Deterministic entanglement of photons through postselection based feedback

Antonio Di Lorenzo[1,*]

[1]*Instituto de Física, Universidade Federal de Uberlândia,*
Av. João Naves de Ávila 2121, Uberlândia, Minas Gerais, 38400-902, Brazil

We propose a method to entangle deterministically two distant photons by having them interact with an ancillary photon in a Mach-Zehnder interferometer through a hypothetical device that rotates the polarization of a photon or not, depending on the presence of a trigger photon. Then, an appropriate post-selecting measurement is made on the ancillary photon, and finally a local transformation is applied to one of the photon to be entangled, based on the result of the post-selecting measurement. The procedure thus resembles the teleportation protocol. As a result of the proposed procedure, the two photons always end up in a maximally entangled state, for instance $|H,V\rangle - |V,H\rangle$. The setup is inspired by the recent Quantum Cheshire cat phenomenon. However, it does not rely on the weak measurement approximation. The result supports the idea that a single photon is entangled with the vacuum, as the protocol is equivalent to the entanglement swapping, but the initial entangled system is formed by the ancillary photon and the vacuum of the electromagnetic field in the two arms of the Mach-Zehnder interferometer. The result also shows that a photon in an interferometer is, in some sense, simultaneously present in both arms, as it interacts simultaneously with the two other photons that get entangled.

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* dilorenzo@infis.ufu.br

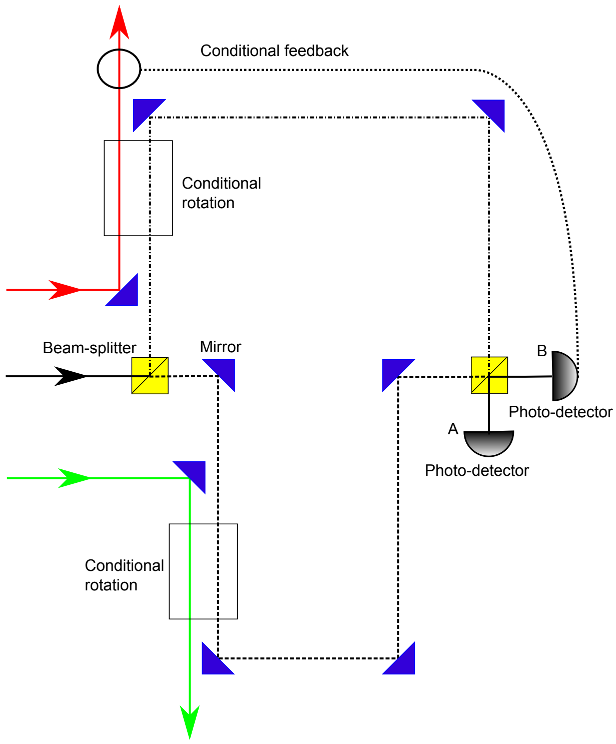

FIG. 1. Three photons are produced. The green and the red photons are initially linearly polarized in the horizontal direction. The middle photon, which works as an ancilla, enters a Mach-Zehnder interferometer. In each arm of the latter there is a hypothetical wave plate that works as follows: if the ancillary photon is present, both photons are rotated to a vertical polarization; otherwise, nothing happens. This procedure ensures that the photon j ($j = 1$ or 2) exits in the state $|V_j\rangle$ if the ancillary photon is also present, or in the state $|H_j\rangle$ otherwise. Finally, if the photo-detector A clicks, the green and red photon are in the state $|H,V\rangle - |V,H\rangle$. If B clicks, they are in $|H,V\rangle + |V,H\rangle$. By making a conditional feedback operation on one photon, the latter state becomes $|H,V\rangle - |V,H\rangle$.