New half-light half-matter particles may hold the key to a computing revolution

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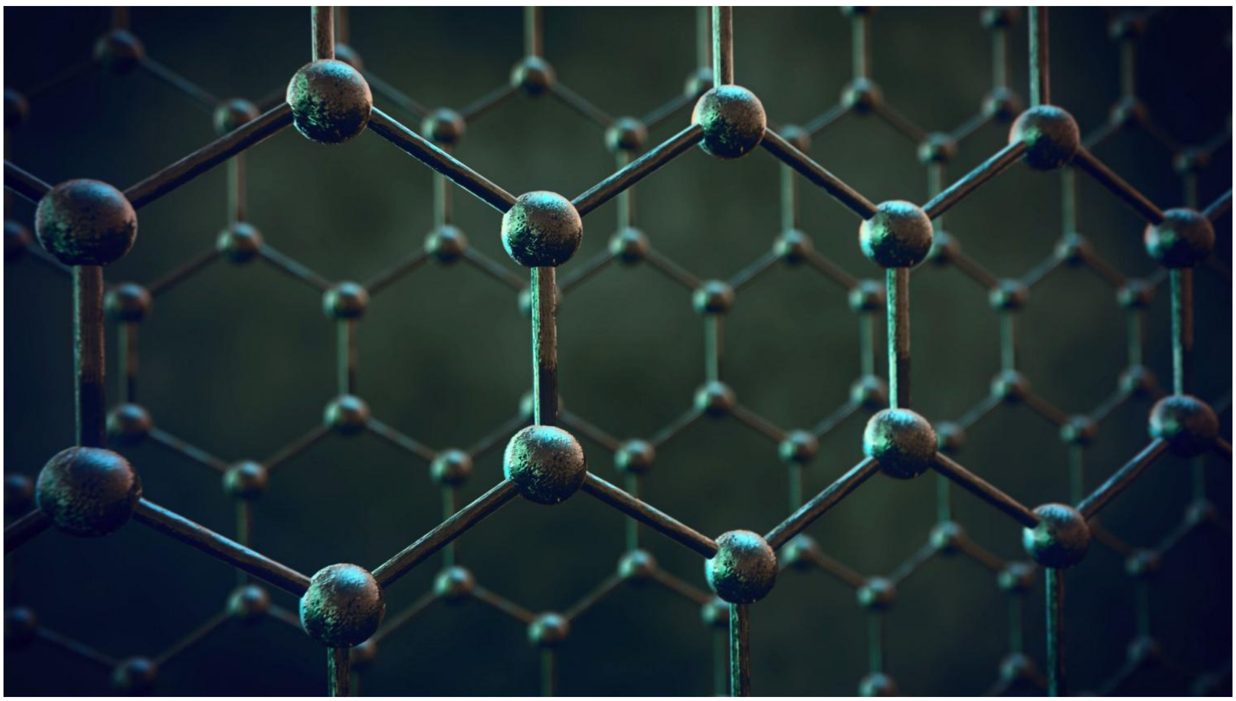

This visualisation shows layers of graphene used for membranes. Credit: University of Manchester

Scientists have discovered new particles that could lie at the heart of a future technological revolution based on photonic circuitry, leading to superfast, light-based computing.

Current computing technology is based on electronics, where electrons are used to encode and transport information.

Due to some fundamental limitations, such as energy-loss through resistive heating, it is expected that electrons will eventually need to be replaced by photons, leading to futuristic light-based computers that are much faster and more efficient than current electronic ones.

Physicists at the University of Exeter have taken an important step towards this goal, as they have discovered new half-light half-matter particles that inherit some of the remarkable features of graphene.

This discovery opens the door for the development of photonic circuitry using these alternative particles, known as massless Dirac polaritons, to transport information rather than electrons.

Dirac polaritons emerge in honeycomb metasurfaces, which are ultra-thin materials that are engineered to have structure on the nanoscale, much smaller than the wavelength of light.

A unique feature of Dirac particles is that they mimic relativistic particles with no mass, allowing them to travel very efficiently. This fact makes graphene one of the most conductive materials known to man.

However, despite their extraordinary properties, it is very difficult to control them. For example, in graphene it is impossible to switch on/off electrical currents using simple electrical potential, thus hindering the potential implementation of graphene in electronic devices.

This fundamental drawback—the lack of tunability—has been successfully overcome in a unique way by the physicists at the University of Exeter.

Charlie-Ray Mann, the lead author of the paper published in *Nature*

Communications, explains: "For graphene, one usually has to modify the honeycomb lattice to change its properties, for example by straining the honeycomb lattice which is extremely challenging to do controllably."

"The key difference here is that the Dirac polaritons are hybrid particles, a mixture of light and matter components. It is this hybrid nature that presents us with a unique way to tune their fundamental properties, by manipulating only their light-component, something that is impossible to do in graphene."

The researchers show that by embedding the honeycomb metasurface between two reflecting mirrors and changing the distance between them, one can tune the fundamental properties of the Dirac polaritons in a simple, controllable and reversible way.

"Our work has crucial implications for the research fields of photonics and of Dirac particles," adds Dr. Eros Mariani, principal investigator on the study.

"We have shown the ability to slow down or even stop the Dirac particles , and modify their internal structure, their chirality, in technical terms, which is impossible to do in graphene itself"

"The achievements of our work will constitute a key step along the photonic circuitry revolution."

The study "Manipulating type-I and type-II Dirac polaritons in cavity-embedded honeycomb metasurfaces" (DOI: 10.1038/s41467-018-03982-7) was published in *Nature Communications*.

More information: Charlie-Ray Mann et al. Manipulating type-I and type-II Dirac polaritons in cavity-embedded honeycomb metasurfaces, *Nature Communications* (2018). DOI: 10.1038/s41467-018-03982-7