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ON ELECTRON AND PHONON TRANSPORT IN NANOSTRUCTURES

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Mathematical modelling and numerical analysis of a number phenomena are suggested, in particular, the low temperature thermal conductance of a dielectric nanofiber and a method to diminish such a conductance; resonant tunnelling in a quantum waveguide of variable cross-section; switching electron beams in a branching waveguide. The studies are based on the same method of computation of scattering matrices.

A possibility to lower the thermal conductance of a dielectric fiber by means of changing its geometry is studied. At low temperature, practically complete reflection can be provided for the phonons which transmit the basic thermal flow. We consider two reservoirs with fixed temperatures connected by a fiber. At low temperatures, the free path of the phonons is much greater than the fiber length, and the thermal flow is conditioned by the probability T (k) of the transition of a phonon with wave number k from one reservoir to the other. We suggest a numerical method to find T (k) in a deformed fiber.

In a corrugated infinite fiber with periodically varying cross-section, a phonon cannot propagate if its energy remains within some intervals (gaps), i.e. the T (k) =0 if the energy of a phonon belongs to a gap. Numerical results show that in a long finite fiber containing a short corrugated inner part (10-15 periods), the T (k) drastically decrease for the phonons with energy in a gap. To extend the energy intervals corresponding to the decay of T (k), we suggest to change the corrugated part with periodically varying cross-section for a goffered part with "perturbed period" linearly varying along the axis of the fiber (i.e., to make a "chirp"). Numerical modelling shows that, in such a manner, one can essentially widen the reflection band of the phonons and, in doing so, lower the thermal conductance of the fiber.

We consider 3-dimensional axially symmetric quantum wires with circular cross-section of radius variable along the axis of a waveguide. In the narrows, there arise effective barriers for the longitudinal motion of electrons. Varying the radius, one can provide conditions for electron resonant tunneling. We suggest a method for the numerical study of such a phenomenon. The method can also be applied to the wires not possessing axial symmetry.

A switch of electron beams consists of a “distributor” with control electrode and several adjoint waveguides. Being injected to one of the waveguides, an electron beam has to be directed to a chosen waveguide. We show this can be done with probability 1.

The results can be of use for creating various devices in nano- and microelectronics (low temperature thermoinsulating structures, high sensitivity bolometers, resonant transistors and switches of new types, etc.).