Quantum memcapacitance and thermometry with artificial two levels system

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Qubit-resonator system

One of the most intriguing and counterintuitive phenomena in the fields of atomic physics and quantum optics is lasing. Recently there have been a number of experimental demonstrations of lasing and population inversion in superconducting systems. We study lasing in the strongly driven qubit-resonator system.1,2,3

Theoretical model

\[ \rho = -\frac{i}{\hbar}[H', \rho] + \kappa D[\sigma] \rho + \Gamma D[\sigma] \rho + \frac{\Gamma_a}{2} D[\sigma_a] \rho. \]

For the transmon-resonator system:

\[ V = \langle \tilde{V} \rangle = V_{\text{max}}(a e^{-i\omega t} + a^\dagger e^{i\omega t}) = 2V_{\text{max}} \text{Re} \langle a e^{-i\omega t} \rangle \]

\[ q = C_{\text{mem}} V + \frac{C_{\text{mem}}}{2} e(\langle n \rangle) \equiv C_{\text{mem}} V \langle n \rangle = \text{const} \times \sigma. \]

\[ \text{The memcapacitor’s dynamics is defined by resonator and qubit, via } \langle a \rangle \text{ and } \langle a^\dagger \rangle. \]

Processes in the system

The interaction of the qubit and the resonator can be considered as the interaction of the atom with a two-mode field. A high-amplitude signal of the resonator interacts with the qubit. The dressed qubit can amplify or attenuate output signal.

Consider now the sensitivity of the system to the changes of temperature. How the behavior of the observables changes? Is this useful for a single-qubit thermometry?

To respond to such questions, we describe below both dynamical and stationary behavior for non-zero temperature.

\[ A = \sqrt{I^2 + Q^2} = 2V_0 \langle a \rangle. \]

\[ I = 2V_0 \text{Re} \langle a \rangle, \quad Q = 2V_0 \text{Im} \langle a \rangle \]

Pinched-hysteretic as a fingerprint of a memcapacitive behaviour

Quantum memcapacitance

We plot the time evolution of the quadratures for the real parameters4 take into account non-zero T. The figure demonstrates that both evolution and stationary values (at long times, independent of initial conditions) are strongly temperature dependent.