Optical metacage blocks light from entering or escaping

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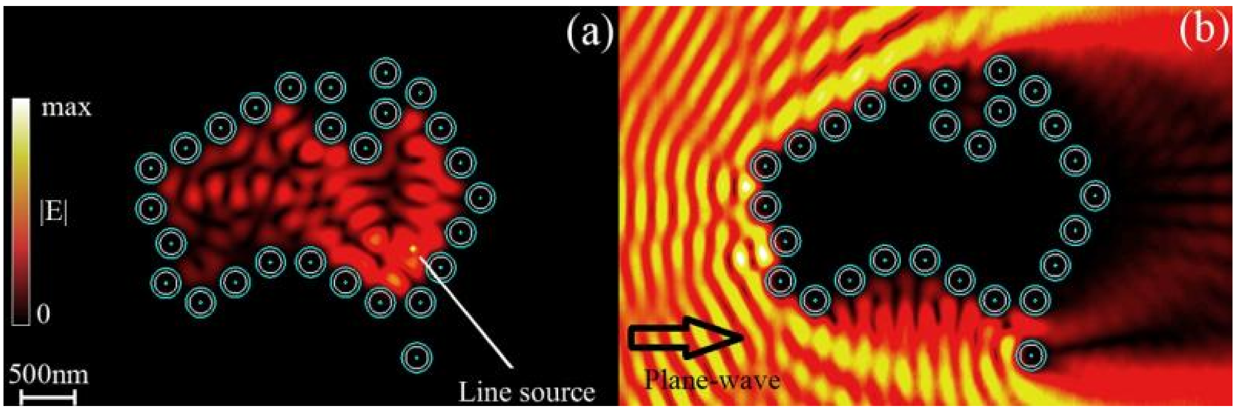


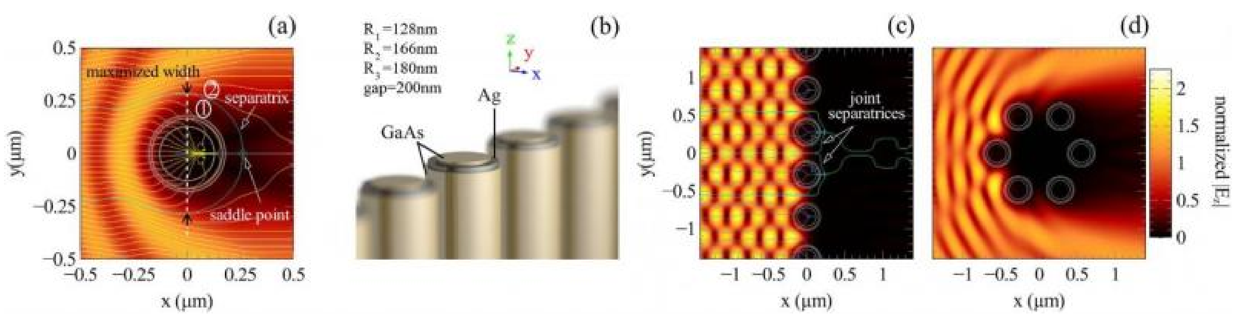
(a) When a light source is placed inside the metacage (here, in the shape of Australia), the radiation is contained inside. (b) When a light source is located outside the metacage, the radiation cannot enter. Credit: Mirzaei, et al. ©2015 American Physical Society

(Phys.org)—Physicists have built a nanowire cage that blocks one or more wavelengths of light from either entering or escaping, yet allows liquids and gases to pass through the small gaps between the nanowires. The "optical metacage" takes advantage of the optical properties of nanowire structures, and could have applications including protecting microorganisms from radiation, optically shielding nanophotonics components, and laser-driven drug delivery.

The researchers, Ali Mirzaei, et al., at the Australian National University, have published a paper on the optical metacage in a recent issue of *Physical Review Letters*.

"We have introduced a new class of optical and electromagnetic shielding structures based on nanowires," Mirzaei told *Phys.org*. "These structures, which we call metacages, can provide either wide or narrow band electromagnetic shielding. Remarkably, metacages can be designed with large gaps between the nanowires, with enough space for liquids and gasses to freely pass through. The discrete nature of metacages offers great flexibility in designing shielding structures of almost arbitrary shapes."

In some ways, the optical metacage is similar to an invisibility cloak, since both types of devices shield objects from electromagnetic radiation. However, the optical metacage remains visible while invisibility cloaks do not. Also unlike invisibility cloaks, the optical metacage can shield objects of arbitrary shape, which the scientists demonstrated by building a metacage in the shape of Australia.



(a) The separatrix divides region 1 (where light is absorbed by the nanowire) and region 2 (where light flows around the nanowire). (b) Array of multilayer nanowires with a small gap between them. (c) Light is blocked by a one-dimensional chain of nanowires whose separatrices overlap. (d) Nanowires shield an enclosed volume, which can have an almost arbitrary shape. Credit: Mirzaei, The optical metacage can be made of different types of nanowires (semiconductors, ceramics, or metals) with different numbers of layers, including two- and three-layer structures. The nanowires are spaced so that the gaps between them are approximately the size of the nanowire radius. Light cannot pass through these gaps because the nanowires absorb light that comes within this close range. The boundary lines between the region where the light is close enough to be absorbed by the nanowire and the region where it flows around the nanowire without being absorbed are called "separatrices."

In order to block light from passing through the metacage, the nanowires themselves don't have to overlap, but the separatrices of adjacent nanowires must overlap. This is why the metacage can have gaps while still blocking light transmission. Calculating the separatrices requires accounting for not only individual nanowires, but also the interactions between multiple nanowires.

The optical metacage can be designed to block a wide range of wavelengths by adjusting the size of the gaps. By decreasing the gap size to about 5-20 nm, the researchers showed that it's possible to shield bandwidths of up to 600 nm, which is large enough to shield the entire visible range. Metacages can also be designed to block two different wavelengths simultaneously (such as 440 nm and 600 nm), while allowing light of other wavelengths to pass through.

Although these gaps are relatively small, they are large enough to allow liquid and gas molecules to pass through. This ability makes the metacages promising for biological applications, where they can be used to protect living microorganisms and cells from radiation, while allowing nutrients and water to enter to keep the living things alive.

The metacages could also be used in optical circuits, where they could optically isolate circuit components in order to eliminate unwanted interference. Another potential application is in drug delivery, where cages containing drugs could be used for controlled drug release.

In the future, the researchers plan to further investigate these applications and design new metacage configurations.

"The idea of overlapping the separatrices and blocking the wave propagation by arrays of nanowires can be expanded to other nanostructures, such as nanospheres, that can form complete 3D metacages," Mirzaei said.

More information: Ali Mirzaei, et al. "Optical Metacages." *Physical Review Letters*. DOI: 10.1103/PhysRevLett.115.215501