Scientists view a quantum jump in real time

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(PhysOrg.com) -- For more than two decades, scientists have been "watching" electrons in atoms make the jump between energy levels in real time. "Atoms have energy levels, and when electrons 'jump' from one level to another, you can detect this optically. You can encode information in real atoms to make a quantum bit, or qubit," Irfan Siddiqi tells *PhysOrg.com*.

While the formation of a qubit from real atoms has the advantage of long coherence times, Siddiqi points out that by the same token single atoms are difficult to couple to each other and have fixed parameters. Qubits made from 'artificial atoms' have the advantage of tunability and can, in principle, be produced en masse. The use of superconducting electrical circuits, engineered to have discrete energy levels, is a way to develop artificial atoms.

"These artificial atoms make use of circuitry so that we can control the parameters. We are able to realize analogues of experiments performed with real atoms, and are even able to access different parameter regimes but at the expense of short-lived quantum coherence," Siddiqi says. "A problem with these superconducting circuits, though, is that it has not been possible to continuously monitor their state with high fidelity," he continues. This lack of measurement sensitivity has limited the possibility of real time quantum feedback. Until now.

Siddiqi, a professor at the University of California, Berkeley, along with Dr. Rajamani Vijay and Daniel Slichter, created an experiment that allowed them to watch the quantum state of a superconducting qubit acting as an artificial atom. Their work is described in Physical Review Letters: "Observation of Quantum Jumps in a Superconducting Artificial Atom."

“In real atoms, the jump between energy levels typically happens on the timescale of seconds and changes another optical process which can be readily detected,” Siddiqi points out. “Artificial atoms typically undergo jumps in less than a microsecond. Furthermore, they are typically probed with weak microwave frequency signals and are much harder to detect.”

In order to get around this problem, the team constructed a superconducting amplifier of their own design, made with thin aluminum films and Josephson junctions. The qubit was also constructed from the same basic building blocks and cooled down to 30 mK inside a cryogenic dilution refrigerator.

“When the jump is made, it modifies the resonant frequency of an adjacent circuit which we continuously probe with on average a few microwave photons,” Siddiqi explains. “The emission is spontaneous, so you don’t know when it will happen. We now had the ability to detect an individual jump. By tallying the jump times, we reproduced the average ensemble behavior that we were all familiar with..”

Hopefully, this will lead us one step closer to realizing a quantum computer. “In order to correct errors which will occur in any realistic quantum computer, we need to detect them quickly and efficiently,” Siddiqi points out. “Now that we have shown that it is possible to track changes in the quantum state in real time, it should be possible to apply this functionality to quantum information processing.”

Next, Siddiqi and his group want to work on error correction. “It should be possible now that we have this ability. Implementing this would be a major step for solid-state quantum computing.”

More information: R. Vijay, D.H. Slichter, and I. Siddiqi, "Observation of Quantum Jumps in a Superconducting Artificial Atom," *Physical Review Letters* (2011). Available online: link.aps.org/doi/10.1103/PhysRevLett.106.110502