**Controlling Superconducting Qubits Utilizing Nonadiabatic Transitions**

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Fast and accurate quantum gate control is essential for the practical development of quantum computers. Many conventional gate operations rely on external electromagnetic waves to induce resonance transitions, which typically require multiple oscillation cycles to complete. However, there are alternative quantum control methods for gate operations that do not involve electromagnetic waves and are expected to be faster than the methods utilizing resonance effect.

In certain quantum systems, controllable parameters exist within the system's Hamiltonian. For instance, in superconducting qubit systems such as fluxonium, the Hamiltonian is given by  , where represents the charge operator, denotes the flux operator, and ​ is the external flux, which is a controllable parameter. By varying the parameter , the Hamiltonian changes, consequently altering the system's eigenenergies. For some values of the parameter , the gap between eigenenergies may become small, which indicating that a time-dependent around those points can induce nonadiabatic transitions. This implies that quantum control can be achieved by designing . However, to control qubits efficiently and precisely, the design of the parameter is crucial.

We take the fluxonium qubit as a platform to demonstrate our idea. In this talk, we introduce the basic idea of how to design the controllable parameter, which is regarded as in the fluxonium system, and show two applications: X-gate operation and initialization. In addition, we consider the impact of environmental factors on these operations. The robustness and stability of the methods were analyzed, leading to the development of robust control strategies.