Using quantum entanglement to stack light particles: Physicists play Lego with photons

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While many of us enjoyed constructing little houses out of toy bricks when we were kids, this task is much more difficult if bricks are elementary particles. It is even harder if these are particles of light - photons, which can only exist while flying at an incredible speed and vanish if they touch anything.

A team at the University of Calgary has accomplished exactly that: by manipulating a mysterious quantum property of light known as entanglement, they are able to mount up to two photons on top of one another to construct a variety of quantum states of light - that is, build two-story quantum toy houses of any style and architecture.

The results of their research, written in the paper 'Quantum-optical state engineering up to the two-photon level', will be published on *Nature Photonics's* website on Feb. 14.

"This ability to prepare or control complex quantum objects is considered the holy grail of quantum science" says Andrew MacRae, a co-author of the paper and PhD physics student at the U of C. "It brings us closer to the onset of the new era of quantum information technology."

This new generation of technology is expected to endow us with qualitatively new capabilities. This includes measurement instruments of extraordinary sensitivity, dramatically faster computers, secure communication systems and enhanced control over chemical reactions.

"Light is a particularly interesting quantum object," says paper author Alexander Lvovsky, a professor in the Department of Physics and Astronomy, "because it's an excellent communication tool. No matter what future quantum computers will be made of, they'll talk to each other using photons."

U of C researchers used mirrors and lenses to focus a blue laser beam into a specialized crystal. This crystal takes high energy blue photons and converts them into a quantum superposition of lower energy red photons, which emerge in two directions, or 'channels'. By measuring one of the channels using ultra-sensitive single photon detectors, the physicists prepare the desired quantum state in the other.

Such an operation is possible because the photons in the two channels are entangled: a measurement made in one channel would result in an immediate change in the other, regardless of whether the particles were an arm's length apart or light years away. Albert Einstein called this quantum weirdness "spooky action at a distance."

"Quantum light is like an ocean," says Lvovsky, "and it's full of mysteries and treasures. Our task is to conquer it. But so far, physicists were able to control only a tiny island in this ocean. What we have done is to make this island bigger."

Provided by University of Calgary

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