Realization of Quantum state transfer and Quantum gates by use of single photons with different degrees of freedom

Fuli Li
School of Physics, Xi'an Jiaotong University, Xi'an 710049, China

A photon has multiple different degrees of freedom (DoF) such as polarization (spin), orbital angular momentum (OAM), paths, frequencies and so on. All of these DoFs can be employed to 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 and 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. 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. We also propose and experimentally implement quantum Fredkin gate in a single-photon hybrid-degrees-of-freedom system. Besides, we find that a kind of Greenberger-Horne-Zeilinger-like states can be prepared by using the quantum Fredkin gate. I shall also talk about the investigations on high-dimensional quantum steering from a Noisy Environment with a single photon of different DoFs.

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10 July 2023, 3:00 pm
Room O210 (Edificio 8, Viale delle Scienze)