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Beam Bagged: "Reverse Laser" Functions as Near-Perf Light Absorber

Physicists have constructed a sort of anti-laser, a silicon device that turns very specific kinds of light into energy

By John Matson | Friday, February 18, 2011 | 19 comments

Since they were invented 50 years ago, lasers have become extraordinarily commonplace. Anyone with a few dollars to spare c themselves a laser pointer, and every CD, DVD or Blu-ray player uses a laser to read the bits encoded on discs. (It goes withou that the same is true of those old LaserDisc players.) Just about everyone knows how lasers work, at least on the most superfic a concentrated beam of light comes out when energy goes in.

But what if that same process could be run in reverse, like a movie run backward? Last year, a group of physicists at Yale Univ proposed a way to do just that with something called a time-reversed laser. Such a device, which some have described with the appropriate "anti-laser," completely swallows light to produce heat or electricity using an optical cavity that absorbs rather tha amplifies light. In other words, energy comes out when light goes in. Now the same researchers, along with two other Yale colle have actually managed to build an anti-laser, which absorbs more than 99 percent of the light striking it and converts it to ther energy. They reported the advance in the February 18 issue of *Science*.

But the anti-laser does not work for any old light source; the absorption is specific to narrow frequencies of so-called coherent l whose waves are synchronized—which is what an ordinary laser emits. (Put another way, the technology does not make for mo efficient solar cells that could absorb all of the sun's full-spectrum energy.)

The device sprang from a theoretical inquiry into how lasers of all kinds work, and then how they would work under the conditi physicists call time reversal. "I was saying to colleagues, imagine it the other way around," recalls Yale theoretical physicist Dou Stone, a co-author of the new study. "You illuminate it with exactly the same light that the laser would emit, and everything wo absorbed at that frequency." Then, Stone says, came the key question: "Wait a second. Could we really do that?"

Partnering with a group of Yale experimentalists led by Hui Cao, the researchers figured out how such an anti-laser might worl splitting a laser beam and aiming each part onto opposite sides of a polished silicon wafer, the group engineered a system of refl and interference that traps both beams in the silicon. Unable to escape, they are absorbed and their energy dissipates as heat, a says that with proper engineering electrical output is also possible. Less than 1 percent of the light escapes in the demonstratio with better lasers, the researchers say, even greater absorption should be possible.

Making the beams interfere perfectly so that the silicon wafer traps them both is tricky business, a recipe that requires precise controlling the two beams' traits. Splitting a single laser beam ensures that both sides of the silicon wafer are illuminated by ligh the same wavelength and amplitude, and a delay along one of the beam paths controls the relative phase of the beams—whethe of the two beams are in step or out of sync. With the right phase shift a material that would ordinarily reflect (like a mirror) or (like a window) more than a third of the incident light suddenly absorbs nearly all of the laser light striking it. "When you get to special condition, it gets in and bang—it can't get out," Stone says.

A different phase shift does just the opposite, reducing the absorption of the material. In other words, a change to one of the las affects how both beams interact and how much light gets through. "This is really light controlling light," Stone says. "It's a light-controlled switch, and that's pretty new." That switching could be useful for optical circuits, which use light rather than electrici carry information.

The physical properties of the material help determine which wavelengths of light will be perfectly absorbed; for the initial silic the sweet spot is in the near infrared. But Cao says that similar devices could be concocted using the same recipe for visible wav "If we design our structure correctly, we can do it," she says. "We can adjust the parameters to make this happen at the visible

The fact that the anti-laser's absorption is so sensitive to light's properties limits its usefulness as a collector of raw solar energy could be useful, for instance, in singling out very specific spectral signals. "The simplest thing I can imagine is a detector that is detect radiation in a noisy environment where there are many frequencies," says Princeton University theoretical physicist Ha Türeci.

Stefano Longhi, a physicist at the Polytechnic Institute of Milan, says that the research could lead to any number of possible op wonders. "The experiment is very clean, very impressive," he says. "And one can imagine even more amazing things." One pos a material that goes from being transparent to being a perfect absorber, simply by changing the interference pattern of the ligh strikes it. Or one could envision a material that can be a spontaneous emitter of light or perfect absorber—both a laser and an a in one. "This is the first step toward such fascinating interactions of matter and light," Longhi says.