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Probabilistic cloning and orthogonal complementing of an unknown EPR state

Chao Han, Wei Song, Ming Yang, Zhuo-Liang Cao*

School of Physics and Material Science, Anhui University, Hefei 230039, PR China

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Abstract

In this paper a novel scheme is proposed where with the help of Victor (a state preparer) an unknown EPR pair is copied in a certain probability so that three parties of communication can obtain the EPR state, respectively. The first stage of this scheme is to teleport an unknown EPR state to Carla (one receiver). The second stage of this scheme, Alice (a sender) and Bob (the other receiver) get the same EPR pair or an orthogonal-complement copy of the EPR pair with the help of Victor.

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Keywords: Quantum cloning; Quantum teleportation; Quantum entanglement; Unitary transformation

Quantum teleportation, the process that transmits an unknown qubit from a sender to a receiver via a quantum channel with the help of some classical information, was originally concerned by Bennett et al. [1]. In recent years, much attention has been paid to quantum teleportation [2–5] because of its quantum nonlocality feature together with its important roles in quantum computation and quantum communication. The process of quantum cloning may be regarded as copying quantum information via a cloning machine. Unlike classical information, linearity of quantum theory does not allow us to do so [6]. Though exact cloning is

*Corresponding author.
E-mail address: zlcao@ahu.edu.cn (Z.-L. Cao).

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not possible, in the literature various cloning machines have been proposed, such as deterministic and probabilistic cloning machine [7–13]. Pati proposed a protocol which can produce perfect copies and orthogonal-complement copies of an unknown single qubit state with the help of Victor (a state preparer) in certain probability. In this paper, we discuss the scheme which can create clones and complement clones of an unknown EPR state as an extension to Pati's scheme. In our protocol, Alice has an unknown EPR state which has been sent from Victor (a state preparer). She also shares two quantum channels with Bob and Carla. The purpose of this paper is to investigate the possibility of copying and complementing an unknown EPR state perfectly with auxiliary resources, such as two-particle measurement, single-particle Von Neumann measurement, unitary transformation and classical communication. Can we produce a perfect copy and complement copy of an unknown EPR state in three distant sites? We show our protocol can produce a perfect copy in Carla's site and either a perfect copy or a complement copy in Alice's and Bob's sites, respectively, with the help of Victor. And Victor only sends one bit of classical information to Bob to get a copy or a complement copy of the unknown EPR state.

In the following we will give the scheme.

Suppose Alice has an EPR state which was transmitted from Victor (a state preparer), represented as

$$|\psi\rangle_{12} = a|00\rangle_{12} + b|11\rangle_{12}\,. \tag{1}$$

Let Alice and Bob share a four-particle GHZ source which is used as one quantum channel in a quantum teleportation protocol, represented as

$$|\psi\rangle_{3459} = \alpha|0000\rangle_{3459} + \beta|1111\rangle_{3459}\,. \tag{2}$$

Alice is in possession of particle 3. Bob is in possession of particles 4, 5 and 9. Let Alice and Carla share a three-particle GHZ source which is used as the other quantum channel in the quantum teleportation protocol, given by

$$|\psi\rangle_{678} = \alpha'|000\rangle_{678} + \beta'|111\rangle_{678}\,. \tag{3}$$

Here, Alice has particle 6 and Bob has particles 7 and 8. The input state $|\psi\rangle_{12}$ is unknown to all of Alice, Bob and Carla. The total state of $|\psi\rangle_{12}$, $|\psi\rangle_{3459}$ and $|\psi\rangle_{678}$ can be written as

$$\begin{aligned}|\psi\rangle_{123459678} = {} & (a|00\rangle_{12} + b|11\rangle_{12})(\alpha|0000\rangle_{3459} + \beta|1111\rangle_{3459})(\alpha'|000\rangle_{678} \\ & + \beta'|111\rangle_{678})\,,\end{aligned} \tag{4}$$

without loss of generality, we assume the coefficients a, α, β, α', β' is real and b is a complex number, with $|a|^2 + |b|^2 = 1$, $|\alpha|^2 + |\beta|^2 = 1$, $|\alpha'|^2 + |\beta'|^2 = 1$ and $|\beta| < |\alpha|, |\beta'| < |\alpha'|$.

At the first step, Alice performs a C-NOT operation with particle 2 as the control bit and particle 1 as the target bit, the total state will be transformed into the