Physicists Explain How Human Eyes Can Detect Quantum Effects

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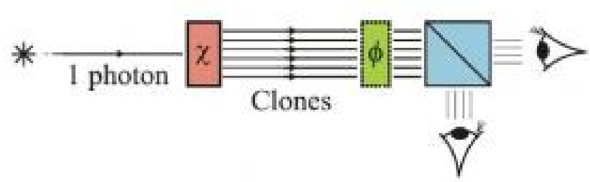

How human eyes could detect quantum entanglement: A single-photon qubit is amplified through cloning via stimulated emission in a nonlinear crystal (red box). The clones are split into two orthogonal polarization modes, with the polarization basis varied with the help of a wave plate (green box). Each mode is then detected by a naked human eye. Image credit: Pavel Sekatski, et al.

(PhysOrg.com) -- By greatly amplifying one photon from an entangled photon pair, physicists have theoretically shown that human eyes can be used as detectors to observe quantum effects. Usually, detecting quantum phenomena requires sensitive photon detectors or similar technology, keeping the quantum world far removed from our everyday experience. By showing that it's possible to perform quantum optics experiments with human eyes as detectors, the physicists can bring quantum phenomena closer to the macroscopic level and to everyday life.

The group of physicists is from the University of Geneva, and includes Pavel Sekatski, Nicolas Brunner (also from the University of Bristol), Cyril Branciard, Nicolas Gisin, and Christoph Simon. In their study published in a recent issue of Physical Review Letters, the scientists theoretically show how human eyes can be used to detect a large Bell inequality violation, which proves the existence of quantum entanglement.

As the physicists explain, the key to achieving human-eye detection of quantum effects is to use the process of quantum cloning by stimulated emission. Recently, using quantum cloning, researchers in Rome have experimentally created tens of thousands of clones starting from a single-photon. Then, by amplifying one photon of an entangled pair, the researchers managed to demonstrate entanglement. In order to do this, specific detectors are required, which can distinguish two orthogonal amplified states with a high success rate.

Now, what Sekatski and co-workers have shown is that the human eye performs extremely well at the task of distinguishing between orthogonal amplified states. This is a consequence of the eye's main characteristic, namely as a detection threshold. Below a certain threshold number of incoming photons, the eye remains blind (no light is seen), whereas above the threshold the efficiency (i.e. the probability of seeing) is close to one.

In their calculations, the authors also considered the influence of experimental imperfections, such as photon losses, which are inevitable in a real experiment. They found that the setup is surprisingly robust. A strong Bell violation can be obtained even in case of high losses, demonstrating the presence of entanglement. This is a very astonishing feature since entanglement is generally an extremely fragile property, highly sensitive to experimental imperfections such as losses.

To solve this apparent paradox, the scientists uncovered a loophole in the system. They showed that a specific multi-photon state could actually behave exactly as the entangled state. Therefore, the high Bell violation actually witnesses the entanglement of the original photon pair, i.e. before the amplification occurs, but not the entanglement between the amplified state and the single photon. Still, the authors show that the amplified state and the single photon are nevertheless entangled, but revealing this entanglement would require more sophisticated measurements. This subtle issue provides a much better understanding of the quantum nature of amplified states, which were recently the subject of a controversy among the scientific community.

As the researchers finally note, using human eyes as detectors in actual quantum experiments will face significant technical challenges. However, the possibility of observing quantum effects directly with our own eyes is fascinating. Naked eye observation would bring the observer one step closer to the quantum world.

"From our theoretical study, the experimental perspectives appear very promising," Brunner told *PhysOrg.com*. He added that, although there will be many technical challenges, Nicolas Gisin's research group in Geneva has already started working on experiments.

More information: Pavel Sekatski, Nicolas Brunner, Cyril Branciard, Nicolas Gisin, and Christoph Simon. "Towards Quantum Experiments with Human Eyes as Detectors Based on Cloning via Stimulated Emission." Physical Review Letters 103, 113601 (2009).