Defining quantum computer bits and pieces

In principle, a computer obeying the laws of quantum mechanics can efficiently solve a number of complex problems that a conventional computer can't handle. This striking capability has stimulated a wide-ranging exploration of the possibility of building such a computer (SN: 1/14/95, p.30).

Three papers in the May 15 PHYSICAL REVIEW LETTERS provide hints of how one might go about designing and assembling the logic units, or gates, needed for quantum computation. They also suggest ways of constructing such gates out of quantum dots, atomic beams, or trapped ions interacting with laser beams.

"These papers represent significant, though incremental steps in our understanding of quantum computation," says David P. DiVincenzo of the IBM Thomas J. Watson Research Center in Yorktown Heights, N.Y.

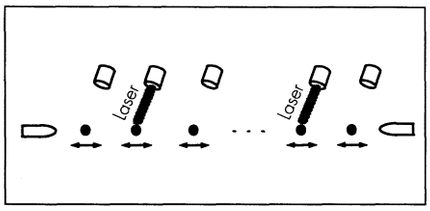
A decade ago, David Deutsch of the University of Oxford in England provided the first theoretical description of how a quantum computer might work. In the May 15 PHYSICAL REVIEW LETTERS, Deutsch, Oxford colleagues Adriano Barenco and Artur Ekert, and Richard Jozsa of the University of Plymouth in England show how one can use a simple type of quantum logic gate as the main building block of an information-processing system.

The researchers focus on the quantum analog of the "controlled-NOT" gate. This gate works with two input bits, leaving the first bit unchanged and changing the second bit from 0 to 1 or 1 to 0 if the first bit is 1. Because it's possible to determine the values of the two input bits from the output values, such a gate is said to be reversible.

In their paper, Tycho Sleator of New York University and Harald Weinfurter of the University of Innsbruck in Austria also look at reversible quantum logic gates. They demonstrate that a two-bit quantum gate is sufficient for building any quantum logic network.

In other words, one can assemble a chain of two-level quantum systems, interacting two at a time, to achieve any computational result desired. Moreover, the identification of such a "universal" quantum gate "considerably simplifies the search for implementations of quantum computational networks," the researchers say.

Peter Zoller and J.I. Cirac of the University of Innsbruck describe how it may be possible to construct quantum gates out of a line of barely jiggling ions confined in a magnetic trap. In this case, the basic computational elements, or qubits, of the quantum computer are the ions themselves.



Zoller, Cirac/Phys. Rev. Lett.

Oscillating ions in a linear trap interacting with different laser beams.

Normally, each ion in the row oscillates about an equilibrium position, and repulsive electric forces between adjacent ions induce a collective motion shared by all the ions (see diagram).

A laser beam shining on an ion causes a transition from one quantum state of the ion to another, which can alter the type of collective motion possible in the ion array. Thus, by selecting appropriate laser frequencies, one can control the interactions between individual ions via their shared movements.

"This paper is the most comprehensive and careful analysis to date about how close you can get to doing quantum operations," says IBM's Charles H. Bennett. But this doesn't mean that anyone is close to building even a rudimentary quantum computer. Many obstacles remain. *— I. Peterson*

Viral proteins lie down on the job

Flaviviruses, responsible for diseases such as dengue, yellow fever, Japanese encephalitis, and tick-borne encephalitis, are deadlier—but less menacing to look at—than their influenza-causing cousins. Flu viruses bristle with spiky surface proteins that they use to insinuate themselves into the cells they infect. Flaviviruses' surface proteins, in contrast, appear to conform to the pathogen's spherical shape, judging from the first three-dimensional pictures of these structures.

This stark difference suggests that viruses have evolved many ways to infiltrate their hosts. "I think this is really exciting. We know so very little about how viruses infect cells," says Peter S. Kim of the Whitehead Institute for Biomedical Research in Cambridge, Mass.

Researchers at Harvard University and the University of Vienna in Austria obtained the new images by first crystallizing the main surface protein of the tick-borne encephalitis (TBE) virus. They then shone intense X rays through this crystal and deduced the protein's structure from the pattern of light produced by the X rays deflecting off atoms.

The resulting viral protein snapshot, described in the May 25 NATURE, surprised everyone. It looked nothing like hemagglutinin, the influenza surface protein whose structure had been revealed in 1981.

"Everyone thought it would be spikes. [Hemagglutinin] has been the model for 14 years," says Harvard's Felix A. Rey, a coauthor of the report.

On the flu virus, three hemagglutinin molecules combine to produce the characteristic spikes. A flavivirus surface protein normally pairs with only one other to form a molecule known as a dimer. The X-ray data show the dimer to be rod-shaped and slightly bent in the middle where the two proteins join, the researchers say.

The dimer's curvature matches that of the virus itself, leading Rey and his colleagues to theorize that rather than jutting upward, dimers cover the virus horizontally. "The biggest surprise is that it's lying down flat. That's very unusual," says Michael G. Rossman of Purdue University in West Lafayette, Indiana, coauthor of an accompanying commentary in NATURE.

In 1993, Kim and Chavela M. Carr proposed a mechanism, based on the 1981 picture of hemagglutinin, by which the flu virus penetrates cells. They argued that deep within each hemagglutinin molecule is a small protein fragment called a fusion peptide. When a virus encounters a cell membrane, a spring-like device launches this fusion peptide into the membrane, like a speargun lancing a whale (SN: 5/29/93, p.340).

This theory was confirmed in 1994, but the structure of the flavivirus surface protein reveals that the method of attacking cells used by the influenza virus "is not the only way nature has solved the problem," says Kim.

Rey and his colleagues think that when the TBE virus meets a cell, the protein dimers on the virus' surface break apart and link up in threes to form trimers. As this happens, they say, each individual protein dramatically rearranges its shape, uncovering its own fusion peptide.

"This fusion peptide sits [inside the protein] snugly. When the dimer disassociates, the peptide then becomes accessible," says Rey. Researchers hope to confirm this theory by snapping an image of the TBE viral protein in its trimer form.

The newly revealed dimer structure also indicates which parts of the viral protein the immune system and other cells in the body see—knowledge that may help scientists trying to develop vaccines for flaviviral diseases. *— J. Travis*