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Their Deepest, Darkest Discovery

Scientists Create a Black That Erases Virtually All Light

By Rick Weiss
Washington Post Staff Writer
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Black is getting blacker.

Researchers in New York reported this month that they have created a paper-thin material that absorbs 99.955 percent of the light that hits it, making it by far the darkest substance ever made -- about 30 times as dark as the government's current standard for blackest black.

The material, made of hollow fibers, is a Roach Motel for photons -- light checks in, but it never checks out. By voraciously sucking up all surrounding illumination, it can give those who gaze on it a dizzying sensation of nothingness.

"It's very deep, like in a forest on the darkest night," said Shawn-Yu Lin, a scientist who helped create the material at Rensselaer Polytechnic Institute in Troy, N.Y. "Nothing comes back to you. It's very, very, very dark."

But scientists are not satisfied. Using other new materials, some are trying to manufacture rudimentary Harry Potter-like cloaks that make objects inside of them literally invisible under the right conditions -- the pinnacle of stealthy technology.

Both advances reflect researchers' growing ability to manipulate light, the fleetest and most evanescent of nature's offerings. The nascent invisibility cloak now being tested, for example, is made of a material that bends light rays "backward," a weird phenomenon thought to be impossible just a few years ago.

Known as transformation optics, the phenomenon compels some wavelengths of light to flow around an object like water around a stone. As a result, things behind the object become visible while the object itself disappears from view.

"Cloaking is just the tip of the iceberg," said Vladimir Shalaev, a professor of electrical and computer engineering at Purdue University and an expert in the fledgling field. "With transformation optics you can do many other tricks," perhaps including making things appear to be located where they are not and focusing massive amounts of energy on microscopic spots.

U.S. military and intelligence agencies have funded the cloaking research "for obvious reasons," said David Schurig, a physicist and electrical engineer at North Carolina State University who recently designed and helped test a cloaking device. In that experiment, a shielded object a little smaller than a hockey puck was made invisible to a detector that uses microwaves to "see."

The first working cloaks will be limited that way, he said -- able to steer just a limited part of the light spectrum around objects -- and it could be years before scientists make cloaks that work for all wavelengths, including the visible spectrum used by the human eye.

But even cloaks that work on just a few key wavelengths could offer huge benefits, making objects invisible to laser beams used for weapons targeting, for example, or rendering an enemy's night goggles useless because objects would be invisible to the infrared rays those devices use.

The Defense Department did not fund development of the new blacker-than-black material, created by Lin and his colleagues. But military officials were among the first to call after a description of the work appeared in this month's issue of the journal Nano Letters, Lin said in an interview.

Substances that absorb every smidgeon of incoming visible light could complement existing stealth coatings that absorb radar waves, Lin said. He and others emphasized, however, that there are also peaceful and more immediate applications for the blackest stuff on Earth.

Solar panels coated with it would be much more efficient than those coated with conventional black paint, which reflects 5 percent or more of incoming light. Telescopes lined with it would sop up random flecks of incidental light, providing a blacker background to detect faint stars.

And a wide array of heat detectors and energy-measuring devices, including climate-tracking equipment on satellites, would become far more accurate than they are today if they were coated with energy-grabbing superblack.

That helps explain why Lin has been fielding queries from solar-energy companies such as SolFocus of Mountain View, Calif., and the European Space Agency.

"The more black the material the better," said Gerald Fraser, a physicist at the National Institute of Standards and Technology, the federal agency that specializes in fine measurements and industrial standards.

That agency offers scientists a chemical mix it calls "standard black," which for years has been the defining measure of blackness. Photographers and printers use it to calibrate their gray scales. Industrial radiologists use it to calibrate X-ray imaging systems that detect radiation or hidden defects in building materials.

That black reflects about 1.4 percent of incoming visible light, and in recent years it has become somewhat outmoded. In 2003, scientists developed a substance made of nickel and phosphorus that reflected just 0.17 percent of visible light, winning it a Guinness World Records listing and kudos in Time magazine as one of that year's 300 "coolest inventions."

The newest black -- which when held next to something conventionally black, such as a tuxedo jacket, is noticeably blacker -- reflects just 0.045 percent of visible light.

It is made of carbon nanotubes: microscopic, hollow fibers whose walls are just one atom thick. Importantly, the fibers are widely spaced, providing plenty of space to allow light in and almost no surfaces to bounce it back out.

"There are a lot of materials that are very absorbing of light so that once the light gets in, very little is reflected. That is not the big issue," said John Pendry, a physics professor at Imperial College London. "The big issue is persuading the light to go in there in the first place" -- something the New York team accomplished by spacing the nanotubes so widely.

While Lin and his colleagues, including Pulickel Ajayan, now at Rice University, pursue applications for their superblack, Pendry and others are hoping to go further by perfecting complete invisibility. The big difference is that a superblack object, even if invisible to the eye, still casts a shadow behind it, while an object shielded by an invisibility cloak does not.

Pendry pioneered much of modern thinking about how to attain full invisibility using "metamaterials" -- substances engineered to manhandle light. Ordinary matter, such as glass or water, slows and bends light as it passes through. Metamaterials contain bits of metal or other substances embedded in precise patterns to make the light bend in an opposite direction from normal paths.

"In a sense you have some negative space," Pendry said. "The light appears to go backward in space."

The first generation, metamaterial "cloaks" are not thin and flexible like Harry Potter's imagined version but are inches thick and solid, resembling canisters, making them able to hide a stationary object but not a moving person. But the science is progressing quickly, physicist Schurig said.

To make a thin, flexible metamaterial cloak, Schurig said, "is technically challenging but not fundamentally impossible." And although no cloak can yet make objects fully invisible to the human eye, he added, it may not be long before scientists can bend the visible spectrum enough to make an object hard to see.

That object might be found "if you know what you are looking for," Schurig said.

"But if you're just scanning, then partial invisibility may allow something to go unnoticed."

There is a flip side to the emerging ability to manipulate light, scientists say. "Think anti-cloaking," said Shalaev, the engineering professor. "Instead of excluding light from an object, you can concentrate light in a small area."

Normally, light cannot be squeezed into a space smaller than its own wavelength, he said, but transformation optics create the possibility of accomplishing just that -- packing loads of energy into a vanishingly small space. Such beams could pack a destructive punch, or could be tamed to serve as ultrasensitive needlelike probes, able to detect even a single molecule of some substance of interest.

Pendry added a cautionary note about invisible cloaks, making a real-life distinction from the stuff of fiction: People inside them will not be able to see out. By definition, if no light is bouncing off them, none can reach their eyes, either. "You'd have to use signals other than light to communicate," Pendry said.

Asked for an example of what would work, he paused for a moment.

"You could always talk to them," he said.