Photonic router is a step toward quantum computing

Weizmann Institute scientists take another step down the long road toward quantum computers as they demonstrate a photonic router: a quantum device based on a single atom that enables routing of single photons by single photons. At the core of the device is an atom that can switch between two states, as reported in the July 10 online edition of *Science* (DOI: 10.1126/science.1254699). The state is set just by sending a single particle of light—or photon—from the right or the left through an optical fiber. The atom, in response, then reflects or transmits the next incoming photon accordingly. For example, in one state, a photon coming from the right continues on its path to the left, whereas a photon coming from the left is reflected backwards, causing the atomic state to flip. In this reversed state, the atom lets photons coming from the left continue in the same direction, while any photon coming from the right is reflected backwards, flipping the atomic state back again. This atom-based switch is solely operated by single photons—no additional external fields are required.

"In a sense, the device acts as the photonic equivalent to electronic transistors, which switch electric currents in response to other electric currents," said Barak Dayan, head of the Weizmann Institute's Quantum Optics Group, including Itay Shomroni, Serge Rosenblum, Yulia Lovsky, Orel Bechler, and Gabriel Guendleman of the Chemical Physics Department in the Faculty of Chemistry. The photons are not only the units comprising the flow of information, but also the ones that control the device.

This achievement was made possible by the combination of two state-of-the-art technologies. One is the laser cooling and trapping of atoms. The other is the fabrication of chip-based, ultrahigh quality miniature optical resonators that couple directly to the optical fibers.

The main motivation behind the effort to develop quantum computers is the quantum phenomenon of superposition, in which particles can exist in many states at once, potentially being able to process huge amounts of data in parallel. Yet superposition can only last as long as nothing observes or measures the system, otherwise it collapses to a single state. Therefore, photons are the most promising candidates for communication between quantum systems as they do not interact with each other at all, and interact very weakly with other particles.

Dayan said, "The road to building quantum computers is still very long, but the device we constructed demonstrates a simple and robust system, which should be applicable to any future architecture of such computers. In the current demonstration a single atom functions as a transistor—or a two-way switch—for photons, but in our future experiments, we hope to expand the kinds of devices that work solely on photons, for example new kinds of quantum memory or logic gates." □

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