Frontiers of Quantum and Mesoscopic Thermodynamics (FQMT'17)

9 July (Sunday) – 15 July (Saturday) 2017, Prague, Czech Republic

http://fqmt.fzu.cz/17/

Topics

- Non-equilibrium statistical physics
- Quantum many body physics, quantum field theory
- Foundations of quantum physics
- Quantum thermodynamics
- Quantum optics
- Photonics, phononics, plasmonics, atomtronics
- Quantum simulations
- Physics of quantum information and computing
- Cosmology, gravitation and astrophysics
- Quantum measurement, entanglement and coherence
- Dissipation, dephasing, noise and decoherence
- Topological states of quantum matter, quantum phase transitions
- Macroscopic quantum behavior
- Cold atoms and molecules, Bose-Einstein condensates
- Mesoscopic, nano-electromechanical and nano-optical systems
- Biological systems, molecular motors and quantum biology

Scientific Background

The program of the FQMT'17 conference will be focused on conceptual and experimental challenges of quantum many body physics, non-equilibrium statistical physics, foundations of quantum mechanics, quantum field theory, and quantum thermodynamics. Further development of all these fields is needed to deal with an increasing requirement for more detailed understanding and use of such phenomena as quantum correlations, entanglement and their dynamics; decoherence and dissipation; light−matter interactions; behavior of closed and open quantum systems far from equilibrium; equilibration and thermalization of systems; roles of initial and boundary conditions; influences of environment, reservoirs and external fields on the time evolution of systems; quantum to classical transitions; dynamics of quantum phase transitions; and topological states of systems. As for systems which enable study of various related questions, the conference will deal mainly with mesoscopic systems. The program will concentrate on discussions of phenomena which are observed in structures and materials such as carbon allotropes, quantum wires and dots, microcavities, single molecule nanomagnets, molecular motors and active gels, various structures in living cells, as well as specific arrangements featuring cold atoms and molecules which can exhibit macroscopic quantum effects and which can be used for testing methods of quantum many-body theory. The above mentioned phenomena, related problems and challenges occur in many fields of physics, astrophysics, chemistry, and biology. Both theoretical and experimental experiences from such seemingly different fields as condensed matter physics, quantum optics, plasma physics, nuclear physics, physics of quantum information and computing, chemistry, biophysics and astrophysics will be discussed during the conference program.

There are several compelling reasons for the above choice of the program:

Recent advances in technologies have led to enormous improvements of measurement, imaging and observation techniques at microscopic, mesoscopic and macroscopic scales. At the same time various methods allow us to investigate not only equilibrium features, but also time evolution of classical and quantum systems (which are in general far from equilibrium) at different time scales. This increasing ability to study subtle details of the dynamics of systems yields new versions of old questions and creates new challenges in many fields of physics.

Various systems, of natural and artificial origin, can exhibit mesoscopic features depending on inner parameters of these systems and interactions with their environment. Typical mesoscopic systems can be of nanoscale size, composed from atoms (molecules). Nanoscale structures include not only very small physical structures, but also structures occurring in living cells, as for example complex molecules, proteins and molecular motors. At the same time, nanoscale technologies enable the preparation of well-defined artificial structures composed of between a few and hundreds of atoms (molecules) to create an enormous diversity of systems with well-defined inner parameters and external fields which can influence them. They can be studied by methods of condensed matter physics and quantum optics in such detail that affords a deeper understanding of quantum physics, as represented by quantum interferences, entanglement, the uncertainty principle, quantum measurement and what is often termed "non-locality". At the same time, studies of these artificial structures can help us on our way to improve our knowledge of the processes in living cells.

Furthermore, the understanding of mesoscopic systems is a challenging task by itself, due to their complexity, diversity, and the fact that these systems are on the borderline between different disciplines (i.e., physics, chemistry, and biology) where the dynamic behavior of these systems and corresponding various methods of their description (individual and statistical, microscopic and macroscopic, classical and quantum) meet. These (often open) systems are commonly dominated by quantum effects, by topology of their structures and states, and by strong interactions with their environment. Due to their position between the macro and micro world, these systems exhibit many surprising phenomena which can lead to a better understanding of quantum mechanics, many-body physics, and the relation between classical and quantum behaviors by sensitive choice of parameters. They are often experimentally investigated via quantum optical and transport phenomena, or their behavior is based upon quantum effects, including quantum coherence, entanglement and tunneling. The development of theoretical concepts for their description and reliable experimental methods is of great importance for investigating these systems, testing theories and designing new nanostructures with well defined, desired behavior.

A good understanding of the time evolution of both classical and quantum systems is essential for an explanation of many observation and experiments of contemporary physics. Observed systems must be often treated as non-equilibrium, open systems in which their behavior is influenced not only by their inner parameters, but also by properties of their environment and time dependent external fields. The theory of non-equilibrium behavior of quantum many-body systems is, however, far from complete. There are lasting and extremely important problems related to modern technologies, including questions of irreversible behavior of real systems in comparison with reversible microscopic laws, emergence of classical macroscopic behavior from microscopic quantum behavior, charge (electron), spin and heat transport, limits to "phenomenological" thermodynamic descriptions, and the problem of how to describe properly open quantum systems far from equilibrium, especially in the case of strong interaction between a small system and reservoirs. The conference program will consider experimental as well as theoretical studies of transport and optical properties and both short and long time dynamics together with the influence of initial and boundary conditions.

Another challenging problem related to the conference program is stochastic behavior of systems caused either by innate features of the systems or by noise related to the fact that the studied systems are open. Studies of quantum and temperature fluctuations, as well as quantum noise, dephasing and dissipation will create an essential part of the conference contributions. Recently, various versions of non-equilibrium fluctuation and fluctuation-dissipation theorems for quantum systems have been discussed. The FQMT'17 conference will follow the discussion of these topics on the FQMT'15 conference and will further support investigations in this direction in order to improve our understanding of these theorems, their use and relations between their various versions for classical and quantum systems. These studies are of key importance since the fluctuations, dissipation and noise are closely related to the performance and the reliability of both artificially created nano-devices as well as natural "engines", as are for example molecular motors in cells.

This theme brings us to the vast field of biophysics. Non-equilibrium processes and the system's environment play a decisive role in the behavior of small structures of living organisms and there are many important questions to be answered before we fully understand the laws which govern the performance of the nanoscopic structures which are essential for life. In this regard, it appears one of the necessary conditions for the proper performance of cells is that their dynamics be based on far from equilibrium states and related nonlinear, non-equilibrium transport. There are also questions about the role of quantum physics in the behavior of various small systems which are essential for living organisms. This brings us to consider under which circumstances quantum effects, coherence, fluctuations and noise have positive or negative influence on a cell's behavior. Therefore, the conference will pay special attention to quantum biology, which is now a re-emerging field dealing with quantum aspects of biological systems. All the above questions and considerations are important not only for an understanding of living organisms, but also for studies of artificially prepared structures which are motivated by nanobiology. In this regard, biomimetics is a quickly developing area of research, which is closely related to the FQMT'17 program.

Behavior of molecular motors and the field of biomimetics are associated with more general considerations related to thermodynamics and the use of various mesoscopic structures. Among the central themes of classical thermodynamics are the concepts of “temperature”, “system”, “reservoir”, and “engine”. Due to quantum features of mesoscopic systems, it is necessary to deal with quantum thermodynamics to discuss possible quantum pumps, heat engines or refrigerators based on features of mesoscopic (molecular) systems. The task of quantum thermodynamics is to provide a good “phenomenological” frame for the “macroscopic” description of open mesoscopic systems coming from more detailed studies of non-equilibrium quantum statistical physics of open systems and the foundations of quantum mechanics. The central question which will also be discussed during the conference is: under which conditions will the thermodynamic behavior still manifest in various small systems.

In general, the above problems arise in dissipation, dephasing and decoherence processes, and, on a very basic level, the foundations of quantum mechanics and related theories of quantum measurement. A better knowledge and insight into the foundations of quantum physics is essential for a proper formulation of the fundamental laws of physics with regard to Bell inequalities and quantum gravity. It is also essential for developing a suitable description of small quantum systems and their applications. This applies particularly to quantum optics and physics of quantum information and computing, where questions of quantum interference, entanglement and decoherence processes, together with knowledge of time scales governing the dynamics of the studied systems, are essential and mutually beneficial.

The above subjects can be well documented by various examples from the physics of quantum computing, information and metrology and the physics of cold atoms and molecules. Many different quantum (two states) systems are nowadays intensively studied in a hope that their parameters and related dynamics will be suitable for quantum computers. There are many candidates: qubits created by electron or nuclear spins; polarization of light or various internal states of systems, realized for example in quantum dots; superconductors (Josephson junction circuits); diamond having nitrogen vacancy centers; doped silicon; fullerenes; trapped ions or atoms coupled to cavities; and Bose-Einstein condensates. An important part of the conference program will be devoted to discussions of the physics of all these systems.

Further included in the conference program are the fields of cosmology, gravitation and particle astrophysics, for the reason that these areas of investigation are strongly related to the foundations of quantum physics, physics of quantum measurement, macroscopic quantum phenomena (e.g. magnetization) and also, mainly due to measurement methods used for observation and detection, to quantum optics, condensed matter physics, and physics of mesoscopic systems.