Miniature invisibility 'carpet cloak' hides more than its small size implies

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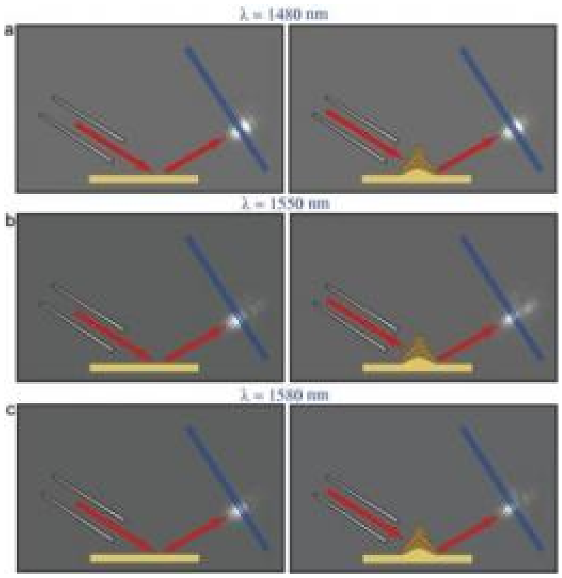

The measured output image from a flat surface (left) and a cloaked protruded surface (right) at 1,480 nm (a), 1,550 nm (b), and 1,580 nm (c). Credit: Technical University of Denmark/*Optics Express*

Invisibility cloaks are seemingly futuristic devices capable of concealing very small objects by bending and channeling light around them. Until now, however, cloaking techniques have come with a significant limitation—they need to be orders of magnitude larger than the object being cloaked.

This places serious constraints on practical applications, particularly for the optoelectronics industry, where size is a premium and any cloaking device would need to be both tiny and delicate.

An international team of physicists from the Technical University of Denmark (DTU), the University of Birmingham, UK, and Imperial College London, however, may have overcome this size limitation by using a technology known as a "carpet cloaks," which can conceal a much larger area than other cloaking techniques of comparable size. The researchers achieved their result by using metamaterials, artificial materials engineered to have optical properties not found in nature. They describe their approach in the Optical Society's (OSA) open-access journal *Optics Express*.

Jingjing Zhang, a postdoctoral researcher at DTU's Fotonik Department of Photonics Engineering and Structured Electromagnetic Materials, and an author of the Optics Express paper, explains that the team's new carpet cloak, which is based on an alternating-layer structure on a silicon-on-insulator (SOI) platform, introduces a flexible way to address the size problem.

"This new cloak, consisting of metamaterials, was designed with a grating structure that is simpler than previous metamaterial structures for cloaks," she says.

Grating structures channel light of a particular wavelength around an object. A grating structure is simply a series of slits or openings that redirect a beam of light.

"The highly anisotropic material comprising the cloak is obtained by adopting semiconductor manufacturing techniques that involve patterning the top silicon layer of an SOI wafer with nanogratings of appropriate filling factor. This leads to a cloak only a few times larger than the cloaked object," says Zhang. In this case, filling factor simply refers to the size of the grating structure and determines the wavelengths of light that are affected by the cloak.

By precisely restoring the path of the reflecting wave from the surface, the cloak creates an illusion of a flat plane for a triangular bump on the surface—hiding its presence over wavelengths ranging from 1480nm to 1580nm (see figure).

In less technical terms, the carpet cloaks work by essentially disguising an object from light, making it appear like a flat ground plane.

"The cloak parameters can be tweaked by tuning the filling factor and the orientation of the layers," says Zhang. "Therefore, layered materials bypass the limitation of natural materials at hand and give us extra freedom to design the devices as desired." In contrast to previous works based on nanostructures, the cloaking carpet used in this work also shows advantages of easier design and fabrication.

The cloak is made exclusively of dielectric materials that are highly transparent to infrared light, so the cloak itself is very efficient and absorbs a negligible fraction of energy.

Zhang and her colleagues are also looking at ways of improving the technology. They report in their Optics Express paper that even though the cloaking ensures that the beam shape is unaffected by the presence of the object, the beam intensity is slightly reduced. They attribute this to reflection at the cloak's surface, and partly by imperfections of the fabrication. They also determined that adding an additional layer of material around the cloak and improving uniformity of the grating would help eliminate reflection and scattering issues.

"Although our experiment was carried out at near-infrared frequencies, this design strategy is applicable in other frequency ranges," notes

Zhang. "We anticipate that with more precise fabrication, our technique should also yield a true invisibility carpet that works in the microwave and visible parts of the spectrum and at a larger size—showing promise for many futuristic defense and other applications."

More information: "Homogenous optical cloak constructed with uniform layered structures," Jingjing Zhang, Liu Liu, Yo Luo, Shuang Zhang, and Niels Asger Mortensen, Optics Express, Volume 19, Issue 9, pp. 8625-8631. Available at: www.opticsinfobase.org/oe/abst … cfm?uri=oe-19-9-8625

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