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Physicists Propose Scheme for Teleporting Light Beams

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Physicists have proposed a scheme for quantum teleportation of a beam of light, which could have applications such as in quantum computation. Image credit: Wikimedia Commons.

(PhysOrg.com) -- Usually when physicists talk about quantum teleportation, they're referring to the transfer of quantum states from one particle to another without a physical link. Now, physicists have investigated a slightly different form of teleportation, in which they teleport a quantum field, or an entire beam of light, from one location to another. This kind of "strong" teleportation is required for some quantum information applications, and could lead to the teleportation of quantum images.

In their study, Changsuk Noh, M.J. Collett, and H.J. Carmichael from the University of Auckland in New Zealand, along with A. Chia from

Griffith University in Queensland, Australia, and Hyunchul Nha from Texas A & M University at Qatar in Dohar, Qatar, have proposed a scheme for teleporting a beam of light, including its fluctuations over time. They hope to show that it's possible that a physical object (e.g. a quantum field) in one location could emerge at another location in the same quantum state, so that any conceivable measurement would yield the same result in both locations. In contrast, previous teleportation schemes do not seriously consider reproducing certain elements, such as temporal fluctuations.

In their proposal, the scientists investigate using a stream of photons that are evenly spaced, or "antibunched." Detecting the individual photons in a stream that is spaced similar to the photon stream at the input would verify teleportation of the full quantum field. The scientists wanted to find the conditions under which this detection could occur. They discover that squeezing light - a technique used to enhance precision measurements - could allow for teleportation of a quantum photon stream if the squeezing is across a broad bandwidth.

"I would say that the greatest significance of our study is at the level of clarifying fundamental principles," Carmichael told *PhysOrg.com*. "The original proposal for quantum teleportation is conceptually simple since the quantum state considered is carried by a material object - a particle. Alice and Bob are both provided with similar particles; the state of Alice's particle is destroyed and acquired by Bob's. When this idea is transferred to the teleportation of light, one faces a fundamental change, because the state of no light (the vacuum) is also a quantum state, and there is an infinity of 'objects' (modes or frequencies of light) in this 'no light' state. Every one of these has to be reproduced in the same 'no light' state in the teleportation. Our paper clarifies the distinction and shows how to achieve the necessary reproduction."

The scientists note that the squeezing levels are demanding, but further investigations into designing experiments could reveal more optimal methods. One of the biggest challenges for realizing the proposal, as Carmichael explained, is the requirement for high quality, flexible sources of squeeze light.

“The technology to realize the scheme is, at the level of fundamentals, already in place; but there are serious challenges in making the technology good enough to carry out an experiment,” he said. “The main step required is to improve the source of squeezed light. Improvements in two directions are needed: first, to achieve higher levels of squeezing, and, second, to squeeze at a high level over a broad bandwidth in the range of frequencies of the input light.”

If physicists can overcome these challenges, the ability to transport light beams could lead to many interesting applications. For instance, the researchers suggest that a multi-channel version - in which two or more beams are teleported in parallel - could be used to teleport quantum images.

“Comunications systems of the current classical sort send information in a patterned sequence of light pulses - a sequence patterned in time, something like the teeth of a comb with the teeth missing in various places,” Carmichael explained. “Our method of teleportation is able to send such a patterned sequence of pulses...in principle, even when each pulse is in an exotic quantum state or when the state of the whole string of pulses is entangled (a quantum comb whose tooth takes on interrelated ‘quantum colors’). Previous ideas about how to do this require a matched pattern of squeezed light pulses and a matched pattern of measurement pulses, both required to execute the teleportation protocol. Thus, our proposal finds application wherever the transmission of such patterned pulse sequences is needed, e.g., in certain schemes for quantum computation on a register of qubits.”

Most importantly, teleporting light beams likely offers yet undiscovered potential. “The greatest significance of our study will therefore hopefully be realized in the minds of readers who come to understand clearly what it means to teleport a quantum field (beam of light), and what the technical challenges are if the full power of this mode of teleportation is to be exploited,” Carmichael said.

More information: Changsuk Noh, A. Chia, Hyunchul Nha, M.J. Collett, and H.J. Carmichael. “Quantum Teleportation of the Temporal Fluctuations of Light.” *Physical Review Letters* 102, 230501 (2009).