New algorithm can discover materials with unusual characteristics—including invisibility

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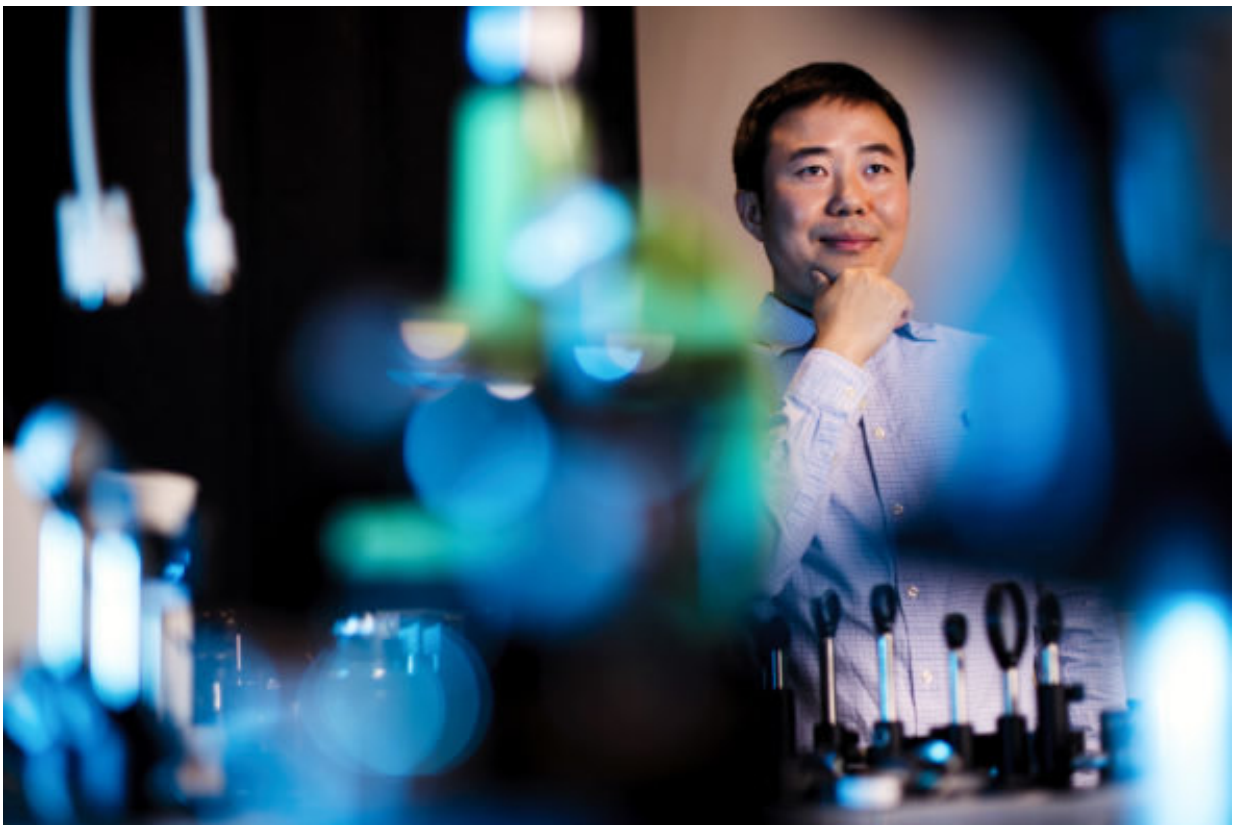

"With this algorithm, we can design new metamaterial properties on demand," said Liu, an assistant professor of mechanical and industrial engineering. Credit: Adam Glanzman/Northeastern University

Metamaterials are artificially engineered materials. Scientists create them by combining multiple elements from composite materials such as a metal and an electrical insulator. The result is an entirely new material with properties not found in nature. Engineers can then use these materials to create new devices or improve existing ones.

Let's say you want to build a real-life invisibility cloak. To achieve invisibility, a metamaterial needs to possess certain optical properties. Specifically, scientists would have to design the material so that they could control how light moves around an object without being reflected or absorbed. This design is possible, but it would take just the right material with just the right structure.

There are hundreds of thousands of potential material structures with optical responses that fall somewhere along the optical spectrum. Sifting through them to find a new material design has traditionally taken hours or even days.

Now, Northeastern professor Yongmin Liu has developed a new method for quickly discovering materials that have desirable qualities. In a paper published recently in *ACS Nano*, Liu and his co-authors describe a machine learning algorithm they developed and trained to identify new metamaterial structures. The new method is much faster and more accurate than previous approaches, paving the way for engineers to design next-generation materials.

The algorithm Liu and his team built was trained with a data set of 30,000 different samples, each representing a specific relationship between a metamaterial structure and corresponding optical property. Once the algorithm learned those relationships, it was able to predict new ones.

"Searching through all possible parameter combinations for materials is

nearly impossible. By introducing artificial intelligence to the metamaterial design, I believe the potential of metamaterials will be fully realized," said Shuang Zhang, a professor of physics at the University of Birmingham. "Prof. Liu's research points to a new research direction which will be followed by many groups in this field."

Engineers can now use the algorithm to discover new materials with specific useful characteristics. For example, current solar panels can only convert 20 to 30 percent of sunlight to energy. Liu is interested in finding a material capable of 100 percent light absorption to create more efficient solar panels.

"With this algorithm, we can design new metamaterial properties on demand," said Liu, an assistant professor of mechanical and industrial engineering. "These novel optical materials will serve as the foundation for a variety of functional devices."

So, how far off is that invisibility cloak? Liu said he's confident the algorithm would be able to identify the right material. But current technology could only assemble the material on a nano-scale. Fabricating a cloak large enough for someone to wear is a significant challenge that Liu believes scientists are still 10 to 15 years away from overcoming.

"We have seen tremendous progress in advanced manufacturing, such as 3-D printing," Liu said. "I hope that people who work in this area come up with some creative ideas to solve the fabrication challenge for a wearable cloak."

More information: Wei Ma et al. Deep-Learning-Enabled On-Demand Design of Chiral Metamaterials, *ACS Nano* (2018). DOI: 10.1021/acsnano.8b03569

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