Critical Parametric Quantum Sensing

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Abstract

Critical quantum systems are a promising resource for quantum metrology applications, due to the diverging susceptibility developed in proximity of phase transitions [1]. Here [2], we assess the metrological power of parametric Kerr resonators undergoing driven-dissipative phase transitions. We fully characterize the quantum Fisher information for frequency estimation, and the Helstrom bound for frequency discrimination. By going beyond the asymptotic regime, we show that the Heisenberg precision can be achieved with experimentally reachable parameters. We design protocols that exploit the critical behavior of nonlinear resonators to enhance the precision of quantum magnetometers and the fidelity of superconducting qubit readout [3].

References

[1] L. Garbe, M. Bina, A. Keller, M. G. A. Paris, and S. Felicetti, Phys. Rev. Lett. 124, 120504 (2020).

[2] R. Di Candia, F. Minganti, K. V. Petrovnin, G. S. Paraoanu, and S. Felicetti, arXiv:2107.04503, accepted in npj Quantum Inf. (2023).

[3] P. Krantz, A. Bengtsson, M. Simoen, S. Gustavsson, V. Shumeiko, W. Oliver, C. Wilson, P. Delsing, and J. Bylander, Nat. Comm. 7, 11417 (2016).

Figures

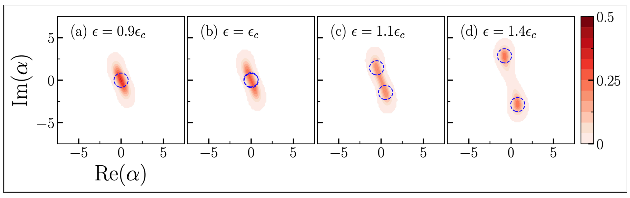

Figure 1: Wigner function of the Kerr resonator system steady-state. The figure shows the transition from the normal (a) to the symmetry-broken [(c) and (d)] phases, taking place at the critical point. The system is highly susceptible in the proximity of the criticality, and so it can be exploited in high-sensitivity magnetometer. The system shows two highly distinguishable phases, corresponding to the vacuum-like (a) and displaced state (d), a feature that can be exploited in high-fidelity qubit readout.

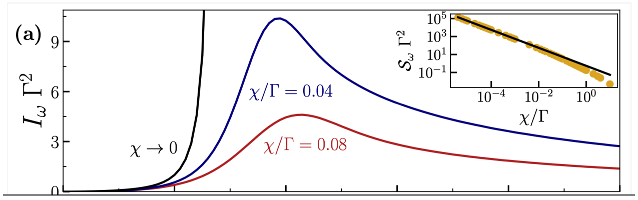

Figure 2: QFI of the estimation of the frequency as a function of the pump, and for various values of the non-linearity. In the inset we show that the Heisenberg scaling is reached for reasonable values of the non-linearity. Homodyne detection virtually saturates the QFI.

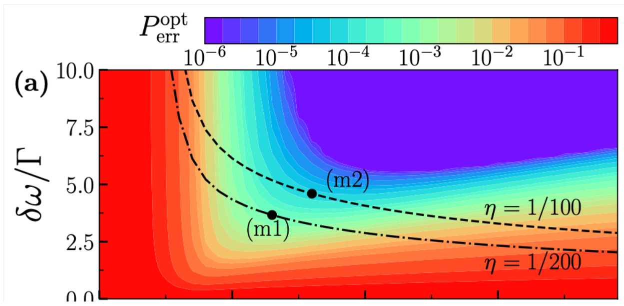

Figure 3: Qubit readout error probability map with respect to the qubit-resonator detuning δω, and for different values of the dispersive parameter η. For η=1/100, we can reach error probabilities values as low as 10^{-4} with the optimal measurement.