Mesoscopic fluctuation of a qubit population in a biharmonic driving field

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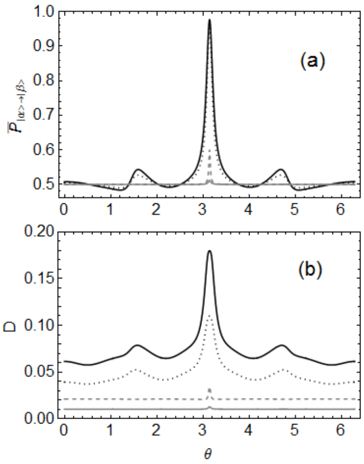
It is well known that the conductance of disordered systems at low temperatures manifests mesoscopic fluctuations, due to interference of electron waves [1]. The large size of the electron trajectories makes the interference corrections to the conductance is very sensitive to the configuration of impurities in low-dimensional systems (a film or a wire): it is enough to move one impurity at a distance of the order of the wavelength of an electron to significantly alter the interference of electron waves. Conductance one-dimensional system is sensitive especially to the impurity configurations because in this case the returnable path of the electrons always pass the same scatterers [2].

In the present paper the mesoscopic fluctuations of the transition probability between the ground and excited states of a superconducting Josephson qubit excited by a superposition of two radio pulses is investigated both numerically and analytically. The Hamiltonian of the qubit is: $H(t)=\left(\varepsilon(t)\sigma_z+\Delta\sigma_x\right)/2$, where $\varepsilon(t)$ - a time-dependent control parameter, Δ - tunneling splitting of levels. It is assumed that initially a qubit is in the ground state, and the transitions to the exited level are induced by an external biharmonic driving field $\varepsilon(t)=\varepsilon_0+A(\cos\omega\, t+\gamma\cos(2\omega\, t+\theta))$, where ε_0 is dc and A is ac components of the driving amplitude; γ and θ - are relative amplitude and phase of mixing pulses. In the adiabatic approximation the qubit can be in states $\phi_\pm(t)$ with the energies $E_\pm(t)=\pm\sqrt{\varepsilon(t)^2+\Delta^2}$. When the control field is changed such a way that the anticrossing levels $E_\pm(t)$ takes place then the Landau-Zener transitions between them may be induced [3]. The rate of the Landau-Zener transitions can controlled by the amplitudes and relative phase of the pulses [4]. By analogy with the theory of mesoscopic systems, we can see that the number of quasicrossings adiabatic levels (number of transitions) during the external field time is analogous to the number of s scatterers which are placed on the length of the wire. For a fixed pulse duration phase is responsible for changing the configuration of the scatterers, and the total duration of the signal behaves like a length of wire.

The transition probabilities between the qubit levels, taking into account the phase noise, are found by solving the equation for the density matrix. The figure shows the results of numerical calculation of transition probabilities (a) and the dispersion (b) depending on the relative phase difference θ. It is shown the transition probabilities and variances depending on the relative phase difference θ for different values of the phase noise of Γ: Γ = 0.0001, black, black dotted Γ = 0.001, gray dotted Γ = 0.01, a gray Γ = 0.1. As can be seen, the noticeable fluctuation in the value of the relative phase $\theta=\pi$. With an increase in the rate of phase relaxation is observed suppression fluctuations similar to the mesoscopic systems. Also the behavior of the fluctuations intensity at different durations of the signal τ has been studied. It is shown that strong mesoscopic fluctuations occur on time scales shorter than the time dephasing ($\tau<1/\Gamma$), whereas at the long-time ($\tau>1/\Gamma$), the variance is completely suppressed. This fact enables us once again emphasize the analogy with the mesoscopic, consisting in the fact that the dependence of the fluctuations of the population of the qubit on the pulse duration is similar to the behavior of conductivity fluctuations on the length of the wire.



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