Physicists succeed in bringing movement of photons and electrons under same laws

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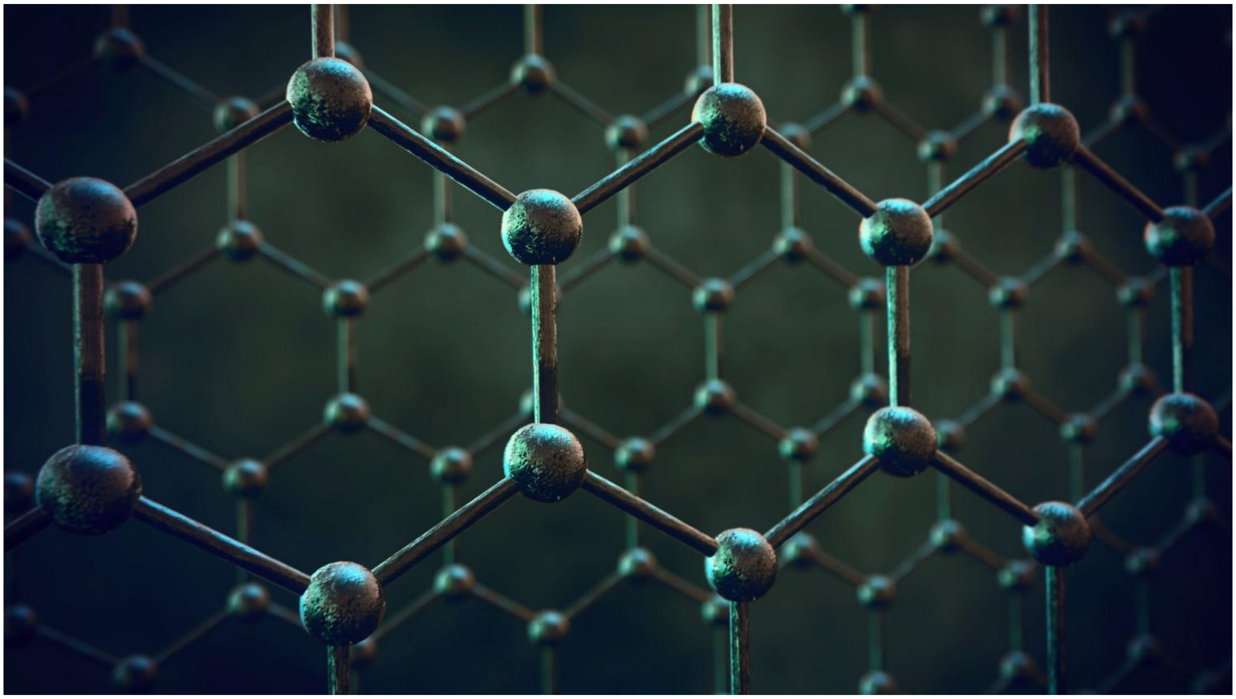

This visualisation shows layers of graphene used for membranes. Credit: University of Manchester

Scientists from ITMO, Sheffield University, and the University of Iceland proved that the movement of electrons and photons in two-dimensional materials with hexagonal symmetry, such as graphene, submits to the same laws. Now, the properties of electrons in solids can be modeled with the help of classical optical systems where this task can be solved easier. The article was published in *Nature Photonics*.

Graphene is the most famous two-dimensional material, and it is durable and has high conductivity. Andre Geim and Konstantin Novoselov got the 2010 Nobel Prize in Physics for its development. Despite being 'light,' it's 300 times stronger than steel. Its unique properties have to do with its structure. The behavior of electrons in a material largely depends on the geometry of the substance's crystal lattice. In the case of graphene, carbon atoms form hexagonal cells, thus electrons can behave as particles with zero effective mass, despite having mass in reality.

"This behavior of electrons in graphene is described by the laws of quantum mechanics, where the electron is not perceived as a particle that moves around an atom's nucleus but as a material wave. Particular properties of waves of different physical nature depend only on a system's symmetry. This makes it possible to create 'photonic graphene.' It resembles a thin transparent plate that looks like a honeycomb. If electrons can behave as particles with no mass in classical graphene, here, photons behave in a similar manner," explains Alexey Yulin, researcher at ITMO's Faculty of Physics and Engineering.

Scientists from Russia, England and Iceland set at the task to reproduce the dynamics of massless electrons that have spin in graphene using massless light that propagates in an optical system. Having created an optical counterpart of graphene, they've studied the effects that emerge when influencing it with photons: it's excited by a focused laser emission that falls under a specific angle. A change in the incidence angle of light falling on a photonic system provided for the emergence of waves with the desired properties.

In the article, scientists studied an instance when they selectively excited massless photons in photonic graphene. The comparison of theory and experiment showed that the proposed mathematical model reproduces the experimental results. For comparison, they've also studied an instance when light in photonic graphene behaves as regular particles with a nonzero mass.

In the course of the experiment, the physicists discovered that the polarization effects are similar to spin effects that are well-known in solid state physics. The scientists also proved the possibility of describing these phenomena with the help of equations from the field of classical physics. Now the properties that are hard to measure or control in solids can be studied using photonic systems where these tasks can be solved relatively easily.

"Thanks to the processes that take place in regular graphene being similar to those in photonic systems, optical systems can be used to imitate the spin dynamics of electrons. Studying spin-orbital interactions in photonic graphene can lead to a better understanding of similar effects observed in solid-state electronics. What's more, the results encourage us to look for such similarities in other systems, for example in acoustic graphene," concludes Alexey Yulin.

More information: C. E. Whittaker et al. Optical analogue of Dresselhaus spin–orbit interaction in photonic graphene, *Nature Photonics* (2020). DOI: 10.1038/s41566-020-00729-z

Provided by ITMO University

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