Path integral approach to quantum thermodynamics

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Work belongs to the most basic notions in thermodynamics but it is not well understood in quantum systems, especially in open quantum systems. By introducing a novel concept of work functional along individual Feynman path, we invent a new approach to study thermodynamics in the quantum regime. Using the work functional, we derive a path-integral expression for the work statistics. By performing the $\hbar$ expansion, we analytically prove the quantum-classical correspondence of the work statistics. In addition, we obtain the quantum correction to the classical fluctuating work. We can also apply this approach to an open quantum system in the strong coupling regime described by the quantum Brownian motion model. This approach provides an effective way to calculate the work in open quantum systems by utilizing various path integral techniques. As an example, we calculate the work statistics for a dragged harmonic oscillator in both isolated and open quantum systems.

[1] K. Funo and H. T. Quan, Phys. Rev. Lett. 121 (2018) 040602.

[2] K. Funo and H. T. Quan, Phys. Rev. E98 (2018) 012113.