Light Fantastic: Flirting With Invisibility

Duke researchers built a simplified version of their cloaking device out of copper rings and wires patterned onto fiberglass sheets and demonstrated that it successfully diverted microwaves.

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Increasingly, physicists are constructing materials that bend light the “wrong” way, an optical trick that could lead to sharper-than-ever
lenses or maybe even make objects disappear.

Last October, scientists at Duke demonstrated a working cloaking device, hiding whatever was placed inside, although it worked only for microwaves.

In the experiment, a beam of microwave light split in two as it flowed around a specially designed cylinder and then almost seamlessly merged back together on the other side. That meant that an object placed inside the cylinder was effectively invisible. No light waves bounced off the object, and someone looking at it would have seen only what was behind it.

The cloak was not perfect. An alien with microwave vision would not have seen the object, but might have noticed something odd. “You’d see a darkened spot,” said David R. Smith, a professor of electrical and computer engineering at Duke. “You’d see some distortion, and you’d see some shadowing, and you would see some reflection.”

A much greater limitation was that this particular cloak worked for just one particular “color,” or wavelength, of microwave light, limiting its usefulness as a hiding place. Making a cloak that works at the much shorter wavelengths of visible light or one that works over a wide range of colors is an even harder, perhaps impossible, task.

Nonetheless, the demonstration showed the newfound

ability of scientists to manipulate light through structures they call “metamaterials.”

Obviously the military would be interested in any material that could be used to hide vehicles or other equipment. But such materials could also be useful in new types of microscopes and antennae. So far, scientists have written down the underlying equations, performed computer simulations and conducted some proof-of-principle experiments like the one at Duke. They still need to determine the practical limitations of how far they can bend light to their will.

The method is not magic, nor are the materials novel. Physicists are taking ordinary substances like fiberglass and copper to build metamaterials that look like mosaics of repeating tiles. The metamaterials interact with the electric and magnetic fields in light waves, manipulating a quantity known as the index of refraction to bend the light in a way that no natural material does.

“There are some things that chemistry can’t do on its own,” said John B. Pendry, a physicist at Imperial College London. “The additional design flexibility with introducing structure as well as chemistry into the equation enables you to reach properties that just haven’t been accessible before.”

When a ray of light crosses a boundary from air to water, glass or other transparent material, it bends, and the degree of bending is determined by the index of refraction.

Air has an index of 1. Water’s index of refraction is about 1.3. That is why rippling water waves distort the view of a pond bottom, for instance. It is refraction that makes a straw in a glass of water look as if it is bending toward the surface, and fish swimming in a pond look closer to the surface than they really are.

Diamonds have a refractive index of 2.4, giving them their sparkling beauty.
For visible light, transparent materials like glass, water and diamonds all have an index of 1 or higher, meaning that when the light enters, its path bends inward, closer to the perpendicular. Because the index is uniform throughout a material, the bending occurs only as the light crosses a boundary.

But with metamaterials, scientists can now also create indexes of refraction from 0 to 1. In the Duke cloaking device, the index actually varies smoothly from 0, at the inside surface of the cylinder, to 1, at the outside surface. That causes the path of light to curve not just at the boundaries, but also as it passes through the metamaterial.

Metamaterials first took center stage in a scientific spat a few years ago over a startling claim that the index of refraction could be not just less than 1, but also negative, less than 0. Light entering such a material would take a sharp turn, almost as if it had bounced off an invisible mirror as it crossed the boundary.
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