Mathematical analysis: It may not be possible to create 'perfect lens'

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Researchers at Purdue University and the Massachusetts Institute of Technology have completed a mathematical analysis showing that it isn't quite possible to build a so-called **"perfect lens,"** but the underlying theory still makes it feasible to design better imaging systems.
A perfect lens would be able to focus light more narrowly than conventional lenses, making it possible to etch finer electronic circuits and create more compact and powerful computer chips. Such lenses also might lead to better fiberoptic communications systems and more precise medical imaging technologies.

Researchers have now shown, through rigorous mathematical analysis, that a perfect lens is not possible, said Kevin J. Webb, a professor of electrical and computer engineering at Purdue.

"It may be possible to build a better imaging system, but it could never be perfect," Webb said. "That's the bottom line."

The findings are detailed in a paper appearing online this week in Physical Review E, a journal published by the American Physical Society. The paper was written by Webb, Purdue engineering doctoral student Ming-Chuan Yang, MIT doctoral student David Ward and Keith Nelson, a professor of physical chemistry at MIT.

Perfect lenses theoretically could compensate for the loss of a portion of the light transmitting an image as it passes through a lens. Lenses and imaging systems could be improved if this lost light, which scientists call "evanescent light," could be restored.

Central to the concept of a perfect lens is the phenomenon called refraction, which occurs when electromagnetic waves, including light, bend slightly when passing from one material into another. Refraction causes the bent-stick-in-water effect, which occurs when a stick placed in a glass of water appears bent when viewed from the outside. Each material has its own "refraction index," which describes how much light will bend in that particular material.

All natural materials, such as glass, air and water, have positive refractive indices. In the late 1960s, researchers hypothesized what would happen if a material had a negative refractive index. At the interface between a material with a positive index and a material with a negative index, light would bend in the opposite direction. In 2000, researcher John Pendry at the Imperial College, London, theorized that slabs of such material might be used to create a perfect lens. The idea was that an imaging system that used a combination of positive and negative refraction could restore the lost evanescent light.

No materials have yet been created that have negative refraction indices for visible light, but in 2001 researchers at the University of California, San Diego, used combinations of copper rings and wires to cause a microwave beam to undergo negative refraction, enlivening the debate about the possibility of perfect lenses.

"Through a rigorous mathematical analysis, however, we have been able to show that, while a negative refraction index could conceivably be used to build better imaging systems, a perfect lens is not possible," Webb said.

The research was supported in part by the U.S. Army Research Office and the National Science Foundation.

"It’s always useful to use effects found either in nature or in fabricated structures to improve optical systems," said Fil Bartoli, a program director in the Electrical and Communications Systems Division within the NSF’s Engineering Directorate. "But any time you employ some cute effect, such as negative refraction, it’s important to quantify it and to determine to what extent it could be useful.

"That is what Dr. Webb and his colleagues tried to do, and I think that they succeeded in quantifying it and making a useful statement."

The concept of using materials with negative refractive indices to improve imaging systems is likely to receive continued attention in the years to come, he said.

"It’s a topical area that has a fair amount of interest in the scientific and engineering communities and still needs to be investigated," Bartoli said.

Source: Purdue University

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