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In quantum physics breakthrough, strange computer is on and off
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BY JEREMY MANIER
Chicago Tribune

CHICAGO − In the bizarre realm of quantum mechanics − the physics theory that stumped even Albert Einstein − tiny things like electrons and packets of light often seem to be in two places at once, in total violation of common sense.

Now a University of Illinois physics team has taken that principle and built something harder to fathom: a quantum−based computer that can be awake and asleep at the same time, and spits out answers even if its program is never triggered.

It's plenty strange, but some experts say such real−world spinoffs of eerie quantum effects are growing so common that it's our understanding of "strange" that needs to change.

"This is the way nature is," said Charles Bennett, an IBM researcher who dreamed up some of the new uses of quantum physics. "We should be learning how to get used to that."

Quantum mechanics is the theory physicists use to understand events at the atomic level, which works far differently than the large−scale world that people inhabit. The theory states that it's impossible to gain complete knowledge about any subatomic particle, and its location and other traits often exist only as probabilities.

That maddening, fuzzy quality is fueling creative ideas about how to put quantum effects to work.

The University of Illinois experiment, published Thursday in the journal Nature, could help refine the young field of quantum computing. In theory, computers based on quantum effects could race through calculations that would take an ordinary computer billions of years to complete. Applications of such computers could include precise simulations of how proteins work in the human body.

Recent research also has raised the prospect of unbreakable quantum codes, a commercial opportunity that some companies already are vying to exploit. Bennett and others have pioneered a form of "quantum teleportation" that can replicate the characteristics of light particles more than a mile away − though nobody expects to be able to beam people around.

The not−quite−technical term many physicists use for such effects is "quantum weirdness." Although quantum theory has proved one of the most successful and accurate ideas in science since Max Planck laid its foundations a century ago, most great physicists have pronounced the theory nearly impossible to reconcile with common sense. Einstein could not accept the theory's glorification of probability, complaining, "God does not play dice with the universe."

University of Illinois physics professor Paul Kwiat, co−author of the new quantum computing study, said one of his favorite quotes on the subject is by Nobel laureate Murray Gell−Mann, who once said: "We know how to use (quantum mechanics) and how to apply it to problems; and so we have learned to live with the fact that nobody can understand it."

Kwiat said he and his team don't need to understand what quantum theory ultimately means for philosophical notions of reality. But they do know that quantum effects allowed them to dream up one really weird computer.

Like a frantic one−man band, a quantum computer gets its unique power by trying to do many things at the same time.

Such devices are far different from the digital computers everyone uses, which can process just one "bit" of electronic information at a time, in a stately procession of 0s and 1s.

The uncanny gift of quantum mechanics is that it could permit computers that calculate many possibilities simultaneously, because their bits can be 0 and 1 at the same time. Such computers exploit the properties of light packets called photons or other particles that seem to exist in more than one physical state at once.

As the number of quantum bits increases, the computer can consider many more combinations of data at a single stroke. That could open the door to a "quantum genie," Kwiat said, offering answers to otherwise impossible problems.

One use of such power may be to find all the possible factors of very large numbers − which unfortunately is just what code−breakers would need to crack the tightest modern security codes. A typical code used in banking transactions would take 100 million personal computers a thousand years to decipher. A sufficiently powerful quantum computer might be able to do that job in minutes.

On the bright side, quantum effects might also make it possible to make tamper−proof codes that no computer − quantum or otherwise − could ever break.

University of Illinois graduate student Onur Hosten, who co−wrote the Nature paper with Kwiat, said he has always been fascinated by ways of seeing quantum weirdness in the ordinary world.

"I spend a lot of time thinking about how far we can push these effects," Hosten said.

So Hosten wanted to see if he could get accurate information from a quantum computer even if its program never runs. It turned out he could.

That's not as crazy as it sounds, if you try to use what Bennett calls "quantum intuition."

Hosten and Kwiat knew the same physical laws that allow quantum bits to be 0 and 1 at the same time ought to let them make a quantum computer that is both running and not running at once. That twinning effect is called superposition, and it's at the heart of theories about the world of the very small.

The quantum computer they built is set up to run a simple program using one photon of light at a time. The light goes through a series of lenses and mirrors that give an "answer" by directing the photon to one of many light detectors.

But what if the setup allowed the photon in some cases to be reflected away from the computer before it arrived there? In those cases you would not expect to be able to get any information from the computer.

Yet Hosten and Kwiat were able to learn something about the photon's potential interaction with the computer even if final measurements showed the photon never took that route.

That's because according to quantum mechanics, the photon actually exists in two conditions at once − one in which it went through the computer, and another in which it was bounced away.

The two alternate paths even affect one another, and the interaction can influence which light detector is triggered. That, in turn, provides information about what the computer would have found, even if measurements show the program never actually ran. Specifically, it can exclude one possible answer.

"What gives us the answer is the possibility of the computer running," Hosten said.

Based on that idea, Hosten imagined an even more complicated setup, using still more optical devices to shoot the photon through a figure−eight circuit buzzing with possible outcomes. Such a device, he showed, could narrow down the possibilities to just one answer, even if the photon never actually went through the program.

Such implications of quantum theory may always seem too strange to handle. But Bennett said he hopes that today's youth one day will take quantum weirdness for granted, in a way that Einstein's generation never could.

"They didn't have as many decades to get used to the idea," Bennett said.

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