D-Wave researchers demonstrate progress in quantum computing

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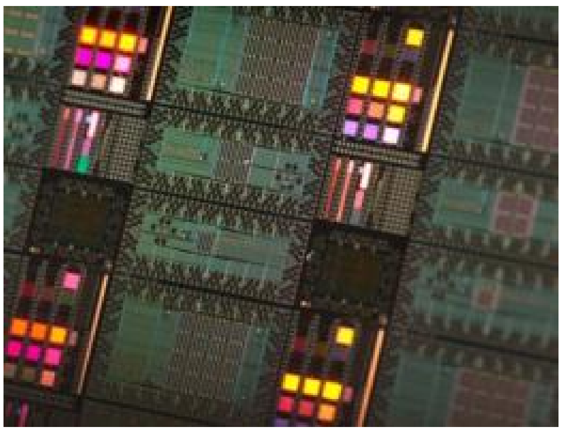

D-Wave's processors. Image credit: D-Wave.

(PhysOrg.com) -- Taking another step toward demonstrating quantum behavior in a quantum computer, researchers from the Vancouver-based company D-Wave Systems, Inc., have performed a technique called quantum annealing, which could provide the computational model for a quantum processor. They have published a study describing the demonstration in a recent issue of *Nature*.

"This is the first time we've been able to open up the black box and show how [D-Wave's devices] are harnessing quantum mechanics in solving problems," D-Wave's chief technology officer Geordie Rose said in a recent news article at physicsworld.com.

D-Wave, which is a spin-out company from the University of British Columbia, made headlines in 2007 when it boldly announced to have built the world's first commercially viable quantum computer. Due to the difficulty in demonstrating that the computer does in fact exhibit quantum behavior, many people have been skeptical of the claim.

Nevertheless, D-Wave has continued to work toward the challenging goal of harnessing the power of quantum computing. In their study, they show that quantum annealing can be used to find the ground state of eight superconducting flux qubits that aren't corrupted by heat or noise. Since many complex problems can be reduced to finding the ground state of a system of interacting spins, quantum annealing has been predicted to provide better methods for solving certain types of complex problems.

To demonstrate quantum annealing, the researchers first adjusted the eight qubits to resemble a 1D chain of magnets, where each qubit wants to point in the same direction (up or down) as its two neighbors. The researchers then set the qubits on the ends of the chain in opposite directions, and allowed the six qubits in the middle to orient their spins with their neighbors. Since this set-up forces two neighboring qubits to have opposing spins, the process resulted in a "frustrated" ferromagnetic arrangement. Then, by tilting the qubits in the same direction and raising the energy barrier, the researchers caused the system to move toward one specific arrangement of frustrated spins, which is the ground state.

Qubits can flip spins in two ways: through a quantum mechanical mechanism (tunneling) and a classical mechanism (thermal activation). Since thermal activation destroys the quantum nature of the qubit, the researchers had to show that the qubits were flipping spins due solely to quantum tunneling. They did this by applying a current to the system until both tunneling and heat-driven transitions stopped, and the qubit "froze." By repeating this process at different temperatures, the researchers could determine that annealing occurred by tunneling alone. In other words, the results cannot be explained by classical physics.

As the researchers explain, increasing the number of spins could enable the system to provide a practical physical way to implement a quantum algorithm. The researchers are currently working on this challenge, and plan to apply the process to areas such as machine learning and artificial intelligence.

According to Rose, the demonstration in this paper is the first of several results to be announced in the near future, including one that he describes as "mind-blowing."

More information: M. W. Johnson, et al. "Quantum annealing with manufactured spins." *Nature*, 473, 194-198, 12 May 2011. DOI:10.1038/nature10012

Abstract
Many interesting but practically intractable problems can be reduced to that of finding the ground state of a system of interacting spins; however, finding such a ground state remains computationally difficult1. It is believed that the ground state of some naturally occurring spin systems can be effectively attained through a process called quantum annealing2, 3. If it could be harnessed, quantum annealing might improve on known methods for solving certain types of problem4, 5. However, physical investigation of quantum annealing has been largely confined to microscopic spins in condensed-matter systems6, 7, 8, 9, 10, 11, 12. Here we use quantum annealing to find the ground state of an artificial Ising spin system comprising an array of eight superconducting flux quantum bits with programmable spin–spin couplings. We observe a clear signature of quantum annealing, distinguishable from classical thermal annealing through the temperature dependence of the time at which the system dynamics freezes. Our implementation can be

configured in situ to realize a wide variety of different spin networks, each of which can be monitored as it moves towards a low-energy configuration13, 14. This programmable artificial spin network bridges the gap between the theoretical study of ideal isolated spin networks and the experimental investigation of bulk magnetic samples. Moreover, with an increased number of spins, such a system may provide a practical physical means to implement a quantum algorithm, possibly allowing more-effective approaches to solving certain classes of hard combinatorial optimization problems.

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