Controlling Photons for Use in Quantum Computing

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"Quantum information science makes use of the quantum nature of particles to perform computation," Gerhard Rempe explains to *PhysOrg.com*. "One approach is to use single particles of light – photons – as the basis of the computer, storing information in a property of the light such as its polarization. To do this, you need a source able to produce photons under full control."

Rempe, a Director at Germany's Max Planck Institute for Quantum Optics, and a team of fellow scientists believe they have solved the problem of producing and controlling photons by using an optical cavity.

Rempe and his colleagues, Doctors Wilk, Webster and Specht at the Max Planck Institute, and Doctor Kuhn at the University of Oxford, have completed an experiment in which they were able to control the direction of a photon emitted from an atom, and its polarization. "This represents a great single-photon source that we can control," Rempe says. The team details the results of the ground breaking experiment in a paper that appears in *Physical Review Letters* with the title, "Polarization-Controlled Single Photons."

In the experiment, laser pulses were used to make a single atom emit photons in a stream. "Typically, if you excite an atom and it emits a photon, you can't control the direction it is emitted in," Rempe explains. He describes, in an email, an optical cavity, consisting of a pair of mirrors facing each other. These mirrors are separated by a distance of only 1 mm, and used to set the direction of the emitted photons. “The cavity influences the atom so that photons it produces are likely to be emitted in a direction perpendicular to the surface of the mirrors,” Rempe says. “Once emitted, a photon bounces between the mirrors thousands of times before passing through one of them to escape into the laboratory in a known direction.”

Rempe admits that the generation of single photons inside an optical cavity has been demonstrated before. But this new experiment adds another layer to the work done before. Rempe’s group takes the control demonstrated in prior optical cavity experiments one step further by being able to determine the polarization of the photons produced. A magnetic field is applied to the atom, allowing different polarizations to be produced, depending on the frequency of the laser pulses used. So, not only can the direction of the photons be controlled, but it is now also possible to completely control all the photon’s degrees of freedom.

This, Rempe says, is only a first step towards using quantum processes for computing and communicating. He hopes that his team’s work can lead to additional advances in quantum information processing. “We should be able to extend our scheme to produce photons that are entangled with the internal state of the atom,” says Rempe. “This would be a first step towards creating a quantum network which would allow quantum information to be transferred between different laboratories.” He emphasizes that this new process “opens more possibilities in quantum information processing.”