Noise-induced Phenomena in Condensed Matter and in Complex Systems

Informationsblatt

Ziel

The main focuses of the project are to investigate and determine the time, spectral, correlation, and probability characteristics of various nonequilibrium processes in condensed matter and biological complex systems described by 1D, 2D, 3D models of noise assisted dynamics of interacting particles of complex shape in a potential field of force. We will consider the potential landscapes, which have complex time-dependent structure with many potential wells (valleys) separated by potential barriers of different height and shape. We will study the transition processes that appear in the system due to the action of various kinds of instabilities, nonequilibrium initial conditions and external fields (random or deterministic).

More specifically we will consider:
1 - Nonlinear dynamics of large fluctuations in transitions processes and study of the noise-induced effects in condensed matter nonlinear systems, which show stochastic resonance (SR), noise enhanced stability (NES), noise delayed decay (NDD) and resonant activation (RA) phenomena.

2 - Noise-induced fluctuations, relaxation phenomena and molecular dynamics in complex biological systems and study of noise models for semiconductor heterostructures, Josephson electronic devices and oscillators, and microwave transistors.

3 - Noise-induced resonant phenomena in population dynamics of ecosystems.

In the framework of the project we will consider physical and biological applications: Josephson electronic devices (RSFQ logic family, SQUIDs), Josephson oscillators, diffusion in semiconductor heterostructures, microwave transistors, molecular machines (enzymes chymotrypsin (ChT) and acetylcholinesterase (AChE)), sea fish population dynamics and species recognition in insect populations.

The investigation of all these noise-induced phenomena in condensed matter and complex biological systems will help to:

- optimize specific electronic devices in order to improve their performance;
- understand the dynamics of enzymes as molecular motors;
- elaborate predictive models of fish population dynamics.

For the analysis of stochastic systems in condensed matter and biophysics the authors of the project have their own methods and approaches which allowed them already to derive for the first time the exact time and spectral characteristics for some nonstationary processes (see part 3.1.5). These new methods will be applied to the analysis of the specific physical situations and will be modified and improved to consider more complicated cases. The effects of NES and NDD of metastable and unstable states, SR, resonant activation phenomenon and the transport across fluctuating barriers will be studied by these new analytical methods.

The specific problems of condensed matter and biological complex systems considered in this project are as follows:

(a) non-linear diffusion processes in semiconductor heterostructures;
(b) the elaboration of a stochastic model for solid state electronic devices;
(c) noise induced phenomena in Josephson electronic devices and oscillators;
(d) molecular dynamics of enzymes;
(e) enhanced propagation of information due to stochastic synchronization in special devices with coupled oscillators;
(f) NES, SR and NDD phenomena for a model of population dynamics of which the associated potential shows metastable or unstable states;
(g) effect of noise signals in species recognition for populations which communicate.
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