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Universal single-qubit non-adiabatic holonomic quantum gates in optomechanical systems

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The non-adiabatic holonomic quantum computation (NHQC) attracts widespread attention in recent years because of its advantage of fast and robustness. It has been realized based on physical systems including superconducting circuits, NMR, and nitrogen-vacancy center in diamond. In this work we propose the first scheme to achieve the NHQC based on an optomechanical system (OS). This OS is composed of two optical cavities coupling to a mechanical oscillator as shown by figure 1. Our NHQC includes single-qubit noncommute NOT gate, phase gate and Hadamard gate, which are obtained in the computational basis of the single excited states of the OS. With these universal quantum gates, we can also achieve the quantum state transfer and the entanglement generation between two cavity-modes. We discuss the corresponding experimental parameters and the fidelity of the scheme with imperfection by numerical simulation. Our scheme is of all the good properties of the NHQC based on a quantum system, such as the built-in noise-resilience, faster operation, less decoherence and non-requirement for the resource and time to remove the dynamical phases. It provides a prototype of quantum gates realized with the mechanical motion degree of freedom. OSs can serve as important platforms for generating various quantum effects in the systems ranging from quantum to classical ones, and our scheme is such an example in quantum computation and quantum information processing.

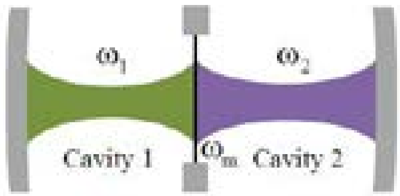

Fig. 1. Schematic diagram of the optomechanical system composed of two cavities of frequencies ω_1, ω_2 and a mechanical oscillator of frequency ω_m. The mechanical oscillator is realized by a membrane fixed in middle.

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Biography

Shan Shan Chen is a graduate student in grade two of Physics Department, Beijing Normal University. Her research field is quantum information and quantum computation.

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