Negative Refraction of Visible Light Demonstrated; Could Lead to Cloaking Devices

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For the first time, physicists have devised a way to make visible light travel in the opposite direction that it normally bends when passing from one material to another, like from air through water or glass. The phenomenon is known as negative refraction and could in principle be used to construct optical microscopes for imaging things as small as molecules, and even to create cloaking devices for rendering objects invisible.

In the March 22 in the online publication *Science Express*, California Institute of Technology applied physics researchers Henri Lezec, Jennifer Dionne, and Professor Harry Atwater, will report their success in constructing a nanofabricated photonic material that creates a negative index of refraction in the blue-green region of the visible spectrum. Lezec is a visiting associate in Atwater's Caltech lab, and Dionne is a graduate student in applied physics.

According to Lezec, the key to understanding the technology is first in understanding how light normally bends when it passes from one medium to another. If a pencil is placed in a glass of water at an angle, for example, it appears to bend upward and outward if we look into the water from a vantage point above the surface. This effect is due to the wave nature of light and the normal tendency of different materials to disperse light in different ways-in this case, the materials being the air outside the glass and the water inside it.

However, physicists have thought that, if new optical materials could be constructed at the nanoscale level in a certain way, it might be possible to make the light bend at the same angle, but in the opposite direction. In other words, the pencil angled into the water would appear to bend backward as we looked at it.

The details are complicated, but have to do with the speed of light through the material itself. Researchers in recent years have created materials with negative diffraction for microwave and infrared frequencies. These achievements have exploited the relatively long wavelengths at those frequencies--the wavelength of microwaves being a few centimeters, and that of infrared frequencies about the width of a human hair. Visible light, because its wavelength is at microscopic dimensions--about one-hundredth the width of a hair--has defeated this conventional approach.

Dionne, one of the lead authors, says that the breakthrough is made possible by the Atwater lab's work on plasmonics, an emerging field that "squeezes" light with specially designed materials to create a wave known as a plasmon. In this case, the plasmons act in a manner somewhat similar to a wave carrying ripples across the surface of a lake, carrying light along the silver-coated surface of a silicon-nitride material, and then across a nanoscale gold prism so that the light reenters the silicon-nitride layer with negative refraction.

Thus, the process is not the same as the one used for negative refraction of microwaves and infrared radiation, but it still works, says Dionne. And this discovery is particularly exciting because visible light, as its name suggests, is the wavelength associated with the world of objects we see, provided they are not too small.

"Maybe you could create a superlens that can beat the diffraction limit," says Dionne. "You might be able to see DNA and protein molecules clearly just by looking at them, without having to use a more complicated method like X-ray crystallography."

Atwater, who is the Howard Hughes Professor and professor of applied physics and materials science at Caltech, says the plasmonic technique indeed has potential for a compact "perfect lens" that could have a huge number of biomedical and other technological applications. "Once the light coming from a nearby object passes through the negative-refraction material, it would be possible to recover all the spatial information," he says, adding that the loss of this information is why there is ordinarily a limit to the size of an object that can be seen in a microscope.

Even more tantalizing is the possibility of an optical "invisibility cloak" device that would surround an object and bend light in such a way that it would be perfectly refocused on the opposite side. This would provide perfect invisibility for the object inside the cloak, in a manner similar to the cloaks used by Harry Potter or the Klingons in the old Star Trek television series.

"Of course, anyone inside the cloak would not be able to see out," Atwater says.

"But maybe you could have some small windows," Dionne adds.

Source: Caltech

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