The Quantum Regime at Thermal Equilibrium

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Abstract

The aim of constructing and designing machines working at the nanometre-length scale, such as atomic motors, photocells, gyrators or heat engines, has boosted the developing of a quantum version of thermodynamics. One of the foundational conundra in this emerging field is, to what extent nanomachines can display quantum features and how this quantum behaviour could be used to improve their efficiency. Intuitively, one can suggest that if the energy of the thermal fluctuations is much smaller than the typical energy scale of the nanosystem, then there is room for the nanosystem to revels its quantum nature. However, as it has been discussed recently in almost all fields related to quantum mechanics (e.g quantum information science, quantum biophysics, nanotechnology, quantum chemsitry or condensed matter physics), the border between the quantum/classical operating regime is far from being trivial. We predict here, at thermodynamical equilibrium, the existence of a regime where, e.g., nanoelectromechanical structures or optomechanical systems can be found in an entangled state at high temperature assisted by the non-Markovian interactions. Complementarily, we report the existence of a second regime, characterized by Markovian interactions at low temperature, where quantum nanodevices do not thermalize into the canonical Boltzmann distribution, and therefore all their thermodynamical properties are expected to deviate, even, from current quantum thermodynamics. Our findings not only provides a solid ground for understanding the presence of quantum features in most of current investigations in bio and handmade systems, but also points out the direction to follow in protecting and isolating of quantum systems.

Keywords: Non-Markovian, entangled state, thermodynamical equilibrium.

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