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Quantum computing: The light at the end of the tunnel may be a single photon

May 18 2012

Quantum physics promises faster and more powerful computers, but quantum versions of basic logic functions are still needed to bring this technology to fruition. Researchers from the University of Cambridge and Toshiba Research Europe Ltd. have taken one step toward this goal by creating an all-semiconductor quantum logic gate, a controlled-NOT (CNOT) gate. They achieved this breakthrough by coaxing nanodots to emit single photons of light on demand.

"The ability to produce a photon in a very precise state is of central importance," said Matthew Pooley of Cambridge University and co-author of a study accepted for publication in the American Institute of Physics' (AIP) journal Applied Physics Letters. "We used standard semiconductor technology to create single quantum dots that could emit individual photons with very precise characteristics." These photons could then be paired up to zip through a waveguide, essentially a tiny track on a semiconductor, and perform a basic quantum calculation.

Classical computers perform calculations by manipulating binary bits, the familiar zeros and ones of the digital age. A quantum computer instead uses quantum bits, or qubits. Because of their weird quantum properties, a qubit can represent a zero, one, or both simultaneously, producing a much more powerful computing technology. To function, a quantum computer needs two basic elements: a single qubit gate and a controlled-NOT gate. A gate is simply a component that manipulates the state of a qubit. Any quantum operation can be performed with a combination of these two gates.

To produce the all-important initial photon, the researchers embedded a quantum dot in a microcavity on a pillar of silicon. A laser pulse then excited one of the electrons in the quantum dot, which emitted a single photon when the electron returned to its resting state. The pillar microcavity helped to speed up this process, reducing the time it took to emit a photon. It also made the emitted photons nearly indistinguishable, which is essential because it takes two photons, or qubits, to perform the CNOT function: one qubit is the "control qubit" and the other is the "target qubit." The NOT operation is performed on the target qubit, but the result is conditional on the state of the control qubit. The ability for qubits to interact with each other in this way is crucial to building a quantum computer.

The next step is to integrate the components into a single device, drastically reducing the size of the technology. "Also, we use just one photon source to generate both the photons used for the two-photon input state. An obvious next step would be to use two synchronized photon sources to create the input state," said Pooley.

More information: "Controlled-NOT gate operating with single photons" is accepted for publication in *Applied Physics Letters*.

Provided by American Institute of Physics

Citation: Quantum computing: The light at the end of the tunnel may be a single photon (2012, May 18) retrieved 5 May 2024 from https://phys.org/news/2012-05-quantum-tunnel-photon.html

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