Deterministic secure direct communication by using swapping quantum entanglement and local unitary operations

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(Dated: October 26, 2018)

A deterministic direct quantum communication protocol by using swapping quantum entanglement and local unitary operations is proposed in this paper. A set of ordered EPR pairs in one of the four Bell states is used. For each pair, each of the two legitimate users owns a photon of the entangled pair via quantum channel. The pairs are divided into two types of group, i.e., the checking groups and the encoding-decoding groups. In the checking groups, taking advantage of the swapping quantum entanglement and Alice’s (the message sender’s) public announcement, the eavesdropping can be detected provided that the number of the checking groups is big enough. After insuring the security of the quantum channel, Alice encodes her bits via the local unitary operations on the encoding-decoding groups. Then she performs her Bell measurements on her photons and publicly announces her measurement results. After her announcement, the message receiver Bob performs his Bell measurements on his photons and directly extracts the encoding bits by using the property of the quantum entanglement swapping. The security of the present scheme is also discussed: under the attack scenarios to our best knowledge, the scheme is secure.

PACS Number(s): 03.67.Hk, 03.65.Ud

Quantum key distribution (QKD) is an ingenious application of quantum mechanics, in which two remote legitimate users (Alice and Bob) establish a shared secret key through the transmission of quantum signals. Much attention has been focused on QKD after the pioneering work of Bennett and Brassard published in 1984 [1]. Till now there have been many theoretical QKDs[2-20]. They can be classified into two types, the nondeterministic one [2-14] and the deterministic one [15-20]. The nondeterministic QKD can be used to establish a shared secret key between Alice and Bob, consisting of a sequence of random bits. This secret key can be used to encrypt a message which is sent through a classical channel. In contrast, in the deterministic QKD, the legitimate users can get results deterministically provided that the quantum channel is not disturbed. It is more attractive to establish a deterministic secure direct communication protocol by taking advantage of the deterministic QKDs. However, different from the deterministic QKDs, the deterministic secure direct communication protocol is more demanding on the security. Hence, only recently a number of deterministic secure direct protocols have been proposed [15-16,19]. In these protocols, the quantum entanglement plays very important roles. It is well known that quantum entanglement swapping [21-24] can entangle two quantum system which do not interact with each other and it has ever played very important roles in some nondeterministic QKDs[7,15]. In this paper, we present
a deterministic secure direct communication protocol by using swapping quantum entanglement and local unitary operations. This communication protocol can be used to transmit securely either a secret key or a plain text message.

Let us first describe the quantum entanglement swapping simply. Let \(|0\rangle\) and \(|1\rangle\) be the horizontal and vertical polarization states of a photon, respectively. Then the four Bell states, \(|\Psi^\pm\rangle = (|01\rangle \pm |10\rangle)/\sqrt{2}\) and \(|\Phi^\pm\rangle = (|00\rangle \pm |11\rangle)/\sqrt{2}\), are maximally entangled states in the two-photon Hilbert space. Let the initial state of two photon pairs be the product of any two of the four Bell states, such as \(|\Psi_{12}^+\rangle\) and \(|\Psi_{34}^+\rangle\), then after the Bell measurements on the photon 1 and 3 pair and the photon 2 and 4 pair, since the following equation holds,

\[
|\Psi_{12}^+\rangle \otimes |\Psi_{34}^+\rangle = \frac{1}{2}(|\Psi_{13}^+\rangle|\Psi_{24}^+\rangle - |\Psi_{13}^+\rangle|\Psi_{24}^-\rangle + |\Phi_{13}^-\rangle|\Phi_{24}^+\rangle - |\Phi_{13}^-\rangle|\Phi_{24}^-\rangle),
\]

the total initial state (i.e., \(|\Psi_{12}^+\rangle \otimes |\Psi_{34}^+\rangle\)) is projected onto \(|\eta_1\rangle = |\Phi_{13}^+\rangle \otimes |\Phi_{24}^+\rangle\), \(|\eta_2\rangle = |\Phi_{13}^-\rangle \otimes |\Phi_{24}^-\rangle\), \(|\eta_3\rangle = |\Psi_{13}^+\rangle \otimes |\Phi_{24}^+\rangle\) and \(|\eta_4\rangle = |\Psi_{13}^-\rangle \otimes |\Phi_{24}^-\rangle\) with equal probability of \(\frac{1}{4}\) for each. It is seen that previous entanglements between photons 1 and 2, and 3 and 4, are now swapped into the entanglements between photons 1 and 3, and 2 and 4. Therefore, if \(|\Phi_{13}^+\rangle\) is obtained by the Bell measurements, \(|\Phi_{24}^+\rangle\) should be gained affirmatively by the Bell measurements; if \(|\Phi_{13}^-\rangle\) is obtained, then \(|\Phi_{24}^-\rangle\) is arrived at; and so on. This means that for a known initial state the Bell measurement results after the quantum entanglement swapping are correlated. In the above example \(|\Psi_{12}^+\rangle \otimes |\Psi_{34}^+\rangle\) is chosen as the initial state. In fact, similar results can also be arrived at provided that other choices of the initial states are given. As can be seen as follows:

\[
\begin{align*}
|\Psi_{12}^+\rangle \otimes |\Psi_{34}^-\rangle &= \frac{1}{2}(|\Psi_{13}^-\rangle|\Psi_{24}^+\rangle - |\Psi_{13}^-\rangle|\Psi_{24}^-\rangle - |\Phi_{13}^-\rangle|\Phi_{24}^+\rangle - |\Phi_{13}^-\rangle|\Phi_{24}^-\rangle), \\
|\Psi_{12}^+\rangle \otimes |\Phi_{34}^+\rangle &= \frac{1}{2}(|\Psi_{13}^+\rangle|\Phi_{24}^+\rangle - |\Psi_{13}^+\rangle|\Phi_{24}^-\rangle + |\Phi_{13}^-\rangle|\Phi_{24}^+\rangle - |\Phi_{13}^-\rangle|\Phi_{24}^-\rangle), \\
|\Psi_{12}^+\rangle \otimes |\Phi_{34}^-\rangle &= \frac{1}{2}(|\Psi_{13}^-\rangle|\Phi_{24}^+\rangle - |\Psi_{13}^-\rangle|\Phi_{24}^-\rangle - |\Phi_{13}^-\rangle|\Phi_{24}^+\rangle + |\Phi_{13}^-\rangle|\Phi_{24}^-\rangle), \\
|\Psi_{12}^+\rangle \otimes |\Phi_{34}^-\rangle &= \frac{1}{2}(|\Psi_{13}^-\rangle|\Phi_{24}^+\rangle - |\Psi_{13}^-\rangle|\Phi_{24}^-\rangle + |\Phi_{13}^-\rangle|\Phi_{24}^+\rangle - |\Phi_{13}^-\rangle|\Phi_{24}^-\rangle).
\end{align*}
\]

By the way, for the above four known initial states the correlation of the Bell measurement results after the quantum entanglement swapping is very useful in our protocol in detecting the eavesdropping. On the other hand, it should also be noted that different results by the Bell measurements correspond to different initial states for the above four known initial states. For examples, when \(|\Psi_{12}^+\rangle\) and \(|\Psi_{34}^-\rangle\) are obtained by the Bell measurements, the initial state should be \(|\Psi_{12}^+\rangle \otimes |\Psi_{34}^-\rangle\); when \(|\Phi_{13}^+\rangle\) and \(|\Psi_{24}^-\rangle\) are obtained by the Bell measurements, the initial state should be \(|\Psi_{12}^+\rangle \otimes |\Phi_{34}^-\rangle\); and so on. Incidentally, this property is also used in our communication protocol. In addition, it is easily verified that, the four Bell states can be transformed into each other by some unitary operations, which can be performed locally with nonlocal effects. For examples: Let \(u_0,u_1,u_2,u_3\) be in turn the unitary operations \(\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}, \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}\) respectively, then \(|\Psi_{34}^\pm\rangle\) will be in turn transformed into \(|\Psi_{34}^\pm\rangle, |\Psi_{34}^-\rangle, |\Phi_{34}^\pm\rangle, |\Phi_{34}^-\rangle\) after the unitary operations \(u_0, u_1, u_2, u_3\) on anyone photon of the pair, respectively, that is, \(u_0|\Psi_{34}^\pm\rangle = |\Psi_{34}^\pm\rangle\), \(u_1|\Psi_{34}^\pm\rangle = |\Psi_{34}^-\rangle, u_2|\Psi_{34}^\pm\rangle = |\Phi_{34}^\pm\rangle\) and \(u_3|\Psi_{34}^\pm\rangle = |\Phi_{34}^-\rangle\). Assume that each of the above four unitary operations corresponds to a two-bit encoding respectively, i.e., \(u_0\) to ’00’, \(u_1\) to ’01’, \(u_2\) to ’10’ and \(u_3\) to ’11’. Then, taking advantage of the quantum entanglement swapping and the assumption of the two-bit codings, a deterministic secure direct communication protocol can be proposed. We show it later.
Let us turn to depict our communication protocol. The protocol is illustrated in figure 1 and works as follows:

(S1) Bob prepares a series of EPR pairs in $\Psi^+$ states (say, the photon 1 and 2 pair, the photon 3 and 4 pair, etc). He takes one photon from each pair, say, the photons 2, 4, 6, 8, etc, to form a string of photons in a regular sequence (say, the ordered string of photons is '2468. . .'). He sends the ordered photon string to Alice. In accordance with the ordering of the travel photons, Bob stores the remainder photons by way of two photons as a group, i.e., the photons 1 and 3 as the group 1, the photons 5 and 7 as the group 2, etc.

(S2) Alice confirms that she has received the travel photons. Also in a regular sequence, she stores the arrived photons by way of two photons as a group in terms of their coming orders, that is, the photons 2 and 4 as the group 1, the photons 6 and 8 as the group 2, etc.

(S3) Alice chooses randomly some photon groups as encoding-decoding groups (say, the groups 1, 2, etc) for her later two-bit encodings via local unitary $u$ operations. The remainder photon groups are taken as checking groups. Alice first does unitary $u$ operations on one photon of each checking group and then performs the Bell measurements on these checking groups.

(S4) Alice publicly announces her exact unitary $u$ operation, her Bell measurement result and the group order for each checking group.

(S5) Bob performs the Bell measurements on his corresponding photon groups whose orders are same with those publicly announced by Alice. In the case of the group counterpart (i.e., the order of Bob’s group is same with the order of Alice’s group), Bob compares his measurement result with Alice’s measurement result. If Bob finds that each of Alice’s measurement results is correlated with his corresponding measurement result, he publicly tells Alice there is no Eve in the line and the communication continues to (S6). Otherwise, Bob publicly tells Alice that Eve is
in the line. The communication is aborted.

(S6) In accord with the encoding-decoding group ordering, Alice performs her two-bit encodings via local unitary $u$ operations on the encoding-decoding groups according to her bit strings (say, '0110...') needed to be transmitted this time. For instances, $u_1$ operation on one photon of the group 1 to encode '01', $u_2$ operation on one photon of the group 2 to encode '10', etc. After the unitary $u$ operations, Alice performs the Bell states measurements on all the encoding-decoding groups.

(S7) Alice publicly announces her Bell measurement result and the encoding-decoding group order for each encoding-decoding photon group.

(S8) Bob measures his unmeasured photon groups in the Bell states after Alice’s public announcement in (S7). After he knows each of Alice’s Bell measurement results with the group order and his Bell measurement results with group orders, he can conclude the exact unitary $u$ operations performed by Alice on each encoding-decoding photon group, alternatively, he can extract the two-bit encodings (cf. Table 1). In accordance with the photon group ordering, he can get the bit string (i.e., the message). For example, in (S6) since Alice had performed the $u_1$ operation on one photon of the group 1 to encode '01', the initial state is then changed into $\Psi_{12}^+ \otimes \Psi_{34}^-$ (or $\Psi_{12}^- \otimes \Psi_{34}^+$, which is equivalent to $\Psi_{12}^+ \otimes \Psi_{34}^-$ due to the symmetry) from the state $\Psi_{12}^+ \otimes \Psi_{34}^+$. If Alice obtains $\Phi_{24}^+$ by her Bell measurements on her group 1, after Alice’s Bell measurement Bob should get $\Phi_{13}^+$ by his Bell measurements on his group 1. Since Bob can know Alice’s Bell measurement result by her public announcement and his result by his Bell measurement, he can conclude that Alice has performed the operation $u_1$ and therefore extract the bits (01) (see Table 1). Similarly, he can extract other bits, then he can get the bit string '0110...'.

Table 1. Corresponding relations among the unitary $u$ operations (i.e., the encoding bits), the initial states, Bob’s and Alice’s Bell measurement results.

| $u_0(00)$ | $u_1(01)$ | $u_2(10)$ | $u_3(11)$ |
|-----------|-----------|-----------|-----------|
| $\Psi_{12}^+ \otimes \Psi_{34}^+$ | $\Psi_{12}^+ \otimes \Psi_{34}^-$ | $\Psi_{12}^+ \otimes \Phi_{34}^+$ | $\Psi_{12}^+ \otimes \Phi_{34}^-$ |
| $\{\Phi_{13}^+, \Phi_{24}^+\}$ | $\{\Psi_{13}^+, \Psi_{24}^+\}$ | $\{\Psi_{13}^+, \Phi_{24}^+\}$ | $\{\Phi_{13}^+, \Psi_{24}^+\}$ |
| $\{\Psi_{13}^-, \Psi_{24}^+\}$ | $\{\Phi_{13}^-, \Phi_{24}^+\}$ | $\{\Psi_{13}^-, \Phi_{24}^+\}$ | $\{\Psi_{13}^-, \Phi_{24}^-\}$ |
| $\{\Psi_{13}^-, \Phi_{24}^+\}$ | $\{\Phi_{13}^+, \Phi_{24}^-\}$ | $\{\Phi_{13}^+, \Psi_{24}^-\}$ | $\{\Phi_{13}^+, \Phi_{24}^-\}$ |
| $\{\Phi_{13}^+, \Phi_{24}^-\}$ | $\{\Psi_{13}^+, \Psi_{24}^-\}$ | $\{\Phi_{13}^+, \Phi_{24}^-\}$ | $\{\Phi_{13}^+, \Psi_{24}^+\}$ |

Till now we have proposed a deterministic direct communication protocol by utilizing the quantum entanglement swapping and local unitary operations. To investigate the security of this communication protocol, let us further consider some attack scenarios by Eve.

(A) Let us consider the intercept-measure-resend attacks by Eve. In this attack, Eve intercepts the ordered photon string '2468...'. She classifies the travel photons as Alice does in (S4), i.e., the photons 2 and 4 as the group 1, the photons 6 and 8 as the group 2, and so on. Then she performs her Bell measurements on each group. After her measurements, she resends the ordered string '2468...' to Alice. However, because of Eve’s direct measurement, the quantum entan-
glement swapping can not be realized anymore. For examples, suppose Eve gets $\Phi_{13}$ by her Bell measurement on the photons 2 and 4, then Bob will always get $\Phi_{13}^+$ by his Bell measurement on the remainder photons 1 and 3. When Alice receives the photons 2 and 4 on which Bell measurement has been performed by Eve, she performs first her $u_1$ ($u_2, u_3$) operations on the checking groups and then the Bell measurements. After Alice publicly announces her exact operation ($u_1, u_2, u_3$) and her Bell measurement result $\Phi_{24}^+$ ($\Phi_{24}^-, \Psi_{24}^+, \Psi_{24}^-$), Bob performs his Bell measurement on the remainder photons 1 and 3 and gets inevitably $\Phi_{13}^+$. Then in total Bob can find that his Bell measurement results do not correlate with Alice’s corresponding Bell measurement results with possibility of $3/4$ corresponding to the $u_1, u_2$ and $u_3$ operations but the occasional correlation with possibility of $1/4$ corresponding to the $u_0$ operations. By the way, when Alice performs her $u$ operations on the checking groups, she can not exclude the $u_0$ operation to deterministically detect Eve’s attacks for Eve can also do the $u$ operations on the checking groups. However, if the number of checking groups is large enough, Bob can conclude that Eve is in the line because of the detection possibility at the level high up to $3/4$. In addition, Eve can get no information from Alice, because before Alice begins her encoding, Eve is found in the line and accordingly the communication is aborted. Therefore, the present protocol is secure against the direct measurement attack by Eve.

(B) Let us consider the intercept-replace attacks by Eve. Assume that Eve prepares some EPR pairs (i.e., the photon 1’ and 2’ pair, the photon 3’ and 4’ pair, etc) in the same states as Bob prepares, i.e., in the states $\Psi^+$. When Bob sends the ordered photon string ’2468…’ to Alice, Eve intercepts the photon sting and replaces it by her ordered photon string ’2’4’6’8’…’ taken from her EPR pairs. After this Eve has two choices, that is, either after or before Alice’s Bell measurements on the checking groups, she performs her Bell measurements on her photons. Let us first consider Eve’s first choice. In this case, due to the replacement of the travel photons, the quantum entanglement swapping can not be realized anymore, therefore there are no inevitable correlations between Alice’ Bell measurement results on the photons 2’ and 4’ and Bob’s Bell measurement results on the photons 1 and 3. Hence, it is easy for Alice and Bob to find that Eve is in the line in terms of their joint actions on the checking groups. This is very similar to the detection on Eve in (A). So in this case the present protocol is also secure. Let us turn to consider Eve’s second choice, i.e., Eve performs her Bell measurements at first. In this case, it is obvious that Eve can not get any information from Alice’s encoding by her prior Bell measurements. In the following let us investigate the detection on Eve. If Eve performs her Bell measurements on the photon 1’ and 3’ pair and the photon 2 and 4 pair, then the situation turns to her first choice. Therefore, she should carry out her Bell measurements on the photon 1’ and 2 pair and the the photon 3’ and 4 pair. Incidentally, her Bell measurements on the photon 1’ and 4 pair and the the photon 3’ and 2 pair are equivalent to her Bell measurements on the photon 1’ and 2 pair and the the photon 3’ and 4 pair due to the symmetry. The initial state of the system including Eve’s EPR pairs is

$$[\Psi_{12}^+ \otimes \Psi_{34}^+] \otimes [\Psi_{12}^+ \otimes \Psi_{34}^+]$$

$$= \frac{1}{4} (|\Psi_{13}^+|\Psi_{24}^+ - |\Psi_{13}^-|\Psi_{24}^-) + |\Phi_{13}^+|\Phi_{24}^+ - |\Phi_{13}^-|\Phi_{24}^-)$$

$$\otimes (|\Psi_{13}^+|\Psi_{24}^+ - |\Psi_{13}^-|\Psi_{24}^-) + |\Phi_{13}^+|\Phi_{24}^+ - |\Phi_{13}^-|\Phi_{24}^-)$$
CNOT gate operations as used in [25] to add an ancilla to each travel photon. Then the initial under Eve’s such attacks.

when Alice and Bob perform their joint actions on the checking group, in each checking group the So after Eve’s Bell measurements on the photon 1’ and 2 pair and the photon 3’ and 4 pair, when Alice and Bob perform their joint actions on the checking group, in each checking group the detection possibility on Eve is also at the level high up to 3/4 due to Eve’s attacks. Therefore, when the number of the checking group is big enough, then the present protocol is also secure under Eve’s such attacks.

(C) Let us consider the adding-ancilla attacks by Eve. Suppose Eve can take advantage of CNOT gate operations as used in [25] to add an ancilla to each travel photon. Then the initial state including the ancillas is

\[
C_{222} \Psi_{12}^+ |0\rangle_2 \otimes C_{444} \Psi_{34}^+ |0\rangle_4
\]

\[
= \frac{1}{2} (|0\rangle_1 |1\rangle_2 |1\rangle_2' + |1\rangle_1 |0\rangle_2 |0\rangle_2') \otimes (|0\rangle_3 |1\rangle_4 |1\rangle_4' + |1\rangle_3 |0\rangle_4 |0\rangle_4')
\]

\[
= \sqrt{\frac{1}{2} \left[ (|\Psi_{13}^+ \rangle |\Psi_{24}^+ \rangle - |\Psi_{13}^- \rangle |\Psi_{24}^- \rangle ) |\Psi_{24}^+ \rangle + (|\Phi_{13}^+ \rangle |\Phi_{24}^- \rangle - |\Phi_{13}^- \rangle |\Phi_{24}^+ \rangle ) |\Phi_{24}^+ \rangle \\
+ (|\Psi_{13}^+ \rangle |\Psi_{24}^- \rangle - |\Psi_{13}^- \rangle |\Psi_{24}^+ \rangle ) |\Psi_{24}^+ \rangle + (|\Phi_{13}^+ \rangle |\Phi_{24}^- \rangle - |\Phi_{13}^- \rangle |\Phi_{24}^+ \rangle ) |\Phi_{24}^- \rangle \right],
\]

where \( C \) stands for the CNOT operation. From this equation, one can find that Eve can not get any information form Alice’s encoding under this kind of attacks. Let us further investigate the detection possibility on Eve. First, assume that Eve performs her Bell measurement on her two ancilla photons before Alice and Bob’s joint actions. When Eve gets \( |\Psi_{24}^+ \rangle \) or \( |\Phi_{24}^+ \rangle \), she performs the local \( \sigma_1 \) operation on one of the two travel photons. In this case, Eve can successfully avoid the detection on her. However, her attack does not affect the communication between Alice and Bob at all. Secondly, assume that Eve does noting but adding the ancilla photons. In this case, for each checking group Alice and Bob can find Eve with possibility of 1/2 in terms of their joint actions. So when the number of the checking groups is big enough, then Eve can be found in the line. So the present protocol is also secure against such attacks.

To summarize, under the above attack scenarios to our best knowledge, the present protocol is secure. So in this paper, we have proposed a deterministic secure direct quantum communication protocol by using the entanglement swapping and local unitary operations. Incidentally, an alternative scheme of the present protocol can be achieved, i.e., different from the fact that it is always Bob who prepares the entangled photon pairs and sends the travel photons to Alice in the present scheme, in the alternative scheme both Alice and Bob prepare the entangled photon pair and they send one photon of the entangled pair to each other.

This work is supported by the National Natural Science Foundation of China under Grant No. 10304022.
[1] C. H. Bennett and G. Brassard, in Proceedings of the IEEE International Conference on Computers, Systems and Signal Processings, Bangalore, India (IEEE, New York, 1984), p175.
[2] A. K. Ekert, Phys. Rev. Lett. 67, 661 (1991).
[3] C. H. Bennett, Phys. Rev. Lett. 68, 3121 (1992).
[4] C. H. Bennett, G. Brassard, and N.D. Mermin, Phys. Rev. Lett. 68, 557(1992).
[5] L. Goldenberg and L. Vaidman, Phys. Rev. Lett. 75, 1239 (1995).
[6] B. Huttner, N. Imoto, N. Gisin, and T. Mor, Phys. Rev. A 51, 1863 (1995).
[7] M. Koashi and N. Imoto, Phys. Rev. Lett. 79, 2383 (1997).
[8] W. Y. Hwang, I. G. Koh, and Y. D. Han, Phys. Lett. A 244, 489 (1998).
[9] P. Xue, C. F. Li, and G. C. Guo, Phys. Rev. A 65, 022317 (2002).
[10] S. J. D. Phoenix, S. M. Barnett, P. D. Townsend, and K. J. Blow, J. Mod. Opt. 42, 1155 (1995).
[11] H. Bechmann-Pasquinucci and N. Gisin, Phys. Rev. A 59, 4238 (1999).
[12] A. Cabello, Phys. Rev. A 61,052312 (2000); 64, 024301 (2001).
[13] A. Cabello, Phys. Rev. Lett. 85, 5635 (2000).
[14] G. P. Guo, C. F. Li, B. S. Shi, J. Li, and G. C. Guo, Phys. Rev. A 64, 042301 (2001).
[15] A. Beige, B. G. Englert, C. Kurtsiefer, and H.Weinfurter, Acta Phys. Pol. A 101, 357 (2002).
[16] Kim Bostrom and Timo Felbinger, Phys. Rev. Lett. 89, 187902 (2002).
[17] G. L. Long and X. S. Liu, Phys. Rev. A 65, 032302 (2002).
[18] F. G. Deng and G. L. Long, Phys. Rev. A 68, 042315 (2003).
[19] F. G. Deng, G. L. Long, and X. S. Liu, Phys. Rev. A 68, 042317 (2003).
[20] Daegene Song, Phys. Rev. A 69, 034301(2004).
[21] M. Zukowski, A. Zeilinger, M. A. Horne, and A. K. Ekert, Phys. Rev. Lett. 71, 4287 (1993).
[22] S. Bose, V. Vedral, and P. L. Knight, Phys. Rev. A 57, 822(1998).
[23] L. Hardy and D. Song, Phys. Rev. A 62, 052315(2000).
[24] J. W. Pan, M. Daniell, S. Gasparoni, G. Weihs, and A. Zeilinger, Phys. Rev. Lett. 86, 4435 (2001).
[25] A. Wojcik, Phys. Rev. Lett. 90, 157901 (2003).