Loopy photons clarify 'spookiness' of quantum physics

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Researchers at the National Institute of Standards and Technology and the Joint Quantum Institute (NIST/University of Maryland) have developed a new method for creating pairs of entangled photons, particles of light whose properties are interlinked in a very unusual way dictated by the rules of quantum physics. The researchers used the photons to test fundamental concepts in quantum theory.

In the experiment, the researchers send a pulse of light into both ends of a twisted loop of optical fiber. Pairs of photons of the same color traveling in either direction will, every so often, interact in a process known as "four-wave mixing," converting into two new, entangled photons, one that is redder and the other that is bluer than the originals.

Although the fiber's twist means that pairs emerging from one end are vertically polarized (having electric fields that vibrate up and down) while pairs from the other end are horizontally polarized (vibrating side to side), the setup makes it impossible to determine which path the newly created photon pairs took. Since the paths are indistinguishable, the weird rules of quantum physics say that the photon pairs actually will be in both states—horizontal and vertical polarization—at the same time. Until someone measures one, at which time both photons must chose one specific, and identical, state.

This "spooky action at a distance" is what caused Einstein to consider quantum mechanics to be incomplete, prompting debate for the past 73 years over the concepts of "locality" and "realism." Decades of experiments have demonstrated that measurements on pairs of entangled particles don't agree with the predictions made by "local realism," the concept that processes occurring at one place have no immediate effect on processes at another place (locality) and that the particles have definite, preexisting properties (called "hidden variables") even without being measured (realism).

Experiments so far have ruled out locality and realism as a combination. But could a theory assuming only one of them be correct? Nonlocal hidden variables (NLHV) theories would allow for the possibility of hidden variables but would concede nonlocality, the idea that a measurement on a particle at one location may have an immediate effect on a particle at a separate location.

Measuring the polarizations of the pairs of entangled particles in their setup, the researchers showed that the results did not agree with the predictions of certain NLHV theories but did agree with the predictions of quantum mechanics. In this way, they were able to rule out certain NLHV theories. Their results agree with other groups that have performed similar experiments.

Citations:

1. J. Fan, M.D. Eisaman and A. Migdall, Bright phase-stable broadband fiber-based source of polarization-entangled photon pairs. *Physical Review A* 76, 043836 (2007). Abstract at link.aps.org/abstract/PRA/v76/e043836 .

2. M.D. Eisaman, E.A. Goldschmidt, J. Chen, J. Fan and A. Migdall. Experimental test of non-local realism using a fiber-based source of polarization-entangled photon pairs. *Physical Review A*., upcoming.

Source: National Institute of Standards and Technology