Energy and temperature fluctuations in the single electron box

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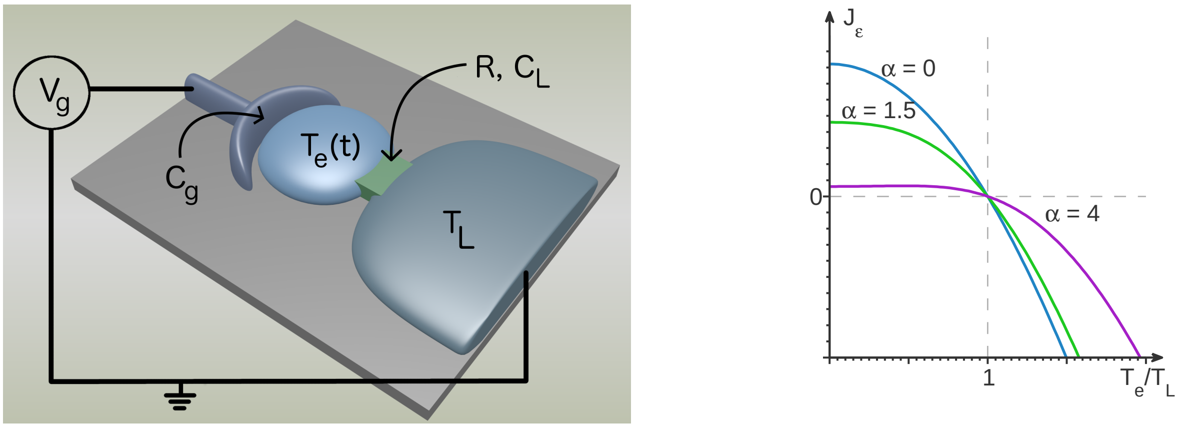
In mesoscopic and nanoscale systems at low temperatures, charge carriers are typically not in thermal equilibrium with the surrounding lattice. The resulting, non-equilibrium dynamics of electrons has only begun to be explored. Experimentally the time-dependence of the electron temperature (deviating from the lattice temperature) has been investigated in small metallic islands[1],[2]. Motivated by these experiments we investigate theoretically the electronic energy and temperature fluctuations in a metallic island in the Coulomb blockade regime, tunnel coupled to an electronic reservoir, i.e. a single electron box. We show that electronic quantum tunneling between the island and the reservoir, in the absence of any net charge or energy transport, induces fluctuations of the island electron temperature. The full distribution of the energy transfer as well as the island temperature is derived within the framework of full counting statistics. In particular, the low-frequency temperature fluctuations are analyzed, fully accounting for charging effects and non-zero reservoir temperature. The experimental requirements for measuring the predicted temperature fluctuations are discussed.



Left: Schematic of the single electron box. A metallic dot is coupled capacitively, C_g, to an electrostatic gate, kept at a voltage V_g. The dot is further coupled via a tunnel barrier, resistance R and capacitance C_g, to a metallic reservoir. The reservoir, in thermodynamic equilibrium, is grounded and kept at the lattice temperature T_L. In the dot, the electrons are in local thermal equilibrium at a temperature $T_\mathrm{e}(t)$ fluctuating in time. Right: Energy current j_ε (in arbitrary units) as a function of T_e/T_L, for different Coulomb blockade strengths (α).

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[3] Tineke L. van den Berg, Fredrik Brange and Peter Samuelsson, submitted NJP (Quantum Thermodynamics special issue).