Frontiers of Quantum and Mesoscopic Thermodynamics (FQMT'19)

14 July (Sunday) – 20 July (Saturday) 2019, Prague, Czech Republic

https://fqmt.fzu.cz/19/

Topics

- Non-equilibrium quantum phenomena
- Foundations of quantum physics
- Quantum measurement, entanglement and coherence
- Dissipation, dephasing, noise and decoherence
- Many body physics, quantum field theory
- Quantum statistical physics and thermodynamics
- Quantum optics
- Quantum simulations
- Physics of quantum information and computing
- 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
- Cosmology, gravitation and astrophysics

Scientific Background

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.

A good understanding of the time evolution of both classical and quantum systems is essential for an explanation of many observations 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. Important problems include such questions as 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. Thus, further experimental as well as theoretical studies of short to long time dynamics (via transport as well as optical properties) and the influence of initial and boundary conditions (e.g. in quenched or annealed systems) are needed.

Mesoscopic systems are of special importance for these studies. Various systems, of natural and artificial origin, can exhibit mesoscopic features depending on inherent inner parameters and interactions with their environment. Typical mesoscopic systems are of nanometer size, enabling fast developing nanoscale technologies for the preparation of structures with well defined inner parameters, providing an enormous diversity of systems subject to interaction with the external environment. Nanoscale structures include not only very small artificially prepared structures, but also structures occurring in living cells, as for example complex molecules, proteins and molecular motors.

Such 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. 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. 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 and quantum measurement processes.

Another challenging problem is stochastic behavior of such systems caused either by innate features of the systems or by noise related to the studied systems being open. Studies of quantum and temperature fluctuations, as well as quantum noise, dephasing and dissipation are of key importance, since these phenomena 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 and processes in cells in general.

Non-equilibrium processes and the system’s environment play a decisive role in living organisms and there are many questions to be answered before we fully understand the laws which govern the performance of the nanometer 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 systems which are essential for living organisms, i.e., under which circumstances quantum effects, coherence, fluctuations and noise can influence a cell’s functions.

Behavior of molecular motors is 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.

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. 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. Various quantum (two states) systems are nowadays intensively studied in a hope that their parameters and related dynamics will be suitable for quantum computers.

Many of the above mentioned problems are also important for such seemingly distant fields as cosmology, gravitation and astrophysics, for the reason that these areas of investigation are strongly related to non-equilibrium statistical physics, many body physics, 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.

Thus, the FQMT'19 program will be focused on conceptual and experimental challenges of non-equilibrium statistical physics, quantum many body physics, quantum thermodynamics, foundations of quantum mechanics, and quantum field theory. 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 also 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, but in fact strongly correlated, 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.