Session: Phonon Properties and Thermal Transport

(Invited) Anderson-like localization of phonon in nano-structures

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Based on a recent theory of wave localization and the development of a mathematical tool (the localization landscape) we propose an approach that predicts the localization of thermal phonons in disordered lattices. An analogy between the Schrödinger equation and the classical equation of motion is introduced to demonstrate that localization of thermal energy in phonon systems arises from atomic disorder through which the localization landscape can be revealed. This approach, illustrated on disordered graphene, provides a powerful framework for engineering heat conduction in nanostructures using wave effects.

Thermionic cooling devices based on AlGaAs/GaAs heterostructures

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Efficient cooling devices in nanoelectronics and optoelectronics is a matter of urgency. For in- stance, it is well-recognized that self-heating of microprocessors is one of the fundamental limit to system performance [1]. Recently, nanostructured devices have attracted broad interest since they have enhanced thermoelectric effects with respect to their bulk counterparts [2]. The present work theoretically investigates thermionic cooling devices based on AlGaAs/GaAs heterostructures. To do so, we couple self-consistently the non-equilibirum Green's function (NEGF) equations for electrons with 1D-Poisson equation for electrostatic and 1D- heat equation [3], [4]. Phonon scattering in the elec- tron transport is described *via* the concept of self-energy in the self-consistent Born approximation (SCBA). It includes interactions with acoustic and non-polar optical phonons as well as long range polar optical interactions of the Fro¨hlich type treated within a diagonal (*i.e.* local) approach [5].

Figure 1 represents the studied semiconductor het- erostructure refrigerator (SHR) initially proposed in Ref.[6] which couples tunneling injection with thermionic extraction. The cold electrons are in- jected into the active region by resonant tunneling through a potential barrier, while the hot electrons are removed from the active region by thermionic emission over a thicker barrier that serves as a thermal wall to reduce the heat backflow. Since the left access region cools while the right one heats up, the central region acts then as an energy-selective filter [7].

Figure 2 shows the current characteristics obtained for three different temperatures enforced at the contacts without (empty symbols) and with (solid symbols) the treatment of the heat equation. We can see that the self-heating inside the active region has almost no influence on the current even at higher temperatures. However, the two physical phenom- ena described in Figure 1, namely the resonant tun- neling and the thermionic emission above the thick barrier are clearly visible in the current spectrum (Fig.3). In particular we see in Figure 4 that the current injected from the left part of the active region corresponds to the energy of the resonant state in the central GaAs quantum well.

Moreover, as shown in Figure 5, the electronic heat power density (*i.e.* the power transferred locally between the electrons and the lattice) is negative in the left region (the lattice is cooled by the electron current) and peaked at the position of the resonant level.