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Charge fluctuations and single-electron oscillations in current-biased tunnel junctions

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Ultra-small current-biased tunnel junctions have been widely studied theoretically in the mid-1980s since it was suggested [1] that the time-correlation of tunneling events due to the underlying Coulomb blockade could result in an almost periodically oscillating voltage. The fact that the transport of electrons, in principle purely stochastic in such systems, can possibly become periodic is a fascinating phenomenon. The theory of these so-called single-electron tunneling (SET) oscillations has been developed by Likharev & al. [2, 3], based on the earlier studied analogous phenomenon of Bloch oscillations [4]. The actual advanced state-of-the-art in measuring currents and noise triggers a new interest in this kind of systems: we carry out a theoretical analysis of transport in a current-biased normal tunnel junction, corroborating the theoretical analysis with numerical simulations in a Monte Carlo fashion. We distinguish between different possible transport regimes, focusing on SET oscillations and clarifying the conditions and limits in which they appear. We calculate the charge fluctuation spectral density and discuss in particular the width of the peak at frequency $f \sim \mathsf{e}/I$, with I the bias current and e the electron charge. The SET oscillation regime provides in principle an extremely controllable one-electron source: interesting applications to nanomechanics can be envisaged, for example in a current-biased single-electron transistor coupled to an oscillator.

Références

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