Invisibility Cloak Blurs Line Between Magic and Science (w/Video)

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These three images depict how light striking an object covered with the carpet cloak acts as if there were no object being concealed on the flat surface. In essence, the object has become invisible. Credit: Image by Thomas Zentgraf

(PhysOrg.com) -- The great science fiction writer Arthur C. Clarke famously noted the similarities between advanced technology and magic. This summer on the big screen, the young wizard Harry Potter will once again don his magic invisibility cloak and disappear. Meanwhile, researchers with Berkeley Lab and the University of California Berkeley will be studying an invisibility cloak of their own that also hides objects from view.

A team led by Xiang Zhang, a principal investigator with Berkeley Lab's Materials Sciences Division and director of UC Berkeley's Nano-scale Science and Engineering Center, has created a "carpet cloak" from nanostructured silicon that conceals the presence of objects placed under it from optical detection. While the carpet itself can still be seen, the bulge of the object underneath it disappears from view. Shining a beam of light on the bulge shows a reflection identical to that of a beam reflected from a flat surface, meaning the object itself has essentially been rendered invisible.

"We have come up with a new solution to the problem of invisibility based on the use of dielectric (nonconducting) materials," says Zhang. "Our optical cloak not only suggests that true invisibility materials are within reach, it also represents a major step towards transformation optics, opening the door to manipulating light at will for the creation of powerful new microscopes and faster computers."

Zhang and his team have published a paper on this research in the journal Nature Materials entitled: An Optical Cloak Made of Dielectrics. Co-authoring the paper with Zhang were Jason Valentine, Jensen Li, Thomas Zentgraf and Guy Bartal, all members of Zhang's research group.

Previous work by Zhang and his group with invisibility devices involved complex metamaterials - composites of metals and dielectrics whose extraordinary optical properties arise from their unique structure rather than their composition. They constructed one material out of an elaborate fishnet of alternating layers of silver and magnesium fluoride, and another out of silver nanowires grown inside porous aluminum oxide. With these metallic metamaterials, Zhang and his group demonstrated that light can be bent backwards, a property unprecedented in nature.

While metallic metamaterials have been successfully used to achieve invisibility cloaking at microwave frequencies, until now cloaking at optical frequencies, a key step towards achieving actual invisibility, has not been successful because the metal elements absorb too much light.

Says Zhang, "Even with the advances that have been made in optical metamaterials, scaling sub-wavelength metallic elements and placing them in an arbitrarily designed spatial manner remains a challenge at optical frequencies."

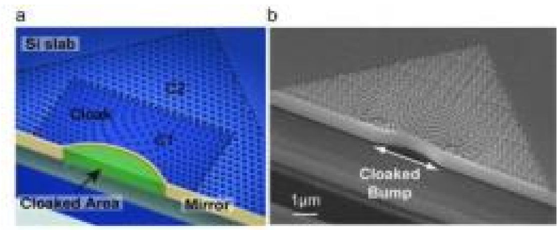

Image (a) is a schematic diagram showing the cloaked region (marked with green) which resides below the reflecting bump (carpet) and can conceal any arbitrary object by transforming the shape of the bump back into a virtually flat object. Image (b) was taken with a scanning electron microscope image of the carpet coated bump. Credit: Image by Thomas Zentgraf

The new cloak created by Zhang and his team is made exclusively from dielectric materials, which are often transparent at optical frequencies. The cloak was demonstrated in a rectangular slab of silicon (250 nanometers thick) that serves as an optical waveguide in which light is confined in the vertical dimension but free to propagate in the other two dimensions. A carefully designed pattern of holes - each 110 nanometers in diameter - perforates the silicon, transforming the slab into a metamaterial that forces light to bend like water flowing around a rock. In the experiments reported in Nature Materials, the cloak was used to cover an area that measured about 3.8 microns by 400 nanometers. It demonstrated invisibility at variable angles of light incident.

Right now the cloak operates for light between 1,400 and 1,800 nanometers in wavelength, which is the near-infrared portion of the electromagnetic spectrum, just slightly longer than light that can be seen with the human eye. However, because of its all dielectric composition and design, Zhang says the cloak is relatively easy to fabricate and should be upwardly scalable. He is also optimistic that with more precise fabrication this all dielectric approach to cloaking should yield a material that operates for visible light - in other words, true invisibility to the naked eye.

"In this experiment, we have demonstrated a proof of concept for optical cloaking that works well in two dimensions" says Zhang. "Our next goal is to realize a cloak for all three dimensions, extending the transformation optics into potential applications."

More information: A copy of the Nature Materials paper “An Optical Cloak Made of Dielectrics” by Zhang, et al., can be read here: www.nature.com/nmat/journal/va … t/full/nmat2461.html

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