Quantum computer solves problem, without running

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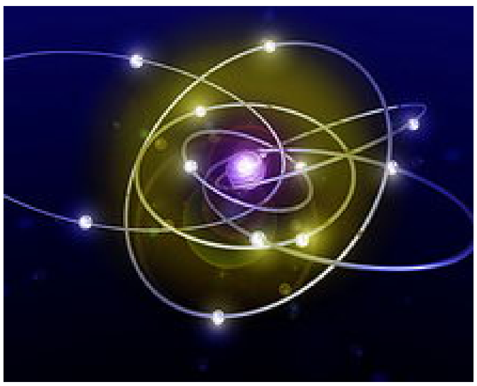

By combining quantum computation and quantum interrogation, scientists at the University of Illinois at Urbana-Champaign have found an exotic way of determining an answer to an algorithm – without ever running the algorithm.

Using an optical-based quantum computer, a research team led by physicist Paul Kwiat has presented the first demonstration of "counterfactual computation," inferring information about an answer, even though the computer did not run. The researchers report their work in the Feb. 23 issue of *Nature*.

Quantum computers have the potential for solving certain types of problems much faster than classical computers. Speed and efficiency are gained because quantum bits can be placed in superpositions of one and zero, as opposed to classical bits, which are either one or zero. Moreover, the logic behind the coherent nature of quantum information processing often deviates from intuitive reasoning, leading to some surprising effects.

"It seems absolutely bizarre that counterfactual computation – using information that is counter to what must have actually happened – could find an answer without running the entire quantum computer," said Kwiat, a John Bardeen Professor of Electrical and Computer Engineering and Physics at Illinois. "But the nature of quantum interrogation makes this amazing feat possible."

Sometimes called interaction-free measurement, quantum interrogation is a technique that makes use of wave-particle duality (in this case, of photons) to search a region of space without actually entering that region of space.

Utilizing two coupled optical interferometers, nested within a third, Kwiat's team succeeded in counterfactually searching a four-element database using Grover's quantum search algorithm. "By placing our photon in a quantum superposition of running and not running the search algorithm, we obtained information about the answer even when the photon did not run the search algorithm," said graduate student Onur Hosten, lead author of the Nature paper. "We also showed theoretically how to obtain the answer without ever running the algorithm, by using a 'chained Zeno' effect."

Through clever use of beam splitters and both constructive and destructive interference, the researchers can put each photon in a superposition of taking two paths. Although a photon can occupy multiple places simultaneously, it can only make an actual appearance at one location. Its presence defines its path, and that can, in a very strange way, negate the need for the search algorithm to run.

"In a sense, it is the possibility that the algorithm could run which prevents the algorithm from running," Kwiat said. "That is at the heart of quantum interrogation schemes, and to my mind, quantum mechanics doesn't get any more mysterious than this."

While the researchers' optical quantum computer cannot be scaled up, using these kinds of interrogation techniques may make it possible to reduce errors in quantum computing, Kwiat said. "Anything you can do to reduce the errors will make it more likely that eventually you'll get a large-scale quantum computer."

Source: University of Illinois at Urbana-Champaign

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