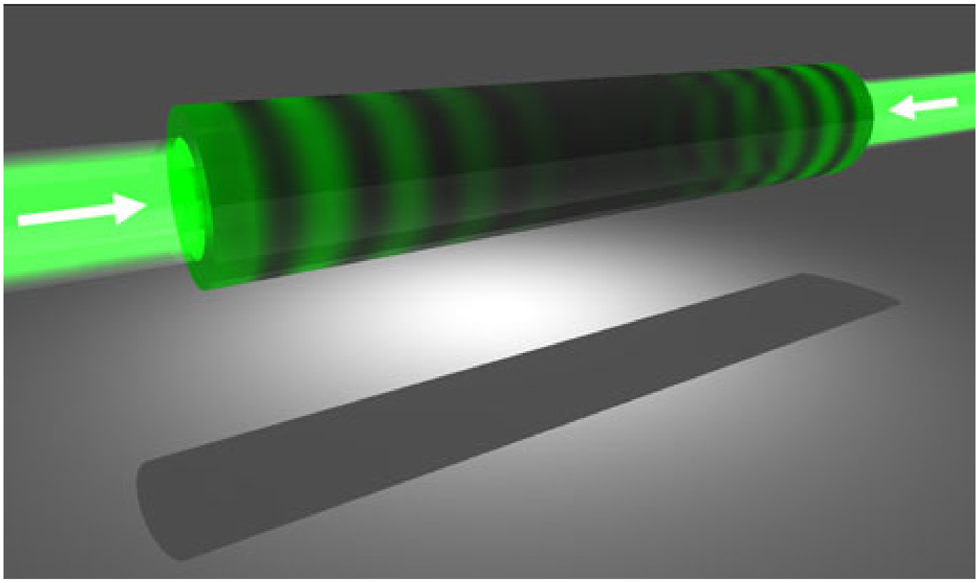

Photo: Science/AAAS

17 February 2011—Yale University physicists have built an antilaser, a device capable of completely absorbing coherent light beams instead of scattering them as most other things do. If such a device proves practical, it might provide a way to build miniature silicon optical switches or lead to new types of photonic sensors.

The device works on the same principle as a laser but in reverse, and uses "time-reversal symmetry," a concept from electromagnetic theory. In essence, explains A. Douglas Stone, a professor of applied physics at Yale, "anything that could go forwards, the same process could go backwards."

In a laser, light or electricity is usually pumped into a gain medium, such as the semiconductor gallium arsenide, creating an abundance of electrons in heightened energy states. As the electrons drop to lower energy states, they emit photons, which travel back and forth in a laser cavity, exciting more electrons, until a coherent beam of light of a specific wavelength emerges from one end.

In the antilaser, which Stone and colleagues describe in this week's *Science*, a coherent beam of light is inserted into a loss medium, which can be the same material as the gain medium or one less likely to emit light, such as the silicon used in this experiment. Any material will absorb some photons and scatter the rest, but picking just the right wavelength for the particular material and the length of the antilaser cavity ensures that all the photons will be absorbed if they stay in the material long enough.

To trap the photons, the Yale team split the laser beam in two and shone each one on opposite sides of a 110-micrometer-thick silicon wafer. They tuned the phases of the separate beams to create an interference pattern. "Destructive interference"—spots where the lasers' phases canceled one another out—imprisoned the photons in the silicon, keeping them there long enough to be absorbed. The "coherent perfect absorber," as the researchers call it, consumed more than 99 percent of the photons; fluctuations in the frequency of the laser beams prevented them from reaching 100 percent.

The amount of absorption was tunable, the scientists found. If they moved one beam slightly out of phase with the other, they could decrease the absorption of photons to about 30 percent. In a more complicated system of alternating layers of silicon and silica, Stone says, it should be possible to toggle the absorption from 1 to 99 percent. That could allow them to turn a light beam on and off or encode data onto it. "We think that our device definitely can function as a modulator and a switch," says Hui Cao, a professor of applied physics who worked with Stone on the antilaser.

Engineers would have to decide whether such devices would be preferable to existing modulators and switches, she says.

"In my opinion, this is a very important achievement," says Stefano Longhi, associate professor of physics at the Polytechnic Institute of Milan. "You can make a material, which is in itself mostly transparent, a perfect absorber for a certain excitation of light." Longhi says it would be interesting to make a device that was both a laser and an antilaser: "It would simultaneously behave like a source and a drain of light."

Absorbing photons would release energy into the loss medium as heat or electricity. That might provide a way to deliver a burst of energy inside a living cell, for instance. By adding a bias voltage the antilaser can function as a photovoltaic device, says Cao. So the device could be used to create a signal in a photodetector.

But because the antilaser works with a specific wavelength in a coherent beam, it wouldn't have any practical use in solar cells. It also wouldn't help with stealth technology, and it's not a shield against laser beams, Stone points out.

The physicists are talking to researchers at Cornell University, in Ithaca, N.Y., about whether the antilaser might aid in the development of a hybrid optical and electronic computer that uses light instead of electrons for some calculations. Right now, "mostly people are trying to get their heads around it and understand what it is," Stone says. "We'll find out if there's a killer app for this or not."

About the Author

Neil Savage writes about nanotech, optoelectronics, and other technology from Lowell, Mass. In February 2011, he reported on the first programmable logic device made from nanowires.