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By LEE GOMES

Quantum Computing May Seem Too Far Out, But Don't Count on It

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Science, including the science of building computers, often works in three phases. First, a scientist has an idea that other scientists regard as more science fiction than science. A few years later, a few other scientists begin to realize that the idea isn't so improbable after all. And a few years after that, the idea starts to be taught to undergraduates as though it is old hat.

That's what's happening with quantum computing, a radical redesign of computers that could result in unimaginably fast machines. A generation ago, a few physicists had the brainstorm that such machines might be possible -- even though Albert Einstein himself regarded it all as nonsense. Now, at the University of California, Berkeley, you have C191: Quantum Information Science and Technology, a senior-level class that's a co-production of the school's physics, chemistry and computer-science departments.

Twice a week, two dozen undergraduates -- all male, by the way -- shuffle in to a Wheeler Hall classroom, turn off their cellphones and slump into their seats. Most of them, like Marty Greenia, a computer-science major, are there because quantum computing, while hardly yet practical, is getting too interesting to ignore.

For an outsider, the class is a good way to track the methodical process by which a science frontier gets tamed.

A regular computer makes use of bits, or pieces of information that are either ones or zeros. Quantum computing also has bits, called qubits, and these bits can also be either ones or zeros. But because of one of the Fun Facts from quantum mechanics -- the study of very small things that provides the foundation for quantum computing -- qubits can also, while you are not looking at them, be every possible number between one and zero, and be all of those numbers at once. Certain known probabilities help predict how the qubits will act.

ABOUT LEE GOMES

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There is another quantum mechanical Fun Fact that is important for quantum computing: that two or more qubits can be linked together, so that something that affects one of them affects all the others, too.

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In a quantum computer, then, you line up a row of qubits, set them off, and then allow the probabilities of each of them to interact with the probabilities of the others. You let that happen as long as your program needs it to, and then you look and get your answer.

Researchers have already demonstrated that a quantum computer could decrypt in a few seconds an encoded message that it would take a regular computer billions of centuries to crack. It would need, though, thousands of qubits to do so, and so far, no quantum computer has been built with more than a handful.

As the students in C191 are learning, scientists all over the world are racing to build qubits out of just about anything they can think of: atoms, electrons, photons and more.

Last Tuesday's class lecture was about one of those approaches. Michael Crommie, a UC physicist and co-instructor, introduced Thomas Schenkel, a physicist at the nearby Lawrence Berkeley Lab who is working with our old friend silicon.

Prof. Schenkel's plan is to make a qubit out of a specially prepared phosphorus atom that is placed ever so precisely on an extremely pure silicon wafer. Those atoms have a "spin" that is either up or down, which corresponds to the one or zero needed to do computing.

Prof. Schenkel has to use a specially constructed machine the size of a bedroom to place the phosphorous atom. (A cruel irony of this sort of physics research is that the smaller the thing you want to work with, the bigger the apparatus you need to use.) He reports success at getting one or two atoms successfully parked.

But as for the next steps -- being able to talk to the phosphorous qubit, or get an answer out of it, or link it up with many other qubits -- well, all that is down the road, as it is with every other quantum computing researcher.

Prof. Schenkel said he chose to work with silicon because it is well known for maintaining the spin of the phosphorus atom long enough to do something useful. How sweet it would be, he notes, if the next generation of computers were made of the same materials as the current one.

The professor began his presentation with an homage to Gordon Moore, the Intel co-founder who, 40 years ago this month, formulated his famous law about computer chips doubling in capacity every year or so. Most quantum researchers believe that their approach is the only way to keep that progress going for another 40 years.

Mr. Moore, interestingly enough, disagrees. In a recent interview, he said he didn't think quantum computers would ever be built because the physics involved is just too hard.

Berkeley students, though, should pay Mr. Moore no heed. Surely some jolly and distinguished veteran of the vacuum-tube industry once told young engineers to calm down, because the newfangled "transistors" they were starting to get excited about would not, could not, ever amount to much.

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