Playing ping-pong with single electrons: Research provides important technique for transferring quantum information

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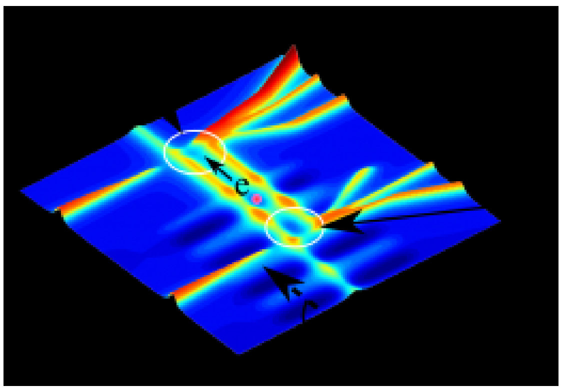

Illustration of the potential-energy landscape seen by an electron, and the potential wave produced by a sound pulse (surface acoustic wave, SAW) coming from bottom right and moving past the first dot, along the channel towards the other dot.

Scientists at Cambridge University have shown an amazing degree of control over the most fundamental aspect of an electronic circuit, how electrons move from one place to another.

Researchers from the University's Cavendish Laboratory have moved an individual electron along a wire, batting it back and forth over sixty times, rather like the ball in a game of ping-pong. The research findings, published today (22 September) in the journal *Nature*, may have applications in quantum computing, transferring a quantum 'bit' between processor and memory, for example.

Imagine you are at a party and you want to get to the other side of a crowded room to talk to someone. As you walk you have to weave around people who are walking, dancing or just standing in the way. You may also have to stop and greet friends along the way and by the time you reach the person you wanted to talk to you have forgotten what you were going to say. Wouldn't it be nice to be lifted up above the crowd, and pushed directly to your destination?

In a similar way, electrons carrying a current along a wire do not go directly from one end to the other but instead follow a complicated zigzag path. This is a problem if the electron is carrying information, as it tends to 'forget' it, or, more scientifically, the quantum state loses coherence.

In this work, a single electron can be trapped in a small well (called a quantum dot), just inside the surface of a piece of Gallium Arsenide (GaAs). A channel leads to another, empty, dot 4 microns (millionths of a metre) away. The channel is higher in energy than the surrounding electrons. A very short burst of sound (just a few billionths of a second long) is then sent along the surface, past the dot. The accompanying wave of electrical potential picks up the electron, which then surfs along the channel to the other dot, where it is captured. A burst of sound sent from the other direction returns the electron to the starting dot where the process can be repeated. The electron goes back and forth like a ping-pong ball. Rallies of up to 60 shots have been achieved before anything goes wrong.

"The movement of electrons by our 'surface acoustic wave' can also be likened to peristalsis in the oesophagus, where food is propelled from the mouth to the stomach by a wave of muscle contraction," explains Rob

McNeil, the PhD student who did most of the work, helped by postdoc Masaya Kataoka, both at the University of Cambridge's Department of Physics, the Cavendish Laboratory.

"This is an enabling technology for quantum computers," Chris Ford, team leader of the research from the Semiconductor Physics Group in the Cavendish, says. "There is a lot of work going on worldwide to make this new type of computer, which may solve certain complex problems much faster than classical computers. However, little effort has yet been put into connecting up different components, such as processor and memory. Although our experiments do not yet show that electrons 'remember' their quantum state, this is likely to be the case. This would make the method of transfer a candidate for moving quantum bits of information (qubits) around a quantum circuit, in a quantum computer. Indeed, our theorist, Crispin Barnes, proposed using this mechanism to make a whole quantum computer a long time ago, and this is an important step towards that goal."

More information: *Nature*, September 22nd 2011; doi:10.1038/nature10444

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