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NANO HIGHLIGHT
Quantum Integrated Circuit Finds One-in-a-Billion Atom Defect

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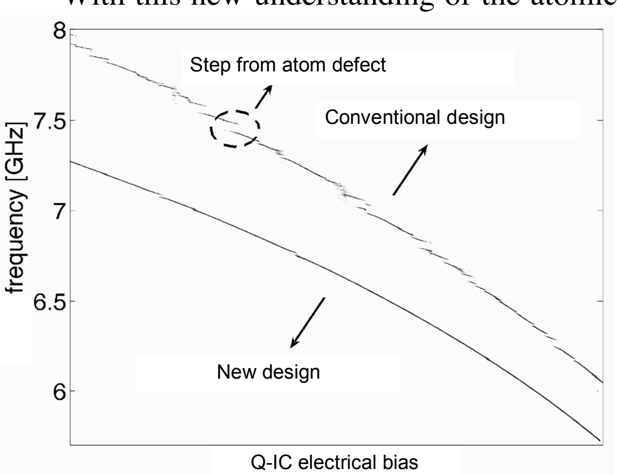
A current frontier of physics is the construction of "Quantum Integrated Circuits" (Q-IC), where the currents and voltages of an electrical device can no longer be described by classical numbers, but by probability amplitudes that obey the laws of quantum mechanics. Being sensitive to even a fraction of the energy of a single microwave photon, these quantum devices can be used as sensors with unprecedented sensitivity.

These electrical devices are made from superconductors and Josephson tunnel junctions, and are operated at temperatures within 0.02 Kelvin of absolute zero in order to freeze out electrical noise. The application of microwave pulses produce atomic-like quantum transitions between two energy states in the Q-IC device. These transitions are strong only when the microwave photon energy matches the device energy. Such a spectroscopic measurement is illustrated in the bottom figure, where the Q-IC energy level is shown to decrease as the electrical bias to the device is increased.

The expected behavior from spectroscopy is a smooth curve. However, step-like structures are observed that arise from the Q-IC interacting with single atom defects in the tunnel junction; these defects are activated when their oscillation frequency matches with the Q-IC. The number of defects is extremely small compared to the number of atoms in the tunnel junction, and corresponds to observing a defect in approximately one chemical bond per billion atoms. The positions and magnitudes of the defects have been used to study their electrical properties and discover their fundamental origin.

Photomicrograph of a "Quantum Integrated Circuit" (Q-IC) made from superconductors.

With this new understanding of the atomic defects, new Q-IC devices have been made that have more ideal behavior, as shown in the bottom curve. With this breakthrough, we now believe it is possible to use Q-IC devices to build a prototype quantum computer with 10 quantum bits.



Spectroscopy measurement of a Quantum Integrated Circuit show steps from atom defects.

Understanding atomic defects is important for a variety of technological materials and applications. We believe that measurement methods developed in this project may be a useful diagnostic for amorphous Silicon, which is used for flat-panel displays and solar cells.

[1] For further information about this project link to http://gabriel.physics.ucsb.edu/~martinisgroup/#home or email **martinis@physics.ucsb.edu**