

# Thermodynamics in Quantum Regimes

KIM Myungshik

Thermodynamics is one of the most powerful tools to study nature at the macroscopic level. Its applications span from heat engines to information and communication theories. Quantum mechanics, on the other hand, is the most successful theory to explain nature from first principles, supposedly at the atomic scale. Can we understand the overarching laws of thermodynamics at the quantum regime where microscopic motions are important in non-equilibrium states? We try to answer the question in this talk.

Fluctuation theorems are at the heart of non-equilibrium thermodynamics – the first and second laws of thermodynamics can be derived from the fluctuation theorems. By assuming microscopic reversibility, the relationship between the transition probabilities of the forward and backward processes is established, and macroscopic irreversibility as known as the second law of thermodynamics can be derived from this. One of the highly non-trivial questions here is whether the fluctuation theorems can be generalised to a quantum system and a quantum channel which can include coherences. The difficulties arise due to the fact that the way to understand the reversible process in quantum mechanics is very different from the classical theory due to the existence of coherences. In this presentation, we show how the fluctuation theorems can be generalised for an arbitrary quantum process, which then allows to establish a powerful framework to understand quantum information theory and thermodynamics. We discuss various issues in the derivation of the quantum fluctuation theorems. We also discuss how coherences in atomic interactions play a role here.