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Not just a light story

As modern fabrication techniques enable the realization of structures on the nanometre scale, we are presented with the opportunity to manipulate properties of matter at a much larger scale. For example, lithographic techniques are easily capable of producing structures much smaller than the wavelength of visible light. Artificial assemblies of subwavelength patterns could therefore be used to control light in a way that is not possible with the materials provided to us by nature. Hence, these man-made structures are termed 'metamaterials', with the Greek prefix 'meta' meaning 'beyond'.

"UN DIMANCHE APRÈS-MIDI À L'ILE DE LA GRANDE JATTE" BY GEORGES SEURAT, PAINTED IN THE POINTILLISM STYLE HE INVENTED.

The technological potential of metamaterials and the opportunities that their flexible design suggests has only just begun to be realized, and goes far beyond the field of photonics. But the idea to use small objects to create an impact on a much larger scale has been around for a long time. In a wider sense, some of the most pleasing examples are those where our senses are manipulated into perception of a stimulus made of indistinguishable subunits. An example is the artistic style of pointillism. Pointillist paintings are composed of tiny dots of a large variety of vibrant colours that only merge into a meaningful composition when looked at from a distance.

Obviously, it is far more complex to fabricate structures that are on the scale of the wavelength of fundamental particles such as electrons, photons and phonons. Nevertheless, nature provides us with the beautiful example of photonic-crystal structures, which are responsible for the brilliant colours that can be found on the wings of certain butterflies. Only in the late 1980s was technology available to create similar two- and three-dimensional structures on the same scale as the wavelength of visible light.

More flexible structures are possible if the building blocks of metamaterials can be made even smaller. Unlike the butterfly wings, however, nature no longer offers a template. An example of the unusual properties such structures could have is negative refractive index. Although a negative refractive index is not forbidden in principle, no natural material with a true negative refractive index has yet been discovered.

The understanding of this problem goes back for more than one hundred years, although it was only in 1967 that Victor Veselago demonstrated the technological potential that materials with a negative refractive index could have for applications in imaging[1,2]. It was not until 1999 that the use of artificial structures to achieve such unusual properties was pioneered by John Pendry[3,4], which eventually led to the first realization of a negative-index material by Shelby, Smith and Schultz[5].

But what will the lasting legacy of metamaterials be? The current main technological promise is superlensing — imaging with subwavelength resolution. But this use seems to be limited to applications in near-field optics. Interestingly, new concepts take metamaterials entirely beyond the realm of photonics. For example, ultrasonic metamaterials[6] suggest their use in medical diagnostics or for enhanced sonar devices.

The ease with which the propagation of light can be controlled in metamaterials might provide the key for powerful new applications in photonics and other fields. As was recently shown, with an appropriate structure it is possible to guide light along any arbitrary path[7,8]. A lot of unnecessary hype has been generated about the use of this approach for cloaking of objects from electromagnetic fields. But the real applications could reach far beyond the present imagination: although this is restricted to electromagnetic waves, similar theories might be developed for equations describing the propagation of other waves, such as acoustic, which could lead to the realization of complex metamaterials in such systems.

It will certainly be thrilling to observe future developments. Already, it is obvious that the achievements by Victor Veselago, John Pendry, David Smith and others contributing to this field represent a triumph of mind over matter.

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