

# **Bright and pure source of high-fidelity entangled photons for quantum computation and teleportation**

July 15 2004

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Like virtuosos tuning their violins, researchers at the University of Illinois at Urbana-Champaign have tuned their instruments and harmonized the production of entangled photons, pushing rates to more than 1 million pairs per second. The brighter and purer entangled states could assist researchers in applications involving quantum information processing – such as quantum computation, teleportation and cryptography – and help scientists better understand the mysterious transition from quantum mechanics to classical physics.

“Entangled states are the quintessential feature of quantum mechanics,” said Paul Kwiat, a John Bardeen Professor of Electrical and Computer Engineering and Physics at Illinois. “All the manifestations of quantum mechanics in the world around us arise from the basic but bizarre coupling that exists between entangled particles.”

For example, the properties of entangled photons are inextricably linked to each other, even if the photons are located on opposite sides of the galaxy. To study this “correlation at a distance,” Kwiat and graduate students Joseph Altepeter and Evan Jeffrey produce pairs of polarization-entangled photons by passing a laser pulse through two adjacent nonlinear crystals.

“You can think of polarization as the ‘wiggle’ direction of the photon – either horizontal, vertical or diagonal,” Kwiat said. “As soon as you

determine the wiggle direction of one photon in an entangled pair, you immediately know the wiggle direction of the other photon, no matter how far apart they are.”

A major production problem, however, is that entangled photons are emitted in many directions and with a wide range of polarization phase relationships, each acting like an individual singer in a large choir.

“Instead of hearing a soloist hit one note, we were hearing many choir members, some of whom were singing off-key,” Kwiat said.

The trick was to come up with a way of tuning the system. “We found that we could pass the photons through another crystal – one that has a different phase profile – to compensate for the different phase relationships,” Kwiat said. “The dissonance is corrected and the system becomes harmonized.”

In the same manner as a corrector lens in a telescope removes chromatic aberration and improves image quality, the researchers’ special birefringent crystal removes distortions in the quality of the entanglement. “After the compensator crystal, the photons are all entangled in exactly the same way,” Altepeter said. “We can open the iris and get more than 1 million useful pairs per second.”

Ultrabright, ultrapure sources of entangled photons are essential for pursuing quantum computing and quantum networks, as a resource for teleportation in quantum communication, and for sending more information faster by means of quantum cryptography. High fidelity quantum states can also provide researchers with a clearer picture of how the universe works on a very fundamental level.

“Using a low-brightness source is like looking into the quantum world through a foggy window,” Altepeter said. “With a bright, pure source,

we have a very clear window that allows us to see phenomena we couldn't see before.”

The ultimate goal is to understand and develop an intuition for the quantum nature of reality, said Kwiat, who will report the team's findings at the International Conference on Quantum Communication, Measurement and Computing, to be held July 25–29 in Glasgow, United Kingdom. “Higher production rates of nearly perfectly entangled photons will help us better understand the rules of the quantum universe, how to navigate that universe, and how to characterize it in a very precise way.”

Citation: Bright and pure source of high-fidelity entangled photons for quantum computation and teleportation (2004, July 15) retrieved 10 April 2024 from <https://phys.org/news/2004-07-bright-pure-source-high-fidelity-entangled.html>

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