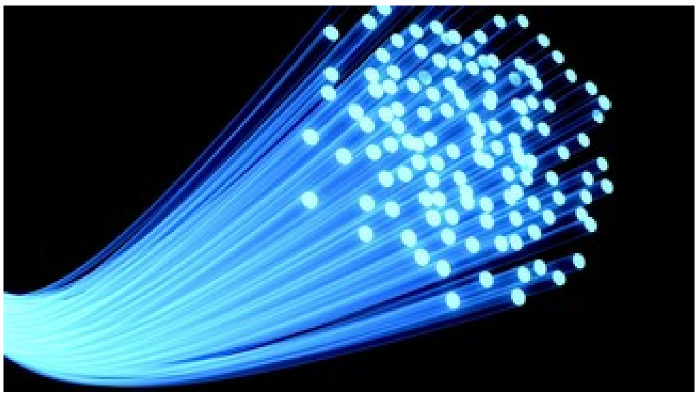
# Modeling metamaterials

January 10 2014, by Nik Papageorgiou



Credit: Photos.com

EPFL scientists have developed an innovative mathematical method to greatly improve computer modeling of metamaterials.

Metamaterials are artificial materials engineered to have properties that are not normally found in nature. Typical examples include cloaking materials that can render a person or an aircraft completely invisible to detection. In addition, metamaterials are being explored in a number of cutting-edge technologies including perfect lenses, antennas and terahertz devices. As the field grows, it is becoming increasingly necessary to model metamaterials, which is a difficult task considering their unconventional nature and delicate properties. Publishing in the Journal of Computational Physics, an EPFL-led team has found a way to create computational models that can be applied to a large range of metamaterials.

Metamaterials are the focus of a rapidly expanding field, which is driven by a growing demand for revolutionary technologies. Stealth military aircraft – invisible to radar – represent a textbook example, but metamaterials are also used in smart solar energy systems, optoelectronics and even the nanosciences. Metamaterials are actually made up from microscopic pieces of common materials like metals or plastics, which give metamaterials their exotic properties by being arranged in precise repeating patterns. For example, when designed at sub-wavelength sizes, these patterns can affect and allow manipulation of light or sound waves in unconventional ways.

However, designing new metamaterials to meet technological demands requires an increased understanding of structural possibilities. The best way to predict the full spectrum of metamaterial properties is through computer modeling, which requires a certain degree of mathematical abstraction. This presents metamaterial designers with a problem: How can we develop accurate and efficient tools to model non-standard materials?

A research team led by Jan S Hesthaven from EPFL has developed a computational approach that seeks to address this problem. The scientists used an approach called the discontinuous Galerkin method, which is a class of numerical methods for solving differential equations – equations that describe how one variable changes in relation to another, such as the speed of a car changing over time. Metamaterial modeling involves a set of differential equations known as Maxwell's equations, which describe how electromagnetic waves propagate in space and time and detailed models for how the metamaterials react to electromagnetic waves. But in order for a computer model to work, it is necessary to translate these equations from continuous functions into discrete or non-continuous ones – a common practice for conventional materials, but more complex for the exotic metamaterials.

Building on their previous efforts, the researchers were able to develop a custom-made way of solving Maxwell's equations specifically for metamaterials. The scientists were also able to test their method and demonstrate its applicability on certain models of metamaterials with different structures. "You come up with a model that you think mimics the continuous model, and then you use math to prove that, if you were to use this model, then it would actually solve the continuous equation if you did things as prescribed", says Jan Hesthaven.

The new method can greatly improve computer modeling of metamaterials, thus allowing faster discovery, design and manufacturing of new forms and structures. As demand for unconventional materials increases, the approach is expected to have a far-reaching impact on the future of metamaterials.

**More information:** Jichun Li, Jan S. Hesthaven, Analysis and application of the nodal discontinuous Galerkin method for wave propagation in metamaterials, *Journal of Computational Physics*, Volume 258, 1 February 2014, Pages 915–930.
dx.doi.org/10.1016/j.jcp.2013.11.018

Provided by Ecole Polytechnique Federale de Lausanne