Researchers demonstrate entanglement of two quantum bits inside of a semiconductor

April 13 2012, by Bob Yirka

(Phys.org) -- Research into quantum bits (qubits) for use in a quantum computer has become tied to entanglement, the still mysterious phenomenon whereby subatomic particles exist in an entangled state such that any change to one happens simultaneously to the other, without communication or the passage of time. The reason entanglement of qubits is so important to the future of a quantum computer is because they are able to represent both a "1" and "0" state at the same time and because actions that cause a change in one entangled particle also cause the same change in its partner, theoretically allowing for processing speeds to increase exponentially when adding more entangled qubits. Thus far though, attempts to create entangled particles inside of a semiconductor material have been difficult to measure, and thus verify, due to their short lives.

Now however, a small group of researchers from Harvard University has succeeded in entangling two quantum bits inside of a semiconductor and holding on to them long enough for them to be measured. They describe how they achieved this feat in their paper published in the journal *Science*.

In essence the team overcame the inherent instability of entangled pairs by adding a second electron to the qubits in the semiconducting material which would allow them to be defined by their spin states; doing so they write, added a second level of immunity from decoherence, where the qubit reverts to either a "0" or a "1" after a very short period of time. To cause the actual entanglement, all that was needed was an electrical charge. To make sure that what they thought was happening inside the material truly was, they measured the sample using state tomography.

This experiment shows that creating entangled pairs inside of a material such as the semiconductor used, is no more difficult than doing so with such techniques as manipulating calcium atoms in a laser ion trap, the trick though has been to get them to hold their state long enough to be measured, and that's what this team has achieved. It also demonstrates a process that the team says could be scaled up, a very important element in building a quantum computer.

But this of course, just a first step towards building a quantum computer because entangled pairs of qubits would need to be lined up some distance apart from one another to allow for the construction of circuits. Thus far the team has entangled qubits just a few hundred nanometers apart, the goal is to reach at least a micron.

More information: Demonstration of Entanglement of Electrostatically Coupled Singlet-Triplet Qubits, *Science* 13 April 2012: Vol. 336 no. 6078 pp. 202-205. DOI: 10.1126/science.1217692

ABSTRACT
Quantum computers have the potential to solve certain problems faster than classical computers. To exploit their power, it is necessary to perform interqubit operations and generate entangled states. Spin qubits are a promising candidate for implementing a quantum processor because of their potential for scalability and miniaturization. However, their weak interactions with the environment, which lead to their long coherence times, make interqubit operations challenging. We performed a controlled two-qubit operation between singlet-triplet qubits using a dynamically decoupled sequence that maintains the two-qubit coupling while decoupling each qubit from its fluctuating environment. Using state tomography, we measured the full density matrix of the system and

determined the concurrence and the fidelity of the generated state, providing proof of entanglement.