Discovery at the Interface of Science and Engineering: Science Matters!

Microelectronics and Microsystems
Quantum Electron Transport

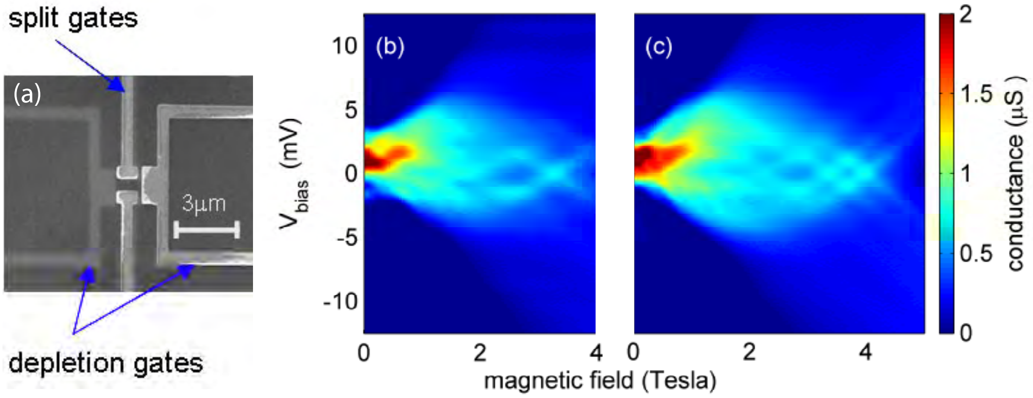

Figure 1. (a) SEM of double quantum wire device. (b,c) Tunneling conductance for two quantum wires at T=30mK separated by a 7.5 nm barrier. In (b), a single 1D subband is occupied in each wire. In (c), two subbands are occupied. The non-interacting theory in Figure 1 can account for some features, such as the crossings at high fields [1 in (b), and 2 in (c)] but cannot account for the additional complication at low magnetic fields.

Tunneling between 1D quantum wires reveals control at wavefunction level

The systems being studied may someday provide a platform for solid-state quantum computing, predicted to be much more powerful than conventional computing.

Sandia is conducting fundamental research in the behavior of electrons in lower dimensions. The ability to control and manipulate electrons at the wavefunction level is a prerequisite to achieving quantum information processing. The systems being studied may someday provide a platform for solid-state quantum computing, predicted to be much more powerful than conventional computing.

A major goal of this work is to discover exotic new quantum states of matter called non-Fermi liquids. Two existing non-Fermi liquid states are superconductivity and the fractional quantum Hall effect, in which electrons group together to form quasiparticles with electric charges that are fractions of the normal electron charge.

Fermi liquid theory describes how electrons behave in metals and semiconductors and shows that even though trillions of electrons interact with each other in a complex multi-body way, it is possible to treat each electron as if it is the only one. This theory provides the underpinning of all modern semiconductor electronics – the electrons in every computer chip form a Fermi liquid.

While we aren’t the only scientists conducting these experiments, our unique contribution is that we’ve made a double quantum wire, with independent contacts to each wire, that is completely tunable. This configuration allows us to explore the entire phase space of wire widths to determine how the wavefunctions (i.e., the energy and momentum states of the electrons) in each wire must be related to each other in order for tunneling to occur.

We’ve found that the data matches the theory, showing that we can control electron states in semiconductor nanostructures at the wavefunction level.

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