Strides in Materials, but No Invisibility Cloak

By HENRY FOUNTAIN
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Blame it on Harry Potter.

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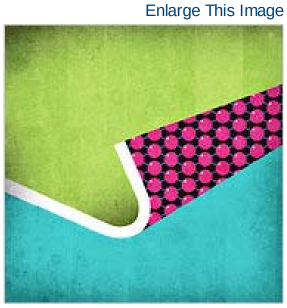

John Hersey

If young Harry and friends had not cruised around Hogwarts unseen, hidden by an "invisibility cloak," much of the hype surrounding metamaterials might itself never have seen the light of day.

But when, half a decade ago, researchers made tentative steps toward what had been considered a theoretical possibility — using an artificially structured "meta" material to manipulate light or other electromagnetic waves in ways not achievable in nature — it did not take more than a clever headline or two to make the connection to the stuff of J. K. Rowling's wildly popular novels.

Scientists cautioned then that optical invisibility was hardly just around the corner. And that caution is repeated today. But researchers in the field point out that great strides have been made in the field of metamaterials, and there are some applications of the concept that may come into use in the next few years.

"It's something that people couldn't do or think about before — manipulate light in ways you couldn't dream about," said Vladimir Shalaev, a metamaterials researcher at Purdue University. Among the potential applications, he said, would be a "hyperlens," an add-on for a microscope that would overcome a fundamental limitation of such instruments, the ability to resolve objects smaller than the wavelength of light.

Metamaterials were first recognized as a theoretical possibility by a Russian physicist, Victor Veselago, who in the 1960s suggested it was possible to create materials with a negative refractive index. (An optical material with a negative refractive index, for example, would "bend" light back, outside of the material.)

Martin Wegener, a physicist at the Karlsruhe Institute of Technology in Germany, described the development of the concept in a broader sense. "People realized that mankind had only played with the electric component of light," he

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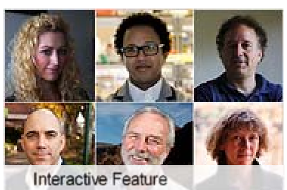

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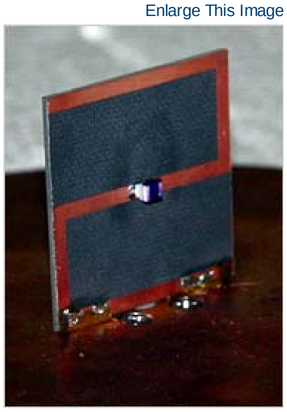

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Antennas with metamaterials are being installed in cellphones because they are smaller and can better handle multiple frequencies.

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said, “and that it might be a lot of fun to play with the magnetic component.”

To do so, researchers had to design physical structures that would allow the two components to be controlled independently. One they came up with was a split-ring resonator, a tiny C-shaped structure that in function is something like an electromagnet. The magnetic field that is produced by the flow of light or other electromagnetic radiation is extremely weak, but arrange countless numbers of these tiny structures in three dimensions and the material becomes polarized and magnetized and can do its magic.

In addition to novel types of lenses (which Dr. Wegener said were “not so sexy, but maybe much more useful than an invisibility cloak”) it is possible to envision metamaterials that are perfect absorbers of light. These “black like hell” materials, Dr. Wegener said, may be useful in solar energy applications, where absorbing more photons means producing more power.

A significant obstacle to creating metamaterials is that the size of the structures required depends upon the particular electromagnetic radiation — the smaller the wavelength, the smaller the structures must be. And the smaller the structures, the more difficult they are to fabricate, even using techniques like electron-beam lithography.

Another problem is that the metals used are inherently “lossy” — they dissipate some of the electromagnetic energy. So although a metamaterial lens, for instance, may manipulate light in interesting ways, it may transmit far less of it, making the lens less useful.

So far, the most progress has been made in metamaterials that work at microwave and radio frequencies, which have relatively long wavelengths. There are now cellphones with metamaterial antennas, which are smaller than conventional ones and can better handle multiple frequencies.

Other potential microwave devices may prove useful for military applications, said Ulf Leonhardt, a researcher at the University of St. Andrews in Scotland. Among these are cloaking devices that could hide an object from radar and antennas that work exactly like conventional ones but can be molded to match the aerodynamic shape of a plane.

The basic concept with these and other applications, Dr. Leonhardt said, is that metamaterials change the perception of space. “Something appears to be at a certain position, when in reality it is somewhere else.”

Metamaterials may help improve magnetic resonance imaging, said George V. Eleftheriades, a researcher at the University of Toronto, by being used in the coils that generate and detect electromagnetic fields. A metamaterial coil could improve the signal-to-noise ratio in these machines, and improve the contrast of images.

It may even be possible to use a metamaterial lens to shift the electromagnetic fields generated by the MRI machine in a difficult-to-access part of the body to a different spot where they would be more readily detected by the coil, Dr. Eleftheriades said.

“It’s all very, very fascinating,” said Dr. Shalaev, describing the possibilities of metamaterials. “The ideas are there, the physics is there, but in terms of the realization of these ideas, there are some difficulties.”

Dr. Shalaev and others said the fabrication hurdles may eventually be overcome by building metamaterials through self-assembly, in which molecules would combine to form the necessary structures. As self-assembly is essentially a chemical process, it could be relatively inexpensive compared to other techniques.

But Dr. Shalaev said that electron-beam lithography and other so-called nanofabrication techniques were steadily improving. “I see more progress in developing nanofabrication methods, which would make metamaterials easier to realize,” he said. “I really think it’s going to happen relatively soon.”

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