AMPLITUDE SPECTROSCOPY OF TWO COUPLED JOSEPHSON QUBITS

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Recently a serious attention has been focused on the spectroscopy of Josephson junctions – superconducting circuits with a weak coupling which can be considered as “macroscopic atoms” with the sizes of the order of ten or hundreds micrometers [1]. The goal of this work is to describe quantum-mechanic phenomena in the system of coupled qubits from the point of view of quasi-energy states and investigate Landau-Zener transitions at different parameters of multi-level systems. The effect of a time-dependent driving field with a large amplitude on the system consisting of two coupled qubits (two-level systems) has been studied. Using the rotating wave approximation (RWA) made it possible to find simple conditions of a multi-level system resonant excitation. As it turned out the obtained conditions include the coupling constant of qubits. The numerical simulation carried out confirms qualitative conclusions following from RWA. When the field amplitude is large the system evolves adiabatically except for the immediate vicinity from quasi-crossing levels where Landau-Zener quantum-coherent transitions are observed. To reveal the peculiarities of resonant transitions caused by the quasi-level motion and crossing in a periodical driving field the Floquet states which determines the precise intermediate states of the system is applied [2]. The developed numerical method of calculating quasi-energy states of multi-level systems made it possible to find transition probabilities and build interference patterns for transition probabilities. The interference patterns demonstrate the possibility of obtaining some additional information about qubits since the positions of transition probability maxima appeared to be dependent on the coupling parameter of qubits.

The theory developed in this work allows to extend the amplitude spectroscopy method earlier effectively used for a single qubit over more complicated systems. It is evident that the quantum spectroscopy can be used for studying the spectra of artificial quantum objects: quantum wells, quantum dot, quantum wire and etc. in which the distances between energy levels are significantly smaller than in atomic ones.

References

[1] D. Berns, M.S.Runder, S.O.Valenzuela, K.K.Bergreen, W.D. Oliver, L.S.Levitov, T.P.Orlando, *Amplitude spectroscopy of a solid-state artificial atom,* Nature, **455**, 51-57 (2008).

[2] J.H. Shirley, *Solution of the Schrodinger equation with a Hamiltonian periodic in time,* Phys. Rev. **138**, B979 **B979-**B987 (1965).