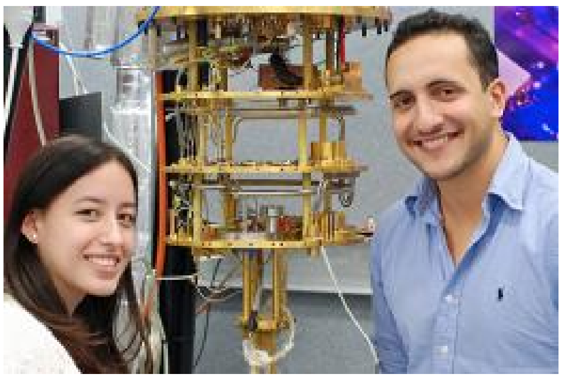
Listening to electrons: New method brings scaling-up quantum devices one step closer

February 1 2013



PhD students James Colless and Alice Mahoney preparing a dilution refrigerator for experiments on quantum dots. Temperatures close to absolute zero are required to study the quantum behaviour.

(Phys.org)—We're now one step closer to quantum computing becoming a reality thanks to research led by a team of University of Sydney physicists, who have found a new way to detect changes in charges smaller than one electron.

The research is published in this week's edition of Physical Review Letters.

"Our new method for detecting charge in quantum systems is exciting and has implications for a range of nanotechnologies," said Associate Professor David Reilly, from the ARC Centre for Engineered Quantum

Systems in the School of Physics at the University of Sydney.

"We've been successful in finding a new, more convenient way to detect changes in charge of a single electron on quantum dots. Quantum dots are nanoscale systems that can confine or trap single electrons," explained Associate Professor Reilly.

"Electrons confined to quantum dots are very nice systems for storing and manipulating quantum information, where data is encoded in the quantum mechanical aspects of the electron. Our goal is to scale-up a large number of quantum dots to ultimately create a machine to process quantum information - a quantum computer."

Ever since Nobel Prize winner Richard Feynman highlighted the potential of quantum computing in the 1980s, scientists have been attempting to build quantum computers capable of solving some of the largest and most complex problems, with much greater efficiency than conventional computers.

"We've focused on quantum dots as their properties can be tuned in the laboratory - we can control their energy spectrum by turning a knob in the lab."

"Being able to detect single electron charges on the quantum dots is absolutely essential, as it's the way information is retrieved from such quantum mechanical systems. We call it 'read-out' and it's analogous to reading information from the memory or a hard drive in a regular classical computer," said Associate Professor Reilly.

"Without the ability to read-out quantum information, we have no way of getting the answer to a computation!"

The team, including School of Physics PhD students James Colless, Alice Mahoney and John Hornibrook, and Associate Professor Andrew Doherty and Associate Professor David Reilly, with two scientists from the University of California, Santa Barbara, have found a new way of detecting charge on the quantum dots using the gate electrodes already in the system.

"Previously, sensitive electrometers which measure minute charges were used to read-out the electron state on quantum dots. These work well, but they are somewhat separate devices built onto the ends of the quantum dot system. They are a bit like having microphones nearby that can pick up the sound of electrons," explained Associate Professor Reilly.

"What we have shown is that the gates or electrodes that are already in place to create the quantum dot in the first place, can also act as read-out detectors. This means you don't need separate devices and you don't need to worry about how to place those separate electrometer devices."

"Whereas the old system was like having microphones nearby to detect sound, our new system could be likened to using the walls of a room as in-built microphones - you don't need separate microphones for every room of the house, just use the walls as microphones," said Associate Professor Reilly.

"Our new method makes the whole quantum system easier to build and use, as adding nanoscale electrometers for every quantum dot in a million-dot-array is a hard problem. By using the electrodes already in the system, we've found an efficient new way to measure charge in the big quantum systems of the future."

The new method of detection allows for read-out in large dot arrays with no limitation on the size of the array for the read-out method to work.

James Colless, whose PhD research contributed greatly to the finding, said, "The technologies that we are developing are part of a global research effort to advance the prospect of quantum computing. In a similar way to how billions of transistors can now be placed on a single silicon computer chip, in the future we would like to engineer semiconductor chips containing huge numbers of interacting quantum two-level systems - called qubits. The work presented in this paper suggests a new method of reading out qubits that enables this goal."

More information: prl.aps.org/abstract/PRL/v110/i4/e046805

Provided by University of Sydney