Quantum hall effect observed at room temperature

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This image is a scanning electron microscope micrograph of a strongly crumpled graphene sheet on a silicon wafer. The lateral size of the image is 20 microns. The Si wafter is at the bottom right corner of the image. Credit: Courtesy of the Foundation of Fundamental Research on Matter, the Netherlands

Using the highest magnetic fields in the world, an international team of researchers has observed the quantum Hall effect – a much studied phenomenon of the quantum world – at room temperature.

The quantum Hall effect was previously believed to only be observable at temperatures close to absolute zero (equal to minus 459 degrees). But when scientists at the National High Magnetic Field Laboratory in the U.S. and at the High Field Magnet Laboratory in the Netherlands put a recently developed new form of carbon called graphene in very high magnetic fields, scientists were surprised by what they saw.

"At room temperature, these electron waves are usually destroyed by the jiggling atoms and the quantum effects are destroyed," said Nobel Prize winner Horst Stormer, physics professor at Columbia University and one of the paper's authors. "Only on rare occasions does this shimmering quantum world survive to the temperature scale of us humans."

The quantum Hall effect is the basis for the international electrical resistance standard used to characterize even everyday materials that conduct electricity, such as the copper wires in a home. It was first discovered in 1980 by the German physicist Klaus von Klitzing, who was awarded a Nobel Prize in 1985 for his discovery. Until recently the quantum Hall effect was considered to belong to the realm of very low temperatures.

That opinion began to change, however, with the ability to create very high magnetic fields and with the discovery of graphene, a single atomic sheet of atoms about as strong as diamond. Together, these two things have allowed scientists to push this fragile quantum effect all the way to room temperature. Now there is a way to see curious and often surprising quantum effects, such as frictionless current flow and resistances as accurate as a few parts per billion, even at room temperature.

The research was carried out by scientists from the University of Manchester in England, Columbia University in New York, the National High Magnetic Field Laboratory in Tallahassee, Florida, the High Field Magnet Laboratory in Nijmegen, Netherlands, and the Foundation for Fundamental Research on Matter, also in the Netherlands. Their article appears in *Science Express*.

The scientists believe that these findings may one day lead to a compact resistance standard working at elevated temperatures and magnetic fields that are easily attainable at the National High Magnetic Field Laboratory.

"The more we understand the strange world of quantum physics, the better we can design the next generation of ultra-small electrical devices, which already are pushing into the quantum regime," said Gregory S. Boebinger, director of the U.S. magnet lab.

"This is a really amazing discovery for a quantum Hall physicist," said Uli Zeitler, senior scientist at the High Field Magnet Laboratory. "For more than two decades, we've focused our research on exploring new frontiers such as very low temperatures and extremely sophisticated materials, and now it appears that we can just measure a quantum Hall effect in a pencil-trace and at room temperature."

The room temperature quantum Hall effect was discovered independently in the two high field labs, in the 45-tesla Hybrid magnet in Tallahassee and in a 33-tesla resistive magnet in Nijmegen. Both research groups agreed that a common announcement on both sides of the Atlantic was the right thing to do.

"Because so many scientists are exploring this exciting new material, we are all on this roller coaster together," said Boebinger. "Sometimes it makes sense to put competitiveness aside and write a better paper together."

Source: National High Magnetic Field Laboratory

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