Realization of Quantum State Transfer and Quantum Gates by Use of a Single Photon with Different Degrees of Freedom

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A photon has several different degrees of freedom(DoF), such as polarization (spin), orbital angular momentum (OAM), paths, frequencies and so on. All of these DoFs can code information. In this way, a single photon can be used to be as multi qubits with different DoFs. In this talk, I shall present our recent work on quantum teleportation, quantum gates based on a single photon with different DoFs. Quantum teleportation is a useful quantum information technology to transmit a quantum state between two objects locating different places. In this study, we perform a quantum state transfer experiment in the linear optical system, transferring a single-photon state in the polarization degree of freedom (DoF) to another photon in the orbital angular momentum (OAM) quantum state via a biphoton OAM entangled channel. Our experimental method is based on quantum teleportation technology. The difference from the original teleportation scheme is that the state to be teleported is known beforehand, and our method is for different particles with different DoFs, while the original one is for different particles with the same DoF. In addition, our experiment is implemented with a high Bell efficiency since each of the four hybrid-entangled Bell states can be discriminated. We use six states of poles of the Bloch sphere to test our experiment, and the fidelity of the quantum state transfer is 91.8±1.3%. Quantum controlled-logic gates, including controlled NOT gate and Toffoli gate, play critical roles in lots of quantum information processing schemes. We design and experimentally demonstrate deterministic Toffoli gate by utilizing orbital-angular-momentum and polarization degrees of freedom of a single photon. The effective conversion rate of the Toffoli gate in our experiment is (95.1±3.2)%. In addition, our experimental setup does not require any auxiliary photons and probabilistic post-selections. In this study, we also propose and experimentally implement quantum Fredkin gate in a single-photon hybrid-degrees-of-freedom system. Polarization is used as the control qubit, and SWAP operation is achieved in a four-dimensional Hilbert space spanned by photonic orbital angular momentum. The effective conversion rate P of the quantum Fredkin gate in the experiment is (95:4±2:6)%. Besides, we find that a kind of Greenberger-Horne-Zeilinger-like states can be prepared using our quantum Fredkin gate.

References

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