Transport via a quantum shuttle

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We investigate electron transport through an electromechanical system in the extreme quantum mechanical and Coulomb blockade limits. We consider a chain of three quantum dots in which the outer dots are connected to external leads. Crucially, the position of the central dot is able to fluctuate about its equilibrium position. Variations in the position of the central dot alter the physical extent of the tunnel barriers to the outer dots and so the tunneling rates onto and off the central dot depend exponentially on its position. Treating the central dot as if it were mounted on a quantum mechanical oscillator, we explore the effect the strong dependence of the tunneling rates on the state of the oscillator has on the system's transport properties. We integrate the equation of motion for the density matrix of the system numerically to obtain the average current as a function of the energy levels in the outer dots for fixed lead voltages. The simplest case of an isolated oscillator at absolute zero, is considered first. Then we generalize the model to finite temperatures and to include the damping effects of the oscillator's environment. We find that the current decays rapidly with increasing difference between the energy levels in the outer dots. However, even when oscillator is in its ground state the decay contains structure and when the oscillator is in a thermal state the decay rate of the current is reduced for large energy differences in the outer dots. We also plan to analyse the case where the central dot is coupled directly to the leads. The system we consider can be regarded as a fully quantum mechanical version of the semiclassical electron–shuttle which was proposed recently [L.Y. Gorelick et al., Phys. Rev. Lett. **80**, 4526 (1998)].