Scientists find new 'quasiparticles'

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Weizmann Institute physicists have demonstrated, for the first time, the existence of 'quasiparticles' with one quarter the charge of an electron. This finding could be a first step toward creating exotic types of quantum computers that might be powerful, yet highly stable.

Fractional electron charges were first predicted over 20 years ago under conditions existing in the so-called quantum Hall effect, and were found by the Weizmann group some ten years ago.

Although electrons are indivisible, if they are confined to a two-dimensional layer inside a semiconductor, chilled down to a fraction of a degree above absolute zero and exposed to a strong magnetic field that is perpendicular to the layer, they effectively behave as independent particles, called quasiparticles, with charges smaller than that of an electron. But until now, these charges had always been fractions with odd denominators: one third of an electron, one fifth, etc.

The experiment done by research student Merav Dolev in Prof. Moty Heiblum's group, in collaboration with Drs. Vladimir Umansky and Diana Mahalu, and Prof. Ady Stern, all of the Condensed Matter Physics Department, owes the finding of quarter-charge quasiparticles to an extremely precise setup and unique material properties: The gallium arsenide material they produced for the semiconductor was some of the purest in the world.

The scientists tuned the electron density in the two-dimensional layer – in which about three billion electrons were confined in the space of a square millimeter – such that there were five electrons for every two magnetic field fluxes. The device they created is shaped like a flattened hourglass, with a narrow 'waist' in the middle that allows only a small number of charge-carrying particles to pass through at a time.

The 'shot noise' produced when some passed through and others bounced back caused fluctuations in the current that are proportional to the passing charges, thus allowing the scientists to accurately measure the quasiparticles' charge.

Quarter-charge quasiparticles should act quite differently from odd fractionally charged particles, and this is why they have been sought as the basis of the theoretical 'topographical quantum computer.' When particles such as electrons, photons, or even those with odd fractional charges change places with one another, there is little overall effect. In contrast, quarter-charge particle exchanges might weave a 'braid' that preserves information on the particles' history.

To be useful for topologically-based quantum computers, the quarter-charge particles must be shown to have 'non-Abelian' properties – that is the order of the braiding must be significant. These subtle properties are extremely difficult to observe. Heiblum and his team are now working on devising experimental setups to test for these properties.

Source: Weizmann Institute of Science