Open Talk

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SPEAKER

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TITLE OF THE TALK

Dynamics of non-Markovian open quantum systems and nonequilibrium quantum thermodynamics

ABSTRACT

Recently, a general theory of non-equilibrium dynamics is developed [1,2] for non Markovian open quantum systems of bosons (fermions) interacting with a general bosonic (fermionic) environment. The exact dissipation and fluctuation dynamics of the open system is explored through an exact master equation, determined by the non-equilibrium Green's functions which account for all the information of non Markovian back-action memory effects. Using this approach, we develop [3] a non-equilibrium theory of quantum thermodynamics for arbitrary quantum systems in contact with heat reservoirs. This creates a new paradigm to the topic of quantum thermodynamics for mesoscopic and nanoscale systems. We address the issue of real-time thermodynamics that is thermodynamic processes taking place under non-equilibrium situations. This non-equilibrium theory of quantum thermodynamics unravels (i) the emergence of classical thermodynamics from quantum dynamics of a single particle system in the weak system-reservoir coupling regime; (ii) the breakdown of classical thermodynamics in the strong coupling regime, induced by non-Markovian memory dynamics; and (iii) the occurrence of negative temperature associated with a dynamical quantum phase transition. The third law of thermodynamics, allocated in the deep quantum realm, is also proved in our theory.

Through this exact master equation approach, we also examine [4] the exact decoherence dynamics and non-Markovian noise power spectrum obtained through the Fourier transform of the exact two time correlation function for a resonator system coupled to an electromagnetic reservoir characterized by a low frequency 1/f noise at finite temperature. We also apply this approach to investigate the transient dynamics of photon statistics through two-time correlation function g2 for optical fields [5]. We find that the transient correlations at different time yield a smooth transition from antibunching to bunching photon statistics in the weak system-environment coupling regime. In the strong-coupling regime, the two-time correlations exhibit bunching

antibunching oscillations that persists both in the transient process and in the steady-state limit. The photon bunching antibunching oscillations is a manifestation of strong non-Markovian dynamics, where the system remains in nonequilibrium from its environment. Recently, we also introduce a non Markovianity measure [6] using two-time correlation functions which shows interesting short-time and long-time behaviors depending upon the properties of the system and reservoir. Such a non-Markovianity can be directly measured in experiments since two time correlation functions are experimentally measurable. In the end, we briefly discuss on our ongoing projects of probing nonclassical electron transport through quantum nanostructure, quantum optomechanical heat machine-beyond weak coupling, and real time dynamics of nonequilibrium transport through quantum dot in the Kondo regime.

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[1] Wei-Min Zhang et al., General non-Markovian dynamics of open quantum systems, Phys. Rev. Lett. 109, 170402 (2012).
https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.109.170402
[2] Wei-Min Zhang et al., Non-equilibrium quantum theory for Nano-devices based on the Feynman-Vernon influence functional, New J. Phys. 12, 083013 (2010).
http://iopscience.iop.org/article/10.1088/1367-2630/12/8/083013/pdf
[3] Md. Manirul Ali,Wei-Min Zhang, Quantum thermodynamics of a single-particle system, (communicated to Phys. Rev. X) arXiv:1803.04658 (2018).
https://arxiv.org/pdf/1803.04658.pdf
[4] Md. Manirul Ali, Ping-Yuan Lo, Wei-Min Zhang, Exact decoherence dynamics of 1/f noise, New J. Phys. 16, 103010 (2014).
http://iopscience.iop.org/article/10.1088/1367-2630/16/10/103010/pdf
[5] Md. Manirul Ali, Wei-Min Zhang, Nonequilibrium transient dynamics of photon statistics, Phys. Rev. A 95, 033830 (2017).
https://journals.aps.org/pra/pdf/10.1103/PhysRevA.95.033830
[6] Md. Manirul Ali, P. Y. Lo, M. W. Y. Tu, W. M. Zhang, Non-Markovianity measure using two-time correlation functions, Phys. Rev. A 92, 062306 (2015).
https://journals.aps.org/pra/pdf/10.1103/PhysRevA.92.062306

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