# Yale scientists bring quantum optics to a microchip

September 8 2004

A report in the journal Nature describes the first experiment in which a single photon is coherently coupled to a single superconducting qubit (quantum bit or "artificial atom"). This represents a new paradigm in which quantum optics experiments can be performed in a micro-chip electrical circuit using microwaves instead of visible photons and lasers. The work is a collaboration of the laboratory of Professor Robert Schoelkopf and the theory group of Professor Steven Girvin in the Departments of Applied Physics and Physics at Yale University.

The Yale researchers have constructed a miniaturized superconducting cavity whose volume is more than one million times smaller than the cavities used in corresponding current atomic physics experiments. The microwave photon is, therefore, "trapped" allowing it to be repeatedly absorbed and reemitted by the 'atom' many times before it escapes the cavity. The 'atom' is a superconducting circuit element containing approximately one billion aluminum atoms acting in concert.

Because of the tiny cavity volume and large 'atom' size, the photon and 'atom' are very strongly coupled together and energy can be rapidly exchanged between them. Under the peculiar rules of quantum mechanics, the state of the system becomes a coherent superposition of two simultaneous possibilities: the energy is either an excitation of the atom, or it is a photon. It is this superposition that was observed in the Yale experiment.

In addition to allowing fundamental tests of quantum mechanics and

quantum optics in a completely new format, this new system has many desirable features for a quantum computer. In a quantum computer the bits of information are replaced by qubits (e.g. an atom), which, paradoxically, can harness quantum uncertainty to vastly speed up certain types of calculations. The ability to couple qubits to photons, demonstrated by the Yale group, could allow qubits on a chip to be wired together via a "quantum information bus" carrying single photons.

Source: Yale University