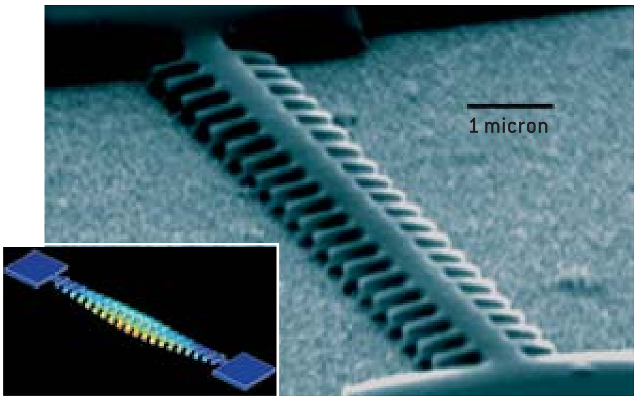
COMPUTING

Qubit Twist

BENDING NANOTUBES AS MECHANICAL QUANTUM BITS BY CHARLES Q. CHOI

Before the advent of electricity, the first computers were mechanical, with the Difference Engine invented by Charles Babbage tackling logarithms and trigonometry 150 years ago. Now advanced quantum computers might go back to mechanical roots, using rows of nanometer-scale bars as moving parts.



SILICON SWING: This multielement bar, consisting of 50 billion silicon atoms, could flex when driven by an oscillating force, according to a computer model (*inset*). Such bars might be the basis for mechanical quantum bits.

The bizarre laws of quantum physics suggest that items the size of molecules and smaller can exist in two or more places or states at the same time. An observation or some other action forces them to collapse out of this "superposition," leading to just one outcome. In theory, because quantum bits, or "qubits," can exist in both an on and off state simultaneously, a quantum computer with just 300 qubits can run more calculations in an instant than there are atoms in the universe.

Existing methods to create qubits rely on trapping atoms with lasers or manipulating nuclear spins in semiconductor crystals, among other approaches. These techniques, however, are highly delicate, and the slightest disturbance can disrupt the superposition of qubits prematurely. At best, researchers have managed to "entangle," or connect up, only a few qubits to form simple logic operations.

A more robust alternative might be mechanically based qubits. Imagine a tape measure extended a few centimeters, explains theoretical physicist Franco Nori of the University of Michigan at Ann Arbor and the Frontier Research System of RIKEN near Tokyo: "Squeeze it along its length. It can buckle either to the left or right." If shrunk to nanometer levels, the tape measure could adopt a superposition of twisting both left and right. In a paper submitted to *Physical Review Letters,* Nori and his colleagues Sergey Savel'ev and Xuedong Hu propose using either carbon nanotubes or bars machined from silicon as mechanical qubits.

A mechanical quantum computer would place molecular bars 10 to 30 nanometers long in rows spaced about 10 nanometers apart. Each bar would bear a charge, so that together their electric fields entangle their behavior, enabling the qubits to act in concert. The bars can get compressed either mechanically or electrically, and detection of each bar's state—the readout for the quantum computer—can be performed either optically or electrically.

It is too early to determine whether mechanical qubits can truly challenge other qubit approaches, such as superconducting circuits, which are also solid-state. "Superconductive devices have been worked on for about 40 years, and therefore much is known and many problems have been solved with these systems," points out physicist Andrew Cleland of the University of California at Santa Barbara. On the other hand, Cleland adds, the potential advantage of a mechanical system over an electronic system is that its qubits might intrinsically lose energy more slowly and thus remain in superposition longer, enabling them to perform more useful, complex calculations.

Nori and his co-workers plan to complete preliminary experiments on buckling nanotubes this year, with nanotubes in vacuum and at temperatures close to absolute zero to prevent interference from gas molecules or heat fluctuations. If they see the nanotubes in superposition as hoped, Nori guesses it will take one to three years to implement their mechanical qubits. He notes that the area seems to be advancing quickly—physicist Pritiraj Mohanty of Boston University and his colleagues in the January 28 *Physical Review Letters* described nanometer-size single-crystal beams of silicon that flicker between two different positions. Remarks Nori: "I can imagine Charles Babbage grinning right now."

Charles Q. Choi is a frequent contributor.

WHERE THE TWAIN SHALL MEET

Whether experiments on mechanical qubits, made out of bending nanotubes, will lead to a robust quantum computer is not yet certain. But being bigger than typical electronic and optical qubits, they should elucidate how the realm of atoms and molecules obeying quantum rules yields to the classical picture of everyday existence, where objects do not exist in two places at once. As Keith Schwab, senior physicist for the National Security Agency's laboratory at the University of Maryland, observes, "It could help to figure out where the border is between classical and quantum mechanics and what causes that boundary."

COURTESY OF P. MOHANTY AND BOSTON UNIVERSITY (*photograph and inset*)