Improving the fidelity of teleportation through noisy channels using weak measurement

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Abstract. We investigate the problem of teleportation through two-qubit noisy channels with the aid of weak measurement to preserve the fidelity of teleportation. In particular, we consider a shared two qubit maximally entangled state as resource for teleportation, allowing one or both qubits to interact with the environment via the amplitude damping channel. We show that application of weak measurement and subsequent reverse measurement at suitable stages of the protocol lead to fidelity greater than 2/3 for any value of the decoherence parameter when only one of the qubits interact with the environment. In the case when both qubits interact with the environment, the above-mentioned technique of weak measurement and its reversal enables one to achieve the fidelity greater than 2/3 for all magnitudes of decoherence for a sub-class of maximally entangled channels. The success probabilty of the protocol decreases with the strength of weak measurement, and is lower when both the qubits are affected by decoherence.

Keywords: Teleportation, entanglement, fidelity, weak measurement, decoherence

In the Ref.[1], the authors show the possibility of protecting entanglement in the presence of decoherence using weak measurement. Here the supplier, say, Charlie, supplies two entangled systems A and B to Alice and Bob through the environment where the interaction is modelled by amplitude damping channel (ADC). In this protocol, the authors use the technique of weak measurement and reverse weak measurement to protect the entanglement. The weak measurement is performed by reducing the sensitivity of detection and employing post-selection of states [2, 3]. The idea of weak measurement originally proposed several years ago [4], has been recently employed for certain interesting applications in foundations of quantum theory [5]. In the present work [6], we use a similar technique to investigate whether the preservation of entanglement is equivalent with the preservation of success probability of a non-classical task, say, the teleportation fidelity.

In particular, we consider a shared two qubit maximally entangled state as resource for teleportation, allowing one or both qubits to interact with the environment via the amplitude damping channel. We show that application of weak measurement and subsequent reverse measurement at suitable stages of the protocol lead to fidelity greater than 2/3 for any value of the decoherence parameter when only one of the qubits interact with the environment. In the case when both qubits interact with the environment, the above-mentioned technique of weak measurement and its reversal enables one to achieve the fidelity greater than 2/3 for all magnitudes of decoherence for a sub-class of maximally entangled channels. The success probabilty of the protocol decreases with the strength of weak measurement, and is lower when both the qubits are affected by decoherence.

Our analysis reveals that the strength of reverse weak measurement required to protect entanglement maximally, has to be altered for the case of preserving teleportation fidelity optimally. Moreover, if one were to discard post-selection from the protocol by retaining the whole ensemble of states, the average entanglement would turn out to be lower for the full rangle of the decoherence parameter if one employs the methode of weak measurement and it's reversal. However, we show that even in such a scenario the teleportation fidelity can be improved using weak measurement and reversal for a certain range of decoherence.

Hence, in conclusion our results using the technique of weak measurement clearly show that the operation of protection of entanglement in a noisy channel is not equivalent to the protection of fidelity of a non-classical task such as teleportation.

References

[1] Y-S. Kim, J.-C. Lee, O. Kwon, and Y-H. Kim, Nature Phys. **8**, 117 (2012).

[2] Y-S. Kim, Y-W. Cho, Y-S. Ra, and Y-H. Kim, Opt. Express **17**, 11978 (2009).

[3] J-C. Lee, Y-C. Jeong, Y-S. Kim, and Y-H. Kim, Opt. Express **19**, 16309 (2011).

[4] Y. Aharonov, D.Z. Albert, L. Vaidman, Phys. Rev. Lett. **60**, 1351 (1988); I. M. Duck, P. M. Stevenson and E. C. G. Sudarshan, Phys. Rev. D **40**, 2112 (1989).

[5] S. Kocsis et al., Science **332**, 1170 (2011); J. S. Lundeen et al., Nature **474**, 188 (2011).

[6] T. Pramanik and A. S. Majumdar, arXiv:1301.0281.

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