Critical Properties of Fisher Information in Quantum Rabi Ring Model for Parameter Estimation and Quantum Sensor

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Quantum Fisher information (QFI) may exhibit the irregular behavior at the critical point of phase transitions of a physical system and be very sensitive to slight variations of some controlling parameters. This parameter sensitivity may be used for quantum parameter estimation or quantum sensing. In this study, taking the quantum Rabi models as an example, we investigate the critical properties of the QFI for the parameter estimation at the critical point. For the standard Rabi model, we show that the QFI goes divergently in the sixth power law T^6 of the parameter coding time around the critical point. After taking into the consumption of energy during the dynamic evolution, we find that the variation of the QFI around the critical point is scaled by the Heisenberg scaling T^2 . It is noticed that for nonclassical initial probe states the scaling of QFI can beat the standard quantum limit as a function of the initial mean phonon number. The homodyne and phonon-number measurement schemes are compared. We find that the quantum Cramér-Rao bound can be reached by use of the phonon number detection scheme. However, it is more sensitive to the noise than the homodyne detection scheme. For the quantum Rabi ring model, we show that the QFI exhibits the divergent behavior from the normal phase to the superradiant phase but the singular properties disappear from the ferromagnetic superradiant phase to chiral superradiant phase. The critical behavior of the QFI can be used as a quantum sensor.

References

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