Giant Faraday rotation spotted in graphene

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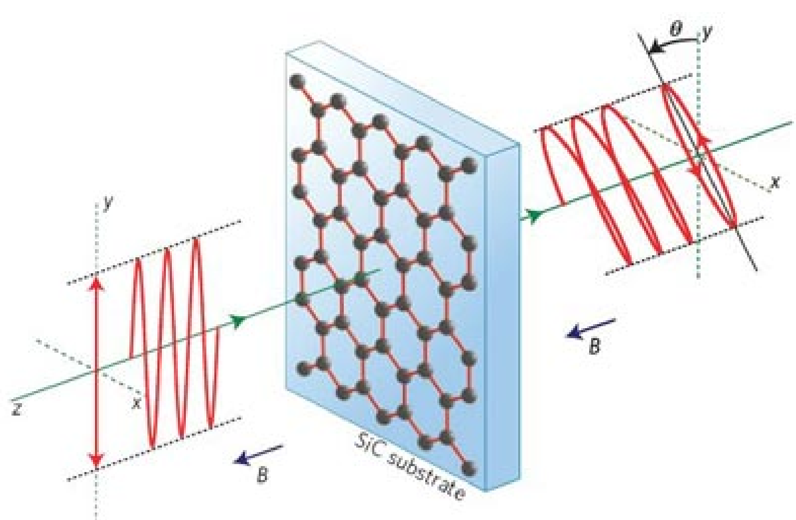

Another surprise from graphene

The polarization of light can be rotated by almost 6° as it passes through a single sheet of graphene in a magnetic field, according to an international team of physicists. This latest property of graphene – a sheet of carbon just one atom thick – was unexpected because large rotations normally occur only in much thicker materials. The scientists believe that this newly discovered property of graphene could be exploited in new devices that switch light using electric and magnetic fields.

The fact that the polarization of light can rotate as it travels through a material exposed to a magnetic field is, of course, nothing new. Physicists have long known that it is to do with that fact that right- and left-circularly polarized light can propagate at different speeds. It means that when linearly polarized light passes through such a material, the right and left components of the light interfere such that the polarization is rotated by a certain angle when it emerges.

But because the size of this "Faraday angle" is proportional to the thickness of the material, graphene – being just one atomic layer thick – was not expected to generate a large rotation. However, Alexey Kuzmenko and colleagues at the University of Geneva have found that the material can twist the polarization of light by 0.1 radians, or about 6°. Researchers at the Fritz Haber Institute in Berlin and the University of Erlangen-Nueremberg – both in Germany – and the Lawrence Berkeley Laboratory in the US were also involved in the work.

A big surprise

According to Kuzmenko, the team made its discovery while using infrared light to study aspects of the quantum Hall effect in graphene. "We didn't expect to see a large [rotation] in graphene," he says "We expected to see a rotation of about 0.01 radians and instead we saw 0.1 radians." The result means that graphene has a bigger Faraday rotation per atomic layer than any other material – beating out its nearest semiconductor rivals in the infrared by a factor of 10.

The team measured the Faraday rotation by passing infrared light

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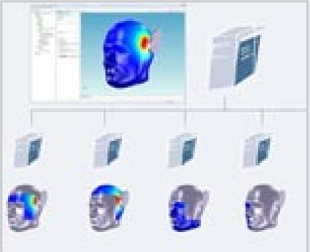

through a polarizing filter to create a linearly polarized beam. This beam was then sent through a graphene sample with a magnetic field perpendicular to its surface. After the light emerged, it was passed through a second polarizing filter and on to a detector. If the polarizations of the two filters are exactly 90° apart, no light should be detected. But if the polarization of the light is rotated as it passes through the graphene, the angle at which no light is detected will be shifted by the Faraday angle.

Unusual orbits

The physicists believe that the large rotation is a result of graphene's electrons behaving as if they have no mass. When subjected to a magnetic field, the electrons occupy a spectrum of circular "cyclotron" orbits that is very different to that found in other materials. Transitions between these orbits affect the circular polarization of the transmitted light and result in a much enhanced Faraday angle.

According to Kuzmenko, the effect could be used to create switches in which light can travel in one direction, but not in the opposite direction. These optical diodes, known as "Faraday isolators", are not currently available for infrared light.

One important benefit of making such magneto-optical devices from graphene is that the direction of the Faraday rotation can be reversed by simply applying an electric field to the graphene. In other materials, in contrast, this is only possible by reversing the applied magnetic field, which is a slower and more complicated process. The reason, according to Kuzmenko, is graphene's unique ability to change the sign of its charge carriers from negative to positive by simply applying an electric field.

Future photonics and optoelectronics

Andrea Ferrari of the University of Cambridge in the UK believes that this newly discovered optical property of graphene is yet more evidence that the material's future lies in photonics and optoelectronics. "The Faraday effect and the associated magneto-optical Kerr effect are widely used in optical communications, data storage and computing," he told *physicsworld.com*. "These, combined with the [other known] properties of graphene, could lead to uniquely performing devices."

There are, however, several challenges involved in making practical devices. One is that about 10 independent layers of graphene would be needed to achieve a rotation of about 45° – which would be required in practical devices. Another problem is that graphene absorbs infrared light, which would lead to significant signal loss in devices.

The research is published in *Nature Physics* doi: 10.1038/NPHYS1816.

About the author

Hamish Johnston is editor of *physicsworld.com*

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