Neutrons confirm Newton’s predictions

MAGNETIC MATERIALS
An optical effect first predicted by Isaac Newton has been shown to occur when neutrons interact with matter. The discovery, which represents yet another affirmation of the wave-particle duality inherent to quantum mechanics, is also the first published science to emerge from the £200 million second target station recently opened at the ISIS Neutron Source in the UK.

Newton suggested in the 17th century that a beam of light reflected at a glass-vacuum surface should undergo a small spatial shift. This arises from an interference effect, such that the light penetrates into the vacuum, “slides” along the interface, and then re-emerges and reflects back into the glass. The scale of the shift between the incident and reflected light is very small, and the effect was only confirmed experimentally in 1947, by the German physicists F Goos and H Hänschen.

Now, a team of scientists led by Rob Dalgliesh and Sean Langridge from the Science and Technology Facilities Council’s ISIS facility and Victor de Haan from the Delft University of Technology (Netherlands) has proved experimentally that the so-called Goos-Hänschen shift also occurs with particles, such as neutrons. The result is therefore in perfect agreement with quantum mechanics, which predicts that, due to the quantized nature of energy, particles can behave as if they were waves, and vice versa.

As part of the second target station at ISIS, Dalgliesh, Langridge, and their colleagues in the Netherlands have designed an instrument called OffSpec, that can resolve length scales down to 10 nanometres. “We calculated that for neutrons, the Goos-Hänschen shift should range from nano- to micrometres, depending on the incident angle of the neutron beam”, explains Langridge. “Our objective was therefore to measure this with OffSpec.”

The trick used by the researchers was to exploit the fact that a neutron has a magnetic moment which can be described in terms of a wave function that has both “up-spin” and “down-spin” components. The Goos-Hänschen shift is different for the up and down wave functions, meaning that the polarization of a beam of neutrons changes upon reflection from a surface. The outcome is that during reflection the up and down spin states become split in space and in time. Langridge points out that only an instrument with a high flux of neutrons with a specific wave length, such as OffSpec, can measure the change in polarization of a neutron beam. “Although our results demonstrate that neutrons behave exactly in the same way of light when they are reflected, they are also a showcase for the kind of things OffSpec can do in the future”.

Andrea Taroni

Graphene origami at the touch of a drop

Graphene can be turned into complex structures by simply placing nanodroplets of water on its surface, say researchers from the University of Illinois at Chicago [Patra et al., Nano Lett. (2009) 9, 3767].

Graphene recently became the focus of many research projects because of its excellent electronic properties. However, until now, folding the material into well-defined structures has proved difficult for three reasons: there are energy potential barriers to folding, folding needs to be guided, and the resulting structure must be stabilized.

Petr Král and his team have now performed molecular simulations to show that nanodroplets of water wrinkle graphene sheets, making them more pliable. In fact, when two water droplets are placed on a 15 x 12 nm² sheet of graphene, they form hollows with a radius of curvature of 5 nm in a process driven by van der Waals interactions. The droplets are highly mobile and advance towards each other by diffusion, until they eventually couple together. This formation of hollows minimizes the energy barrier to bending, and simulations indicate that nanodroplets have the capability to activate and guide folding, such that conformational changes can occur in graphene.

“The dynamics always starts with placing a water nanodroplet on the graphene and observing what will follow. Sometimes the actual place of the nanodroplets determines the dynamics,” explains Král. “We are currently exploring this issue more and self-assemble the systems from a gas phase.”

Complex structures can be obtained from flakes or nanoribbons of graphene, including capsules, knots, rings and other formations through rapid bending, folding, sliding, rolling, and zipping of the material. “We wanted to see how nanodroplets will modify graphene flakes and were surprised that they can self-assemble them according to the actual conditions (sizes of flakes and droplets, type of nanodroplets, temperature, etc.). We have seen all kinds of different scenarios that can be obtained under these conditions, where different structures have been assembled,” Král tells Materials Today.

Král suggests guiding the process by atomic force microscopy to control the sites at which water droplets are delivered to the graphene surface. If such experiments prove successful, they could potentially lead to devices with good mechanical, electrical, and optical properties, as Král explains. “Graphene is potentially a very interesting material for electronics. The self-assembly can be done in principle on a massive scale right on the chip. We believe that the future lies in this option.”

Katerina Busuttil