Can alkaline earth metals be used in quantum computing?

November 14 2008, By Miranda Marquit

(PhysOrg.com) -- "There are a number of different proposals for quantum computing," Andrew Daley tells *PhysOrg.com*. "These include solid state or semiconductor as well as atomic and molecular systems. We are considering atomic systems, and more specifically alkaline earth metals."

Daley is a physicist in the Institute for Theoretical Physics at the University of Innsbruck and the Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences in Austria. He, along with Martin Boyd and Jun Ye at the University of Colorado, and Peter Zoller at Innsbruck, are proposing a quantum computing scheme that would make use of overlaying optical lattices to store information as well as perform computations. Much of this work was performed when the authors were guests at the California Institute of Technology in Pasadena, and their ideas are shared in *Physical Review Letters:* “Quantum Computing with Alkaline-Earth-Metal Atoms.”

Electrons play a vital role in quantum computing with atoms, and when atoms are controlled with light, the electrons are also controlled. “That’s what makes alkali atoms nice to deal with,” says Daley. “They only have one valence electron, which makes the system really simple.” He then points out that alkaline earth metals offer an advantage over alkali atoms: “There are two electrons weakly bound. Even though the system is a little more complicated, there are some very nice properties.”

Daley explains that it is possible to excite an electron to higher energy states in which they remain for a relatively long time. “The idea is to create two different traps using two different colors of light, one for atoms where the electron is excited and the other for atoms where it is not. This is possible because the atoms react to light, and go where the light is. Basically, we can make an array of bright spots of laser light – an optical lattice – where there is an atom in every bright spot.”

In order to store information, Daley says, the spin of the nucleus is adjusted, also with laser light. “Atoms are initially stored in the lattice for the state where the electron is not excited. They can then be transferred to the state with an excited electron and transported to different parts of the system by moving the two different traps relative to each other. This can be used to perform computations with information stored on atoms in different parts of the lattice.”

The paper Daley and his peers wrote expresses theory rather than describing the results of an experiment. However, it is possible that a demonstration might be possible fairly soon. “While this paper is theoretical,” he insists, “we build on techniques demonstrated in the laboratory, making use of technology that is currently applied to make atomic clocks.”

Some of the details still need to be worked out, but Daley feels that it should be possible to build something workable to demonstrate the principle in the relatively near future. “We’ve taken our ideas of what can be done and matched them up with real numbers from experiments. This could lead to the first few steps and then be refined to make larger quantum computations.”

“Our paper is a type of road map to set a course for what could be possible,” Daley continues. “We believe that with our technology it is likely that the first demonstrations are feasible on a timescale of two to three years.”

More Information: Andrew Daley, Martin Boyd, Jun Ye and Peter Zoller. "Quantum Computing with Alkaline-Earth-Metal Atoms," *Physical Review Letters* (2008). Available online: link.aps.org/abstract/PRL/v101/e170504.