Atomtronic transistor and diode could advance quantum computing

October 9 2009, By Miranda Marquit

(PhysOrg.com) -- What if atoms could be used to perform the functions currently the province of electronic devices? The goal of atomtronics is to do just that by creating analogues to the common items found in electronic devices. Ron Pepino, a graduate student at JILA and the University of Colorado, believes that he and his colleagues have found a way to create the atomtronic versions of diode and transistor circuits. The work of Pepino, Cooper, Anderson and Holland is described in *Physical Review Letters*: "Atomtronic Circuits of Diodes and Transistors."

“In our work, we create a one-to-one analogy between conventional electronic circuits and atoms trapped in optical lattices,” Pepino tells *PhysOrg.com*. “In this analogy, the current carriers -- the electrons -- are replaced with neutral, ultracold atoms, the semiconductor material that the electrons traverse is replaced with an optical lattice, and the electric potential difference -- which induces the flow of electrons around the circuit -- is replaced by a chemical potential difference”

“The dynamics of atoms in optical lattices, which are basically crystals of light, have been studied both theoretically and experimentally for many years now. We add to this field by theoretically demonstrating that the electronic properties of the diode and transistor can be observed in specifically tailored optical lattices,” Pepino continues.

The team at JILA believes that it is possible to emulate the behavior of a semiconductor diode in these atomic systems. “We have predicted that

you can take the optical lattice, manipulate its experimentally-tunable parameters in a specific way, and recover diode-like phenomena," Pepino explains, "Our simulations show that this augmented optical lattice will allow atoms to flow across it from left to right, for example, but forbids the atoms to traverse the lattice going the other way. We have modeled this, and we think it might work."

Pepino and his peers have also modeled an atomtronic transistor. "All modern electronics contain transistors; they are the fundamental building blocks of electronics and computers. Naturally, we want an atomtronic version." The transistor designed by Pepino and his colleagues exhibits on/off switching behavior, and acts as an amplifier. By configuring the optical lattice in a manner discussed in their article, they show that it is possible to recover the characteristics of the conventional electronic transistor in the atomic world.

He points out that atomtronics probably won't replace electronics. "Atoms are sluggish compared to electrons, and that means that you probably won't see atomtronics replace current electronic devices. What atomtronics might be useful for is the field of quantum information."

Because electrons lose any possible initial quantum state as they bounce around through the energy dissipating semiconductor or metallic systems, they are ill-equipped for quantum computing. "In quantum computing, you store a quantum state on an object, perform operations on the object and then read out the final state. If the system is not coherent, the initial stored information is lost," Pepino points out. "Atoms trapped in optical lattices have been considered extensively for specific quantum computing schemes due to their inherent energy conserving characteristics. The dynamics of our atomtronic devices would be coherent and potentially useful in quantum computing." He also suggests that there is the possibility that atomtronics could be useful in obtaining sensitive measurements. At the very least, he concludes,

"atomtronic systems provide a nice test of fundamental concepts in condensed matter physics."

While these ideas have been modeled, they have yet to be built. Pepino says that an effort is under way to set up experiments that could provide a proof of principle for the work being done at JILA and the University of Colorado by experimental collaborator and co-author Dana Anderson.

More information: Pepino, et. al. "Atomtronic Circuits of Diodes and Transistors," Physical Review Letters (2009). Available online: http://link.aps.org/doi/10.1103/PhysRevLett.103.140405