Bio-inspired algorithms enable a pattern of thousands of nanoscale holes into metal films for high-tech optical security

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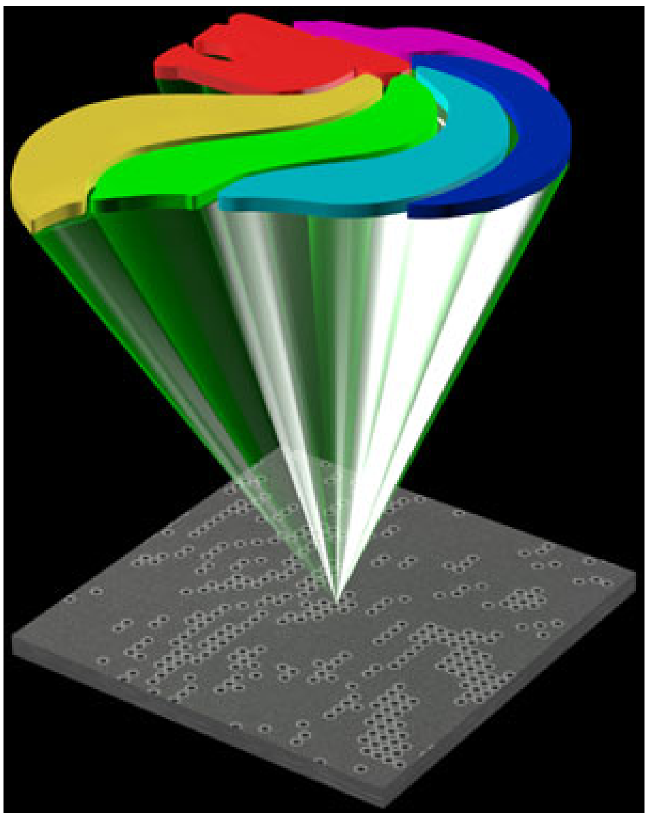

Dense arrays of light scattering nanoholes can make anti counterfeiting holograms more secure. Credit: A*STAR Institute of Materials Research and Engineering

Bank notes and credit cards may soon feature improved anti counterfeiting holograms thanks to a 'photon sieve' developed by A*STAR researchers and co-workers.

Holograms contain complex, three-dimensional image information that makes them difficult—but not impossible—to counterfeit. One way to improve their security is by using sophisticated devices that enhance holographic resolution. Nanophotonic devices deploy arrays of nanoscale light scattering pixels that encode additional layers of information through 'near field' optical interactions between lasers and the pixels.

Recently, researchers have shown nanoscale holes carved into thin metal sheets to be effective light scattering pixels. Surprisingly, when these nanoholes are arranged randomly, instead of periodically, the generated hologram becomes more uniform. Designing devices with randomly arranged components, however, is technically challenging, as parameters such as nanohole radius and spacing can vary over a wide range of values.

To overcome these obstacles, Jinghua Teng from the A*STAR Institute of Materials Research and Engineering and colleagues devised a theoretical method that deconstructs the complex diffracted field from a single nanohole into simple analytical expressions that can be solved exactly. By superimposing the solutions together, they can calculate local, specified electric fields instead of expending significant computational resources to numerically simulate the entire nanophotonic array.

The researchers turned to genetic algorithms to efficiently arrange the holes in a photon sieve arrangement. By repeatedly pairing, crossing, and mutating 'chromosomes' containing different 'genes'—labels of different nanohole sizes and positions—an aperiodic pattern evolves that optimizes holographic light control based on the simplified electric field calculations.

Next, the team used electron-beam lithography to turn their design into a practical device by etching over 34, 000 aperiodic nanoholes into a thin chromium film (see image). The resulting prototype boosted diffraction efficiency by nearly 50 per cent compared to conventional nanophotonic devices with image resolution hundreds of times better. Common holographic errors or 'artefacts' such as twin images were also eliminated through this technique.

"The high quality holographic images are promising for applications like anti counterfeiting, optical encryption and portable information identification system," says Teng. "For example, it could be used in anti counterfeiting in banknotes, with its ultra-compact size, high quality, and even multi level holographs."

The researchers demonstrated another application of their approach by designing a 'superfocusing' system that can resolve objects smaller than the wavelength of light. With the nanoholes arranged into concentric rings, the photon sieve lens focuses light down to spots just 200 nanometers wide—scales useful for biological imaging and optical manipulations.

More information: Kun Huang et al. Ultrahigh-capacity non-periodic photon sieves operating in visible light, *Nature Communications* (2015). [DOI: 10.1038/ncomms8059](https://dx.doi.org/10.1038/ncomms8059)

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