Feedback Control of Quantum Transport

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Monitoring quantum objects during their time evolution usually introduces extra noise, but it can also compensate backaction effects and be used for recycling information in order to control the system dynamics [1]. This is also of interest for various NEMS applications.

In this talk, I will discuss electronic fluctuations which have become a major tool for probing quantum coherence, interactions, and dissipation effects in quantum transport through nanoscale structures [2]. The random tunnelling of electrons in quantum transport is described by the full counting statistics (FCS) of transferred charges. In analogy to equilibrium thermodynamics where, e.g., the cumulants of the particle number distribution in the grand canonical ensemble are proportional to the volume, FCS cumulants in stationary transport linearly increase in time (exceptions are possible). All quantum transport devices thus have to deal with a stochastic element that can become a major obstacle when very regular currents are required.

Here, I show that this situation changes by 'freezing' the cumulants in time, if one applies feedback (closed loop) control [1] to quantum transport. I propose a scheme where a time-dependent signal $q_n(t)$ is used to continuously adjust system parameters such as tunnel rates or energy levels [3] Here, $q_n(t) \equiv I_0 t - n$ is an error charge determined from the ideal 'target' current I_0 and the total charge n that has been collected in (or flown out of) a reservoir during the measurement (e.g., by a nearby quantum point contact detector) up to time t. The error charge determines whether to speed up or slow down the transport process – a form of feedback that is analogous to the centrifugal governor used, e.g., in thermo-mechanic machines like the steam engine. The feedback scheme generates a new kind of FCS that can not be obtained via ordinary transport. This is analogous to feedback control in quantum optics, where an in-loop photocurrent was used in order to alter the photon statistics of a light beam [4].

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