# Plenary, Prize and Evening Talks

## Plenary Talk

PT I Mon 08:30 HSZ 01

**Superfluidity in solid helium and solid hydrogen** — •Moses H.W. Chan — Penn State University, University Park, PA 16802, USA

Recent torsional oscillator measurements of solid helium confined in porous media [1,2] and in bulk form [3] found evidence of non-classical rotational inertia indicating superfluid behavior below 0.2K. Measurements of solid samples at different pressure (and hence different density) allow us to map out the boundary of this supersolid phase. The low temperature supersolid fraction shows a non-monotonic dependence on pressure. It first increases with pressure reaching a maximum of 1.5% near 55 bars and then decreases with further increase with pressure. We have also obtained preliminary results indicating solid molecular hydrogen also exhibit a similar transition, at a much lower temperature and with a much smaller supersolid fraction. This work is done in collaboration with Eunseong Kim, Tony Clark and Xi Lin and it is supported by the (U.S.) National Science Foundation.

[1] E. Kim and M.H.W. Chan, Nature 427, 225 (2004)
[2] E. Kim and M.H.W. Chan, Jour. of Low Temp. Physics, 138, 859 (2005)
[3] E. Kim and M.H.W. Chan, Science 305, 1941(2004)

## Prize Talk

PT II Mon 09:45 ZEU 255

**Biophysics of Cells: Active Matter in Motion** — •Frank Jülicher — Max Planck Institut für Physik komplexer Systeme, Dresden — Träger des Robert-Wichard-Pohl-Preises

A fascinating feature of living cells is their inherently dynamic nature which is exemplified by the ability to generate spontaneous motion. A prototype system to study dynamics and active processes in cells is the cytoskeleton, a complex gel-like filament network which governs the material properties of cells. Complex cellular dynamics is driven by active processes on the molecular scale, for example the action of motor molecules. On the cellular scale, this activity can result in new material properties, emergent collective modes and spontaneous movements which play an important role for processes such as cell locomotion and cell division. Active cellular processes are also directly involved in the amplification of mechanical vibrations by sensory cells of our ear. The nonlinear and active properties of this cellular amplifier are essential to endow the ear with its exquisite abilities to detect sound.

## Prize Talk

PT III Mon 13:15 HSZ 01

**Quantum Dots: Genesis, The Excitonic Zoo and its Applications** — •Dieter Bimberg — Institute of Solid State Physics and Center of Nanophotonics, Technical University Berlin, Hardenbergst.36, Eugene P. Wigner Bld., 10623 Berlin — Träger des Max-Born-Preises

Zero-dimensional structures in semiconductors - quantum dots - resemble in some aspects, like their delta-function density of states, giant atoms in a dielectric cage. Much beyond that they are unique physical systems, since slightest variations of their geometrical properties, their size or shape, change dramatically their electronic and optical properties: The excitonic emission wavelengths are continuously tuneable across large ranges, binding energies of excitonic molecules may change their sign, the excitonic fine structure splitting can be huge, and may change its sign, ...

Self organisation of molecules at surfaces or spinodal decomposition in three-dimensional multernary materials is presently utilized for the creation of QDs. High bit rate and secure quantum cryptographic systems might present some of the first fields of applications of QD-based devices.

## Plenary Talk

PT IV Mon 18:00 HSZ 01

**Nonequilibrium thermodynamics of microscopic systems** — •Christopher Jarzynski — Los Alamos National Laboratory, T-13 Complex Systems MS B213, Los Alamos, NM 87545 USA

In recent years it has been realized that the equilibrium properties of a system are subtly encoded in the fluctuations of the system when it is driven far from equilibrium. I will discuss the theoretical foundations of these results, as well as potential applications to the numerical estimation of free energy differences, and to the analysis of single-molecule experiments.

## Plenary Talk

PT V Tue 08:30 HSZ 01

**Spin Qubits in Nanostructures: Review and Outlook** — •Daniel Loss — Department of Physics, University of Basel, Switzerland

I will give an overview of quantum computing in semiconducting nanostructures based on spin-qubits [1,2], and present the current status of theory and experiment. In GaAs quantum dots, single electrons can be confined, and the qubit is then represented by the spin of this electron. Although the quantum information is stored in the magnetic and not in the charge degrees of freedom of the electron, all basic operations of the qubits, can be implemented by electrical gates—an essential feature for scalability. These operations are single-spin gates, single-spin read out, and controlled spin-spin interactions (two-qubit gates). Interaction gates can be avoided altogether by partial Bell state measurements which can also be implemented by double dot structures [3]. One of the biggest challenges- and physically most interesting aspects- is decoherence. In GaAs structures the known sources for decoherence are spin-phonon processes [4] (via spin orbit interaction) and hyperfine interaction between the electron and about a million nuclear spins in a quantum dot [5]. The nuclear spins generate an extremely rich and complex spin dynamics which cannot be treated with standard rate equations. I will discuss the effects of nuclei in double quantum dots [6,7] where they not only cause decoherence but also provide a means to manipulate the electron spins and, in particular, allow to implement the square-root-of-swap operation needed for XOR, as recently demonstrated experimentally [6]. I will describe nuclear state narrowing, recently proposed [8], which is based on charge measurements forcing the nuclei in a quantum state that can be decoherence free in the ideal limit.

[1] D. Loss and D.P. DiVincenzo, Phys. Rev. A 57 (1998) 120.
[2] For a review, see V. Cerletti et al., Nanotechnology 16 , R27 (2005).
[3] H.-A. Engel and D. Loss, Science 309, 586 (2005).
[4] V. Golovach, A. Khaetskii, and D. Loss, Phys. Rev. Lett. 93, 016601 (2004).
[5] A. V. Khaetskii, D. Loss, and L. Glazman, Phys. Rev. Lett. 88, 186802 (2002); B. Coish and D. Loss, Phys. Rev. B 70, 195340 (2004).
[6] Petta et al., Science 309, 2180 (2005).
[7] B. Coish and D. Loss, Phys. Rev. B 72, 125337 (2005).
[8] D. Klauser, B. Coish, and D. Loss, cond-mat/0510177.

## Prize Talk

PT VI Tue 13:15 HSZ 04

**Glassy Relaxation: a Paradigm for Condensed-Matter Dynamics** — •W. Götze — Theoretische Physik, Fakultät für Physik, Technische Universität München, D-85747 Garching, Germany — Träger der Max-Planck-Medaille

Complex features of the correlation functions and spectra of glass-forming liquids have been identified during the past two decades by experimental and molecular-dynamics-simulation studies. In order to explain these findings, closed non-linear equations of motion have been motivated for a statistical description of the dynamics of strongly-interacting homogeneous matter, which treat density fluctuations and force fluctuation simultaneously. These equations exhibit bifurcations, which all belong to the class of cuspoid singularities. The basic fold bifurcation describes a transition from the dynamics of a liquid to one of an amorphous solid; it deals with an idealized glass transition. The interplay of non-linearities and diverging retardation effects leads to a scenario for a bifurcation dynamics, which has no analogy to the ones studied in other theories of non-linear motion. The basic features of the scenario will be described. Some examples will be shown, which demonstrate the relation between theory and observations made for cooled liquids, concentrated colloids, and dense polymer melts.

## Prize Talk

PT VII Tue 14:00 TRE Phys

**Understanding Scanning Tunneling Microscopy Experiments on Transition-Metal Structures** — •Stefan Heinze — Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg — Träger des Gaede-Preises

Scanning tunneling microscopy (STM) is one of the most important techniques to characterize nanostructures on surfaces with a resolution down to the atomic scale. However, the interpretation of such measure-

ments is not trivial, especially on the atomic scale, due to contributions to the tunneling current from various sources such as structural, electronic, chemical, and magnetic properties. Successful interpretation approaches, e.g. the Tersoff-Hamann model, rely on an accurate description of the electronic structure of the sample. Hence, the combination with modern density functional theory (DFT) calculations has proven a powerful tool for the understanding of STM experiments.

Here, the theory of STM is applied to structures on transition-metal surfaces and a transparent method is introduced to correlate bandstructure features with STM measurements. With this approach surprising effects such as bias-dependent corrugation reversal, imaging of buried nanostructures, and even the detection of small spectroscopic signals due to spin-orbit coupling can be explained based on the electronic structure. Further, the theory of spin-polarized STM (SP-STM) is presented and the potential of SP-STM to unravel complex, e.g. non-collinear, magnetic structures on the atomic scale is demonstrated. A particular striking example is the verification of a two-dimensional antiferromagnetic structure in a monolayer of Fe, the prototypical ferromagnet, on W(001).

## Plenary Talk

PT VIII Wed 08:30 HSZ 01

**Imaging and magnetic characterization of individual nanostructures in a transmission electron microscope (TEM)** — •Josef Zweck, Thomas Uhlig, and Martin Heumann — NWF II - Physik der Universität Regensburg, D-93040 Regensburg, FRG

Magnetic materials are increasingly used for modern devices (sensors, memories, switches etc.) because of their simplicity of operation. These devices promise to be small, fast, cheap and - when used for memories - non-volatile. Then, the question arises whether magnetism in small volumina does still behave the same way as in bulk material. To answer this question, a method is needed which allows to probe each one of these particles individually for their magnetic properties and to be able to in-situ manipulate its state. One of the few techniques capable to do this is Lorentz electron microscopy. Methods and possibilities of modern Lorentz microscopy to measure magnetic properties of patterned materials will be demonstrated. Besides the conventional Fresnel imaging technique, the more advanced techniques of differential phase contrast imaging (DPC) and electron holography are introduced The examples given include a new magnetic ground state, the measurement of hysteresis loops of individual particles, the trapping of magnetic vortices in holes and anisotropy traps as well as thermally assisted switching of pure single domain particles.

## Plenary Talk

PT IX Wed 09:15 HSZ 01

**Coherent Control and Manipulation of Two-Electron Spin States** — •Amir Yacoby — Weizmann Institute of Science, Rehovot, Israel

Entanglement is a fundamental property of quantum mechanics that is recently being harnessed to dramatically improve the acquisition, transmission, and processing of information. Dephasing in mesoscopic systems is intimately connected to entanglement whereby electrons, through unwanted interactions, become entangled with other degrees of freedom such as other electrons or phonons and loose phase coherence. To further the progress in quantum information sciences one must therefore devise ways to generate, control, and manipulate entangled states.

In this talk I shall describe our recent experiments that demonstrate coherent control of two-electron spin states in a double quantum dot allowing state preparation, coherent manipulation, and projective read-out. These techniques are based on rapid electrical control of the exchange interaction. Separating and later recombining a singlet spin state provides a measurement of the spin dephasing time, $T_2^* \sim 10$ ns, limited by hyperfine interactions with the GaAs host nuclei. Using the inevitably present nuclear hyperfine field gradients we demonstrate controlled swap operation between the $|\uparrow\downarrow\rangle$ and $|\downarrow\uparrow\rangle$ spin states. Spin-echo pulse sequences are used to suppress hyperfine-induced dephasing. Using these quantum control techniques, a coherence time for two-electron spin states exceeding 1 $\mu$s is observed.

## Prize Talk

PT X Wed 11:00 HSZ 01

**Magnetoelectric correlations in multiferroics revealed by nonlinear optics** — •Manfred Fiebig — Max-Born-Institut, Max-Born-Straße 2a, 12489 Berlin — Träger des Walter-Schottky-Preises

Recently an enormous interest in multiferroics – compounds uniting two or more forms of long-range ordering in one phase – is observed. The coexistence of magnetic and electric ordering is a particularly promising route to devices with novel "magnetoelectric" (ME) functionalities. Two topics dominate contemporary research: (i) forms of ME coupling between the coexisting ordered states; (ii) ways for ME phase control, like switching the magnetic order by an electric field. I will introduce optical second harmonic generation (SHG) for probing ME correlations in multiferroics. SHG is described by $P(2\omega) = \varepsilon_0\,\chi\,E(\omega)E(\omega)$ with $E(\omega)$ as incident light wave and $P(2\omega)$ as source of a frequency doubled outgoing wave. Since $\chi$ includes magnetic as well as electric contributions, SHG is an ideal tool for studying the magnetic and electric structure with the same setup. Various ME correlations in multiferroic $RMnO_3$ (R = Sc, Y, In, Ho–Lu) will be discussed. These include coupling of magnetic and electric domain walls, induction of ferromagnetism by an electric field, and ultrafast interaction between the ferroelectric and the magnetic subsystems.

## Evening Talk

PT XI Wed 20:00 HSZ 01

**Star Trek – Facts & Fiction** — •Metin Tolan — Universität Dortmund, Fachbereich Physik & DELTA, Experimentelle Physik I, Otto-Hahn-Strasse 4, 44221 Dortmund, Germany

Der große Erfolg von Star Trek und die Faszination, welche die Serie schon seit über 30 Jahren auf viele Menschen ausübt, haben sicher verschiedene Ursachen. Ein Grund für diese Beliebtheit ist die Technik, die dort sehr detailliert und realistisch dargestellt und mit vielen (pseudo-)physikalischen Erklärungen versehen wird. Im Vortrag werden jedoch keine pseudowissenschaftlichen Erklärungen gegeben, sondern es wird der direkte Vergleich zwischen der in Star Trek dargestellten Technik und den realen technischen Möglichkeiten des 21. Jahrhunderts gezogen. Anhand einiger konkreter Beispiele aus dem Star Trek-Alltag werden im ersten Teil technische Entwicklungen aus dem computer- und medizintechnischen Bereich sowie aus der Weltraumforschung vorgestellt. Den Bezugsrahmen bildet der Zeitraum der Erstaustrahlung der Serie. Der zweite Teil des Vortrages widmet sich der Frage, was unser heutiges physikalisches Weltbild zu den faszinierenden Vorgängen des Beamens, des Warp-Antriebs oder des Zeitreisens sagt. Hierbei sollen die hinter diesen Phänomenen steckenden physikalischen Prinzipien erläutert werden. Gefragt wird jedesmal: Was ist machbar? Was verstößt nicht gegen die physikalischen Gesetze? Was muß Phantasie bleiben? Um die diskutierten Themen anschaulich zu präsentieren wird etwa die Hälfte der 90 min Vortragsdauer mit Videosequenzen aus Star Trek gefüllt.

## Plenary Talk

PT XII Thu 08:30 HSZ 01

**Attosecond Physics** — •Ferenc Krausz — Max-Planck-Institut für Quantenoptik, Garching, Ludwig-Maximilians-Universität, München, Germany; Technische Universität Wien, Austria

Fundamental processes in atoms, molecules, as well as condensed matter are triggered or mediated by the motion of electrons inside or between atoms. Electronic dynamics on atomic length scales tends to unfold within tens to thousands of attoseconds (1 attosecond = $10^{-18}$ s). Recent breakthroughs in laser science are now opening the door to watching and controlling these hitherto inaccessible microscopic dynamics.

The key to accessing the attosecond time domain is the control of the electric field of (visible) light, which varies its strength and direction within less than a femtosecond (1 femtosecond = 1000 attoseconds). Atoms exposed to a few oscillations cycles of intense laser light are able to emit a single extreme ultraviolet (xuv) burst lasting less than one femtosecond. Full control of the evolution of the electromagnetic field in laser pulses comprising a few wave cycles have recently allowed the reproducible generation and measurement of isolated 250-attosecond xuv pulses, constituting the shortest reproducible events and fastest measurement to date. These tools have enabled us to visualize the oscillating electric field of visible light with an attosecond "oscilloscope" as well as steering and real-time observation of the motion of electrons in atoms and molecules. Recent experiments hold promise for the development of an attosecond x-ray source, which may pave the way towards 4D electron imaging with sub-atomic resolution in space *and* time.

## Prize Talk

PT XIII Thu 13:15 HSZ 01

**Life in soft elastic shells** — •Erich Sackmann — Professor Emeritus, Physik Department E22, Technische Universität München, Garching, Germany — Träger der Stern-Gerlach-Medaille

Mother nature designed complex biological materials of stunning physical properties. One outstanding example is the cell envelope: a stratified shell composed of multi-component lipid-protein bilayers (the plasma membranes) which is coupled to a quasi-two-dimensional macromolecular

scaffold (the actin cortex). A hierarchical design enables this composite elastic shell to control numerous fundamental life processes. These range from fundamental biochemical reactions such as ATP production in electron transfer chains over the amplification of external signals (triggered by hormones or photons) to cell-cell adhesion and cell locomotion.

The lecture deals with the unique elastic properties of the composite cell envelopes and the control of biological membrane processes by mechanical forces. It focuses on two aspects of this rich playground for physicists. First, the control of the molecular architecture and the transient generation of functional machines within plasma membranes by structural phase transitions, phase separation and the elastic properties of the bilayers are discussed. Secondly, I address the physical basis of cell adhesion by complex interplay of specific forces, generic interfacial interactions and adhesion-induced elastic stresses. Here I discuss the amazing analogy of cell adhesion to first order wetting transitions as an example of the control of life processes by the laws of classical physics. A general aim of the lecture is to point out that the precise measurement of physical parameters is a necessity to gain insight into the complex architecture and function of biological materials.

## Plenary Talk

PT XIV Fri 08:30 HSZ 01

**Optical Microscopy of Single Nano-Objects** — •Michel Orrit — Huygens Laboratory, Leiden, The Netherlands

Far-field optical microscopy and spectroscopy of individual organic molecules and other nanoparticles is relatively non-invasive, but provides first-hand insight into distributions and dynamical fluctuations at nanometer scales. The lecture will illustrate this powerful method with examples from the literature and from our group's recent work. A particulary intriguing observation is the intermittency in the emission intensity of semiconductor nanocrystals and molecules, which follows power laws over a broad range of times. New experimental methods open an ever broadening range of timescales, from the picoseconds of electronic and acoustic relaxation in single metal particles, to days and beyond for the relaxation of dynamical inhomogeneities in supercooled liquids.

## Plenary Talk

PT XV Fri 09:15 HSZ 01

**Translocation and force measurements of DNA molecules in solid-state nanopores** — •Cees Dekker — Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands

Single nanometer-sized pores (nanopores) in an insulating membrane are an exciting new class of nanosensors for rapid electrical detection of and actuation on single biomolecules. I will report (i) our fabrication of solid-state nanopores and translocation measurements of single dsDNA molecules through these pores, and (ii) our recent demonstration of measurements of the force acting on a single DNA molecule that is inserted in the nanopore.

Ad (i): Siliconoxide nanopores are fabricated with single nanometer precision and direct visual TEM feedback. Translocation of double-strand DNA is monitored in the conductance of a voltage-biased pore. We find that DNA molecules can pass the pore both in a straight linear fashion and in a folded state. On molecules with a length from 3,000-100,000 base pairs, we observe a power-law scaling of the translocation time versus length, which we attribute to an effect of the hydrodynamic drag on the section of the polymer outside the pore. Measurements of DNA translocation at various salt concentrations reveal a crossover from a high-salt regime where current dips are seen, to a low-salt regime where current enhancements are observed.

Ad (ii) For force measurements during the voltage-driven translocation of DNA and RNA, we have added an optical tweezer to our setup. With the tweezer, we hold a bead with a DNA molecule attached. Upon insertion of the DNA into the nanopore, the induced bead deflection yields a measure of the local force that acts on the DNA in the pore. The magnitude of the force involved is of fundamental importance in understanding and exploiting the translocation mechanism, yet so far has remained unknown. We obtain a value of 0.24 +/- 0.02 pN/mV for the force on a single DNA molecule, independent of salt concentration. Our data allow the first direct quantitative determination of the effective DNA charge of 0.53 +/- 0.05 electrons per base pair, corresponding to a 73% reduction of the bare DNA charge. Our novel single-molecule technique for local force sensing and actuation bears great promise for biophysical studies, e.g. for the study of DNA-protein binding or unfolding of RNA.