Nonequilibrium Thermodynamics of Electrons in Quantum Dot Systems

The last decades have seen the rapid development of technology and miniaturization of electronics down to the nanometer scale, where quantum processes become to play a crucial role. The question arises: What about thermodynamics of such small systems far apart form equilibrium, when currents flow through them? There was a considerable development of statistical thermodynamics of small systems. The fluctuation theorem has been formulated, which says about rare events with an entropy decrease. Just recently statistical thermodynamics has been unified with information theory, one can say that over 100 years Maxwell's demon is accepted as a full participant in thermodynamic processes.

The main objective of the project is to study thermodynamic properties of electrons in nanostructures with quantum dots. Quantum dots are grateful research objects because one can easily and precisely control their electronic structure, temperature and chemical potentials in the electrodes. One can also easily measure the conductance, the quantum dot occupations, and study dynamics of tunneling events with frequency of the order of GHz. In the project we plan to analyze individual jumps of electron and their mutual correlation, i.e. processes neglected so far. We are interested in a nature of correlated transport of charge and heat, in the entropy production and exchange of information. In particular, we will search for conditions of local cooling or heating in the system. In this context, a special interest shall be devoted to bipartite systems which consist of two subsystems interacting with each other. One of the subsystem can play a role of Maxwell’s demon, which by extracting information about tunneling events from the other subsystem, reduces its entropy by applying negative feedback. We plan also to apply the new methods of stochastic thermodynamics to hybrid systems with an superconducting electrode, and study current dynamics as well as fluctuations between events with single electrons and Cooper pairs.

Although our research concerns quantum dots, similar issues can be found in chemical reactions and biological processes (e.g. in enzymatic reactions or molecular motors) .