Nonclassical behavior in open quantum systems: wave-particle duality, entanglement, and thermo-kinetic uncertainty relations

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A deeper understanding of the differences between quantum and classical dynamics promises great potential for emerging technologies. Nevertheless, some aspects remain poorly understood, particularly concerning the role of quantum coherence in open quantum systems. It remains an open question when mesoscopic quantum transport can be captured by a classical model and when such a model breaks down, implying nonclassical behavior. In this talk, I will present recent results on fermionic and bosonic transport scenarios that shed light onto this question.

In a double-quantum dot, coherence can build up due to electrons traversing the system. On the one hand, this coherence can result in entanglement and even nonlocality. On the other hand, coherent dynamics may lead to a suppression of fluctuations causing violations of thermo-kinetic uncertainty relations that are valid for classical processes. These effects, which describe the breakdown of a classical description, are accompanied by a peak in coherence and occur when the inter-dot tunneling is similar in magnitude to the system-bath coupling. A bosonic two-mode system may be operated as a heat engine when coupled to a hot and a cold thermal reservoir. We compare such a quantum heat engine to two classical models, one based on waves and one based on particles. We find that while the average power output may be reproduced by the classical models, the fluctuations around this average may not. The wave model fails to describe the vacuum fluctuations while the particle model cannot achieve the same bunching as the quantum model. Our results shed light onto the role of the wave-particle duality on transport scenarios and provide guiding principles for the design of out-of-equilibrium devices that exhibit nonclassical behavior.

Pizzas will be provided: https://doodle.com/meeting/organize/id/elRBWX1b
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