'Superdense' coding gets denser

The record for the most amount of information sent by a single photon has been broken by researchers at the University of Illinois. Using the direction of "wiggling" and "twisting" of a pair of hyper-entangled photons, they have beaten a fundamental limit on the channel capacity for dense coding with linear optics.

"Dense coding is arguably the protocol that launched the field of quantum communication," said Paul Kwiat, a John Bardeen Professor of Physics and Electrical and Computer Engineering. "Today, however, more than a decade after its initial experimental realization, channel capacity has remained fundamentally limited as conceived for photons using conventional linear elements."

In classical coding, a single photon will convey only one of two messages, or one bit of information. In dense coding, a single photon can convey one of four messages, or two bits of information.

"Dense coding is possible because the properties of photons can be linked to one another through a peculiar process called quantum entanglement," Kwiat said. "This bizarre coupling can link two photons, even if they are located on opposite sides of the galaxy."

Using linear elements, however, the standard protocol is fundamentally limited to convey only one of three messages, or 1.58 bits. The new experiment surpasses that threshold by employing pairs of photons entangled in more ways than one (hyper-entangled). As a result, additional information can be sent and correctly decoded to achieve the full power of dense coding.

Kwiat, graduate student Julio Barreiro and postdoctoral researcher Tzu-Chieh Wei (now at the University of Waterloo) describe their recent experiment in a paper accepted for publication in the journal *Nature Physics*, and posted on its Web site.

Through the process of spontaneous parametric down conversion in a pair of nonlinear crystals, the researchers first produce pairs of photons simultaneously entangled in polarization, or "wiggling" direction, and in orbital angular momentum, or "twisting" direction. They then encode a message in the polarization state by applying birefringent phase shifts with a pair of liquid crystals.

"While hyper-entanglement in spin and orbital angular momentum enables the transmission of two bits with a single photon," Barreiro said, "atmospheric turbulence can cause some of the quantum states to easily decohere, thus limiting their likely communication application to satellite-to-satellite transmissions."

ource: University of Illinois at Urbana-Champaign