# Controlling the interaction between light and matter

April 30 2010, By Miranda Marquit

(PhysOrg.com) -- "One of the most exciting things about this is that it gives us nice, clean control over the interaction between light and matter," William Kelly tells *PhysOrg.com*. "Our technique has the potential to give delicate and precise control over how artificial atoms interact with photons."

Kelly is with Raytheon BBN Technologies in Cambridge, Massachusetts. Along with a group of others in BBN’s Disruptive Information Processing Technologies division, and with scientists from the National Institute of Standards and Technology in Boulder, Colorado, Kelly took part in an experiment designed to observe superposition of states in a superconducting artificial atom. The group’s results are described in Physical Review Letters: “Direct Observation of Coherent Population Trapping in a Superconducting Artificial Atom.”

“In a classical physics, an atom is in only one energy level at a time, referred to as 0, 1, or 2. In quantum mechanics, though, you get superposition states, in which the exact energy of the atom is not well defined,” Kelly explains. “In similar experiments, you see a lot of two-state interference. Our experiment, though, showed three-state interference. This is a new effect in these kinds of systems.”

To get this effect, Kelly and his colleagues worked with microwaves. “In atomic experiments, this type of thing is done with optical frequencies,” he says. “At room temperature it wouldn’t be feasible to use microwaves because of thermal noise, however at the temperatures we work at thermal noise is not a problem."

The experiment involved super-cooling a tiny superconducting device, which acts as an artificial atom, to less than one tenth of a degree above absolute zero. "You apply microwaves to this system, coupling an electromagnetic field to the device, and use that to control the state the artificial atom is in. By sending in photons with energies that match the energy gap of the artificial atom, it is possible to get the artificial atom to transition states," Kelly says.

One of the potential applications of this technique is in quantum information processing. "There are different possible platforms for realizing quantum information systems. Superconducting artificial atoms and photons are both candidates with their own advantages and disadvantages," Kelly points out. "With this technique, we could potentially use the best of both worlds for quantum information processing." He also points out that there has been a great deal of work done with optical switching, and that down the road this technique could lead to similar work with switching done with microwave frequencies. "We could use this as a sort of microwave transistor."

On a fundamental level, this work could lead to increased knowledge of quantum systems, and the use of artificial atoms. "This is the first time we've seen coherence in three states in a manmade system," Kelly says. "Additionally, there are interesting possibilities for using this to slow microwaves down, or even stop them."

Further development is some while down the road, Kelly acknowledges, but there are some interesting opportunities available now. "We're probably close to using this to demonstrate slow light," he says. "However, there are a bunch of possible applications. With more study of this system, we should be able to figure out some new ways to advance technology."

**More information:** W.R. Kelly, Z. Dutton, J. Schlafer, B. Mookerji, T.A. Ohki, J.S. Kline, and D.P. Pappas, "Direct Observation of Coherent Population Trapping in a Superconducting Artificial Atom," *Physical Review Letters* (2010). Available online: link.aps.org/doi/10.1103/PhysRevLett.104.163601