Application of the Keldysh formalism to heat pumping through nanostructures

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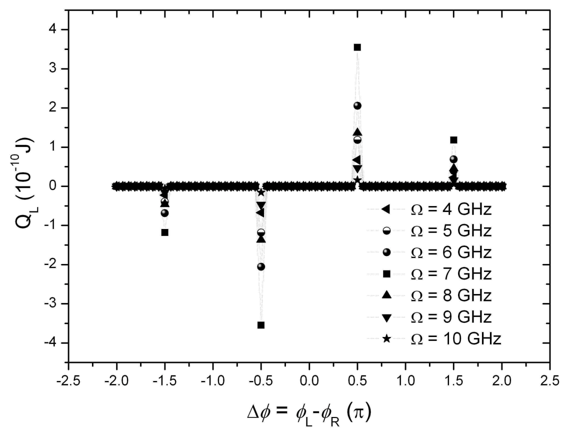
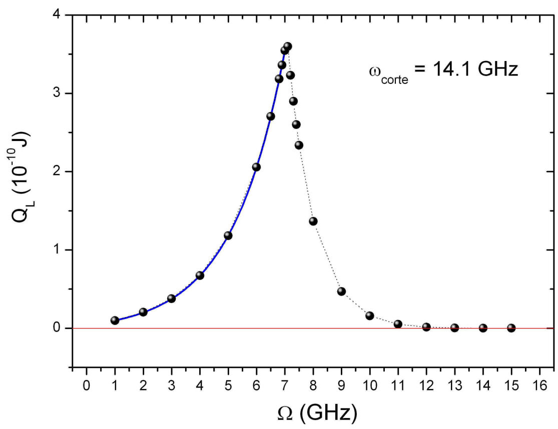
Abstract - In the last years, it was possible to make thermal transport measures in a significative number of nanoscopics devices. Some results show to us that there are analogies between the thermal and the electronic transport. Motivated by the charge pumping problem, the objective of this work is to study the heat pumping phemomenon, making another analogy between the thermal and the electronic cases. We demostrate that, indeed, it is possible to induce a heat flow through a linear chain of atoms connected to two leads in equilibrium to thermal baths at the same temperature by introducing time-dependent perturbations on the system.

In the ballistic regime at low temperatures, the Landauer formula gives a good description of heat transport for nano-junctions, connected to two leads attached to thermal baths at different temperatures. Starting from a microscopic model and using the nonequilibrium Green functions, it is possible to obtain an expression for the thermal conductance in nano-junction equivalent to the Landauer formula. The latest depends on the values of the coupling constants between phonon modes of the central region and leads, as well as on the thermal gradient. The expression for the thermal conductance is quite similar to that obtained for electrical conductance. In this work we present the method to calculate quantities related to heat transport in a regime where there is no temperature gradient between the reservoirs, but the system suffers a time depending perturbation. That is, with a convenient choice of time parameterization of the coupling terms between the nano-junction and the leads it is possible to produce a heat flow in the absence of a temperature difference between the thermal baths connected to the leads. This phenomenon characterizes the heat pumping. We develop a time-dependent transport theory to describe the pumping. The theory is general, depending on the phonons density, intensity and time dependence of the coupling. We apply the formalism in a simple model showing that in principle it is possible to pump heat through a linear chain of atoms without thermal gradient (Fig. (1)).



(a) Pumped heat per cycle Q_L as a function of the phase shift $\Delta\phi$. Each symbol represents a different numerical result for values of the pumping frequency Ω varying from 4 to 10 GHz.



(b) Pumped heat per cycle Q_L as a function of the pumping frequency Ω.

Figure 1: Numerical results for the pumped heat through a semi-infinity linear chain of atoms.