Sandia's inverse approach to software design gives the optical metamaterials field a critical boost

Sandia National Laboratories

The field of optical metamaterials is a giant step closer to realizing its futuristic potential, thanks to an innovative approach to software design developed at Sandia National Laboratories and the support of federal and industry partners.

For more than two decades, man-made optical metamaterials—artificial materials engineered to have properties not found in nature—have been promoted for their ability to manipulate light in extraordinary ways. The 3D geometry and symmetry of a metamaterial dictate how it responds to incoming light.

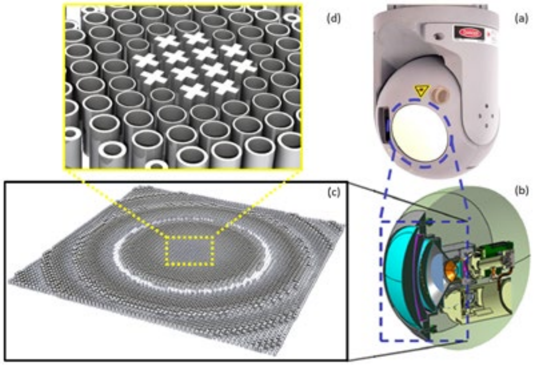
The possible applications for this technology are vast. Three-dimensional (3D) optical chips one day could lead to optical computing, in computers with orders-of-magnitude faster clocking speeds. In fact, metamaterial technology could someday lead to cloaking materials that deflect light around them, rendering objects undetectable.

But the field of optical metamaterials has struggled to achieve its full potential. This is because of its reliance on trial and error to find optimal configurations that result in desired optical behaviors.

MIRaGE (Multiscale Inverse Rapid Group-theory for Engineered metamaterials) software turns this problem on its head using an inverse-design approach conceived by Ihab El-Kady, PhD, Distinguished Member of Technical Staff at Sandia's National Security Photonic Center.

"We cannot solve this problem by trial and error, because of the almost infinite number of possibilities," El-Kady said. "We know the structural symmetry dictates the final behavior, so we reversed the process: We start with what the user is trying to achieve, then we tell them what symmetries the metamaterial has to have, and guide them in building that symmetry."

El-Kady and his team at Sandia built MIRaGE in partnership with a small business software company, Stellar Science, Inc. Initially, the development of MIRaGE was sponsored by the Defense Advanced Research Projects Agency (DARPA) for national security purposes; this funding has been augmented by the National Geospatial Intelligence Agency (NGA). To date, DARPA and NGA have invested more than $10 million for development of MIRaGE and continue to fund further development.



Above: (a) The Air Force fighter jet gimbal. (b) Schematic of the internal structure of the optical imaging assembly where the metalens is being inserted. (c) An image of the metalens designed by MIRaGE for the gimbal. (d) A zoom in image of the metalens core showing the different metamaterial unit cells.

After four years and about six million lines of code, MIRaGE is in use at more than 30 national institutions including universities, government entities, private and publicly traded defense contractors, and small businesses.

A distribution and licensing website was set up to facilitate transfer of the software. An unrestricted version is free to research facilities and contractors engaged in government research, while a restricted version is only available to government entities. Select private companies can obtain MIRaGE, depending on their work.

Technology transfer projects facilitated by MIRaGE include:

- The design of a Fitter-Jet Optical Gimbal (see figure) in collaboration with Northup Grumman for the Air Force under direction from NGA.
- A partnership between Sandia and General Electric Research to design an ultralight wearable optic for night vision in eyeglass form.
- Next-generation 3D electromagnetic antenna designs in collaboration with the University of North Carolina, Charlotte.