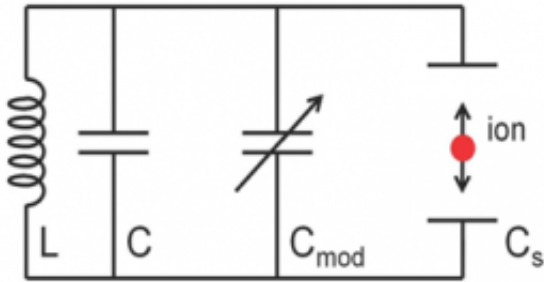


Electrical circuits talk to single atoms

March 6 2012, By Phillip F. Schewe



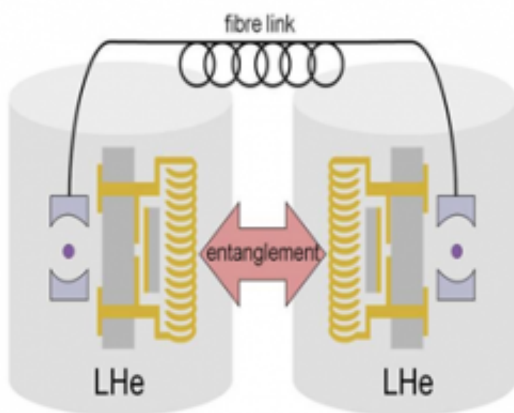
Model for ion-circuit coupling. C stands for capacitance and L stands for inductance. Credit: PRL Authors

(PhysOrg.com) -- If a practical quantum computer is ever to be realized, conventional electronic devices will have to interface with the delicate quantum systems such as atoms or ions in traps or wisps of magnetism near superconducting sensors. A new paper in the journal *Physical Review Letters*, written by experimenters at several Australian Universities and theorists at the Joint Quantum Institute (JQI) in the USA, proposes one way to achieve this kind of quantum interface. It shows how an electrical circuit can be used to enable the transfer of quantum information encoded in a single ion to other quantum systems, such as another isolated ion.

Electronic circuits are good at conveying information and, through the use of [logic gates](#), at processing information. But quantum information, by contrast, is more delicate and needs to be handled with care. The reason for the delicacy of quantum transactions is that quantum states

are easily undone. For example, the atom's spin orientation or an internal electron energy value might be altered if the atom interacts with other atoms. The atom bearing the quantum information has to be buffered from the surrounding environment in order for the full power of quantum information processing to be achieved.

Another obstacle in this case is the vastly different time scales. Here a circuit in which electric currents oscillate at gigahertz (10^9 Hz) frequencies must talk to an ion (confined by electrodes) oscillating at megahertz (10^6 Hz) frequencies. Thus the circuit and the ion lying just offshore inhabit very different worlds. The circuit represents the world of electronics, where information is typically stored in the form of accumulations of charge in a transistor or accumulations of magnetism on a sector of hard drive, while the ion harbors quantum information, typically in the form of internal atomic attributes.



Quantum communication fiber link enabled by circuit-ion couplings in two independent cryogenic environments. Credit: PRL Authors

Actually this is not a typical electric circuit. It would be kept in a bath of

liquid helium at a temperature near absolute zero so as to reduce electrical noise as much as possible. The electrical and [magnetic](#) energy sloshing back and forth in the circuit can be thought of as a microwave photon. The atom and the microwave don't directly interact. Rather they relate to each other through the action of a bulk acoustic wave, or BAW. This acoustic wave of energy moves through a frail slip of matter with a frequency equal to the difference in the microwave and ion frequencies.

What this setup allows observers to do is this: the oscillation of the microwave can be used instead of the ion's motion as a proxy for the ion's internal quantum information. The microwave in the circuit can, in turn, provide a handy linkup with other [quantum systems](#), such as ions held in other atom traps. The next figure illustrates how this works.

The circuit doesn't read out or encode the quantum information in an ion (that's usually done with lasers) but acts as a go-between other ions or quantum bits (qubits) stored in other devices. The information transfer between the electrical system and the ion enables the transfer of quantum information between two distant ions. Such linkups, in the form of entanglement or teleportation, are the heart of future quantum computers. This is illustrated in the second figure, where quantum information will flow from one isolated ion to another via a fiber. This transfer is enabled, however, by the presence of the [electronic circuits](#).

For the circuit-ion linkup to work, the transfer has to happen before the ion's [quantum information](#) leaks away, a time referred to as its decoherence time. "We expect that the coupling between ion and circuit can occur much faster than the ion's decoherence time, which is about a millisecond," said JQI scientist Jacob Taylor, one of the authors of the new paper. "We were pleasantly surprised given how simpler approaches give a much weaker coupling."

More information: Quantum Interface between an Electrical Circuit

and a Single Atom," D. Kielpinski, et al, in press at *Physical Review Letters*.

Provided by University of Maryland

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