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Invisibility-Cloak Materials Bend Light "Backward"

Brian Handwerk
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Invisibility cloaks may be a bit closer to reality, researchers say, thanks to the development of two new materials that are the first to bend visible light the "wrong" way in three dimensions.

The so-called metamaterials are artificial composites designed to manipulate light in ways that natural materials can't—in these cases by refracting it backward. (Related: "The Power of Light" in *National Geographic* magazine.)

If their cloaking capabilities are fully realized, metamaterials could make an object invisible by bending light waves so that they curve around the object and then reconnect, seemingly unaltered, on the other side—similar to the way water flows around a boulder.

"Of course cloaking captures everybody's attention, but these papers aren't [just] about cloaking," said Xiang Zhang, a professor at the University of California, Berkeley, and head of the research teams publishing related papers in two different journals this week.

"[The studies] are about the ability to engineer these material properties that never exist in nature. With that ability one can do many things, and cloaking is only one of them."

Such materials could also boost the power of microchips and antennas and allow the creation of "superlenses" that could image objects smaller than the wavelength of light, the study authors report.

Negative Refraction
One new metamaterial, described in *Science,* is a microscopic arrangement of silver wires—each about 20 times thinner than a human hair—embedded in aluminum oxide.

The other metamaterial, detailed online in *Nature,* is a layer cake of alternating nanoscale strips of silver and magnesium fluoride that were cut into a fishnet pattern.

Both materials exhibit negative refraction—bending visible light in a different direction than expected in nature.

A pencil sticking out a glass of water, for example, normally appears slightly bent at the point where it meets the water's surface but is still seen submerged. With negative refraction, the pencil would appear to stick back out of the water.

Previous metamaterials have been able to achieve a cloaking effect only in two dimensions in larger microwave wavelengths that are not visible to humans.

In addition to having 3-D negative refraction for a broader visible light spectrum, the new advances help overcome the sticky problem of energy loss.

Previous metamaterials actually absorbed most of the light, rather than bending it away, reducing the "invisible" properties. The new materials were designed to keep energy away from the most absorbent materials.

"It's like when you try to cross a river and keep your feet dry. You may jump across stones and cross without getting your feet wet," study leader Zhang said.

"That's exactly what we did. We tried to engineer these materials such that energy passing through is hopping through [other materials] and not the metal—because in the metal you have a big energy loss."

Scaling Up

David Schurig, a physicist and metamaterial expert at North Carolina State University in Raleigh, called the types of materials discussed by both papers "probably the most exciting metamaterials in existence today."

"Even in their current state, or maybe a few generations [later], they could have applications in optical communications or imaging," added Schurig, who was not involved with the research.

But, he noted, efforts to cloak anything above microscopic size are likely quite a ways off.

"You want to cloak things that are big, otherwise they are already essentially invisible, because they are [microscopic]," Schurig said.

"To cloak a person, you need metamaterial that's on that length scale, and that's much, much bigger than what [these papers] have demonstrated."
