Bistability effect in the extreme strong coupling regime of the Jaynes-Cummings model

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We study the nonlinear response of a driven cavity QED system in the extreme strong coupling regime where the saturation photon number is by many orders of magnitude below one. In this regime multi–photon resonances within the Jaynes–Cummings spectrum up to high order can be resolved [1]. We identify an intensity and frequency range of the external coherent drive for which the system exhibits bistability rather than resonant multi photon transitions. The cavity field evolves into a mixture of the vacuum and another quasi–classical state which is well separated in phase space. The corresponding time evolution of the outgoing intensity is a telegraph signal switching between two attractors [2].

We explore the nonlinear input–output relation of a resonator–driven circuit QED system in a broad frequency and intensity range of the driving. The resonator mode and the artificial atomic systems are assumed to be resonant. Two distinct frequency domains of the driving field can be identified: (1) For large detuning from the resonator mode, resolved multi–photon transitions in the lower part of the Jaynes–Cummings ladder appear [3][4]; (2) By tuning the external drive closer to resonance with the mode, the system evolves into a bistability–like steady–state. It is a mixture of two "semiclassical" states, represented by a two–peaked Wigner quasi–distribution function in phase space (Fig. 1). This is an unexpected result since the robust semiclassical bistable state is generated by a single atom. This solution is not connected by any limiting procedure to the result that could be obtained from an ab initio semiclassical description, in contrast to the strong coupling case in cavity QED [5][6]. Moreover, the bimodal Wigner function is not present in the case of exact resonance, as opposed to the familiar case of semiclassical absorptive bistability.

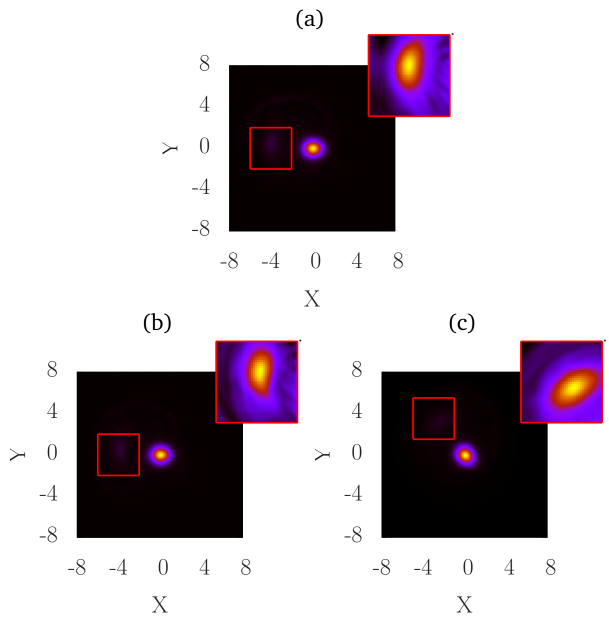

FIG. 1. Wigner functions for the mode in steady-state. For the plots in (a) the detuning is $\Delta_M = -0.17g$, which is in the bistability domain. The plots in (b) correspond to neighboring detuning values $\Delta_M + 0.006g$. The insets zoom into the region indicated by the red box in the main panels, and a different color code scale is used in order to make the peak here visible. In (c) we use the same Δ_M as for (a), but the phase of the drive amplitude is shifted by $\pi/4$. The quasi-classical component is consequently rotated by the same angle in phase space.

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