Physicists propose quantum refrigerator

September 1 2010, by Lin Edwards

(PhysOrg.com) -- Scientists at the University of Bristol in the UK have proposed a refrigerator that consists of just a few quantum particles -- qubits.

Theoretical physicists Noah Linden, Paul Skrzypczyk, and Sandu Popescu, report in the upcoming Physical Review Letters they can in principle make a thermal engine or refrigerator using a few qubits, which are quantum particles with only two possible states: an excited state with fixed energy, and a ground state with zero energy. The researchers have found a way to draw energy out of one of the qubits to cool the third.

The idea of making a thermal machine began in 1824 with the theories of Sadi Carnot, a French engineer who imagined a gas-filled piston brought into contact with either a hot or cold body or 'bath'. In one cycle the piston does work, the gas expands, and heat is absorbed when in contact with the hot bath, and the gas is compressed and releases heat when in contact with the cold bath. If this cycle is reversed, in response to work done on it, the piston absorbs heat from the cold bath and releases it into the hot bath.

In the current theoretical situation three linked qubits are used, two forming the refrigerator, and the third being the object to be cooled. Applying Carnot's ideas to the quantum scale, they expose one of the refrigerator qubits to a cold 'bath' (actually room temperature) and the other to a hot bath. The heated qubit absorbs energy and flips into its excited state, and because the qubits have a quantum connection, they influence each other, resulting in the cold qubit siphoning off energy from the third qubit and cooling it. The energy absorbed by the second qubit then dissipates.

Linden and his team calculate that as the hottest qubit heats up the refrigerator's ability to cool increases. He said that once the system is set up it can run forever as long as the hot bath stays hot. It could in theory cool to near absolute zero.

The three qubits have eight possible states (000, 010, 100, 101, and so on, where 0 = ground state and 1 = excited state), but this can be reduced to six if the second and third qubits are replaced by one qutrit, which is a particle with a zero energy ground state and two excited states. To use a qutrit in the refrigerator these two states would have to be in contact with baths at different temperatures. Linden said the group believes this would be the smallest thing you could possibly term a refrigerator.

Popescu said it may be possible to make a quantum refrigerator using trapped ions for the qubits, and the hot and cold baths could be provided by streams of laser light. This may allow researchers planning to use qubits in a quantum computer to cool some of the qubits using others. The next step in the research is to collaborate with other scientists to design and actually build a quantum refrigerator.

Apart from quantum computers other possible applications include cooling parts of proteins within cells to regulate the speed of their reactions.

More information: The abstract of the upcoming *PRL* paper "How small can thermal machines be? The smallest possible refrigerator" can be viewed at prl.aps.org/accepted .