Hyperbolic metamaterials enable nanoscale 'fingerprinting'

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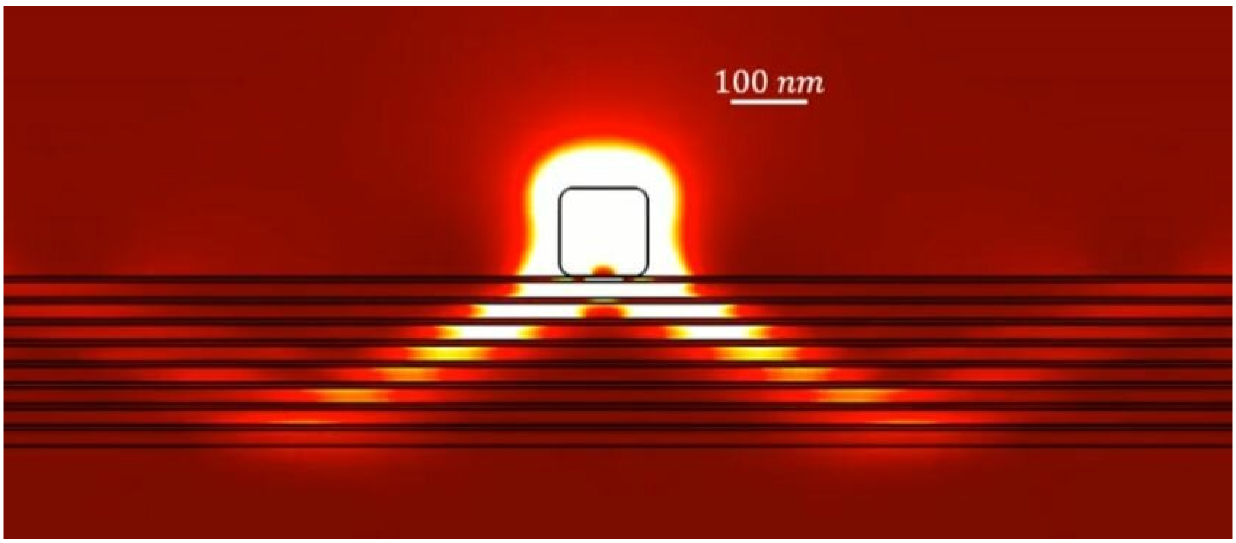

Hyperbolic metamaterials are artificially made structures that can be formed by depositing alternating thin layers of a conductor such as silver or graphene onto a substrate. One of their special abilities is supporting the propagation of a very narrow light beam, which can be generated by placing a nanoparticle on its top surface and illuminating it with a laser beam.

It's extremely challenging to realize in practice subwavelength images of unknown and arbitrary objects, but as University of Michigan and

Purdue University researchers report in *APL Photonics*, it isn't always necessary to obtain a full image when something about that object is already known.

"One familiar example from everyday life is the fingerprint," said Theodore B. Norris, at the University of Michigan. "A fingerprint recognition system doesn't need to obtain a complete high-resolution image of the fingerprint—it only needs to recognize it." So Evgenii E. Narimanov, one of the co-authors, began to think about whether nanometer-scale objects could be identified without the need to obtain complete images.

The propagation direction of the beam inside a hyperbolic metamaterial depends on the wavelength of the light. By sweeping the wavelength of the incident light, the narrow beam will scan across the bottom hyperbolic metamaterial and its air interface. If nano-objects are placed near the bottom interface, they scatter out light; this scattering is strongest when the narrow beam is directed toward them.

"We can measure the scattered light power using a photodetector and plot the scattered light power versus the wavelength of the incident light," said Zhengyu Huang, a graduate student at the University of Michigan. "Such a plot encodes spatial information about the nano-objects through the wavelength of the scattering peak in the plot and encodes their material information through the height of the peak."

The plot serves as a "fingerprint," which allows the researchers to determine the distance of a bottom nano-object to be sensed relative to the top nanoparticle, as well as the separation between two nano-objects, and their material composition.

Gaining access to the nanoscale world via optics has been one of the most vigorously pursued frontiers in optics during the past decade. "The traditional microscope is limited in resolution by the wavelength of light," said Huang. "And, using a conventional microscope, the smallest feature one can resolve is about 250 nanometers for visible light—also known as the Abbe limit."

Moving beyond this limit and resolving smaller features will require some advanced technologies. "Most are imaging methods, with images containing the objects of interest as the measurement," explained Huang. "But instead of following the imaging approach, our work demonstrates a novel route to obtain spatial and material information about the microscopic world through the 'fingerprinting' process." Significantly, it can resolve two objects that are just 20 nanometers apart from each other—well beyond the Abbe limit.

"Our work could potentially find applications in biomolecular measurement," Huang said. "People are interested in determining the distance between two biomolecules with nanoscale separation, for example, which can be used to study the interaction between proteins. And our method may also be used for industrial product monitoring to determine whether nanostructured parts were manufactured to specification."

More information: Zhengyu Huang et al, Nanoscale fingerprinting with hyperbolic metamaterials, *APL Photonics* (2019). DOI: 10.1063/1.5079736

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