Plenary Talk PV I Mon 9:15 V53.01

How to use dust particles for diagnostics in process plasmas? — •Holger Kersten — Institute of Experimental and Applied Physics, University of Kiel, D-24098 Kiel, Germany

Complex (dusty) plasmas, which can form plasma or Coulomb crystals are at recent a topical research subject in plasma physics. The complexity of dusty plasmas results in complicated interactions at different scales in energy, space, time and mass, which is a subject of investigation in the SFB-TR 24.

Experimental and theoretical studies initiated the idea of using externally injected small particles, which are negatively charged and affected by several forces in plasmas, as micro-probes. From the behavior of the particles in the surrounding plasma local electric fields can be determined (particles as electrostatic probes) [1,2]. Moreover, momentum fluxes in energetic ion beams (particles as force probes) [3] as well as energy fluxes towards the particles (particles as thermal probes) [4] have been studied.

[1] Schubert,G., Basner,R., Kersten,H., Fehske,H., Eur. Phys. J. D 63(2011), 465.

[2] Beckers,J., Ockenga,T., Wolter,M., Stoffels,W.W., vanDijk,J., Kersten,H., Kroesen,G.M.W., Phys. Rev. Lett. 106(2011), 115002.

[3] Maurer,H., Schneider,V., Wolter,M., Basner,R. Trottenberg,T., Kersten,H., Contrib. Plasma Phys. 51(2011), 218.

[4] Maurer, H., Kersten, H., J. Phys. D: Appl. Phys. 44(2011), 174029.

Plenary Talk PV II Tue 8:30 V53.01

Rydberg atoms on the move — •Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden

The combination of Rydberg excitation with very low kinetic energies in an ultracold gas is a new way to create low energy physics. While previously mostly realized through skillfully designed and fabricated quantum dots, well defined electronic low energy systems can be "imprinted" into ultracold gases through the interaction with laser light. This has allowed to realize and study low dimensional condensed matter quantum systems with optical lattices and has also lead to a strong interest of information science in cold Rydberg physics. In these applications the motion of the atoms is mostly an unavoidable perturbation due to "finite temperature".

Here, we will demonstrate that the motion of the atoms can be used to create electronic dynamics closely interwined with atomic motion putting ultracold Rydberg gases into the context of chemical and exciton physics. Indeed, ultralong range molecules exist [1] with unusual properties: They are bound by internal quantum reflection [2] and have a permanent dipole although they are homonuclear [3]. Furthermore, a quantum analogon of Newton's cradle, namely almost lossless excitonic transport of electronic entanglement in an ultracold electronic [4] gas promises future application in information science.

[1] V. Bendkowsky etal., Nature 458, 1005 (2009).

[2] V. Bendkowsky etal., Phys. Rev. Lett. 105, 163201 (2010).

[3] W. Li etal., Science 334, 1110 (2011).

[4] S. Wüster, etal., Phys. Rev. Lett. 105, 0534004 (2010).

Plenary Talk PV III Tue 9:15 V53.01

Attosecond physics: the first decade — •Ferenc Krausz — Max-Planck-Institut für Quantenoptik, Garching, Germany — Ludwig-Maximilians-Universität München, München, Germany — www.attoworld.de

Electron motion and light waves form the basis of life: the microscopic motion of electrons creates light, which supplies our globe with life-giving energy from the sun; electrons transform light into biological energy during photosynthesis and into biological signal endowing us with the capability of seeing the world around us. Upon their motion inside and between atoms, electrons emit light, carry and process information in biological systems and man-made devices; create, destroy, or modify molecules, affecting thereby biological function. Consequently, they are key players in physical, chemical, and life sciences; information, industrial, and medical technologies likewise.

During the past ten years (2001-2011), advances in laser science opened to door to watching and controlling these hitherto inaccessible dynamics: the motion of electrons at the atomic scale and light wave oscillations (being mutually the cause of each other) evolving on attosecond time scales.

Key tools include waveform-controlled few-cycle laser light and attosecond pulses of extreme ultraviolet and soft-X-ray light. They provide a force capable of steering electrons inside and between atoms and a probe for tracking their motion. Insight into and control over microscopic electron motion are likely to be important for developing brilliant sources of X-rays, understanding molecular processes relevant to the curing effects of drugs, the transport of bioinformation, or the damage and repair mechanisms of DNA, at the most fundamental level, where the borders between physics, chemistry and biology disappear. Once implemented in condensed matter, the new technology will be instrumental in advancing electronics and electron-based information technologies to their ultimate speed: from microwave towards light-wave frequencies.

Plenary Talk PV IV Wed 8:30 V53.01

Optische Eigenschaften von Mikropartikeln - Phänomene und Anwendungen — •Andreas Ostendorf — Ruhr-Universität Bochum, Laseranwendungstechnik

Glas- bzw. Polymer-Mikropartikel können unter geeigneter Bestrahlung mit Laserlicht interessante Effekte aufweisen. Abhängig von Eigenschaften wie Größe, Form, Brechungsindex der Partikel in Bezug zur Umgebung, Richtung der einfallenden Strahlung und eingestrahlter Wellenlänge können z. B. optische Resonanzen simuliert, realisiert und experimentell beobachtet werden. Derartige optische Resonanzen mit hohen Gütezahlen lassen sich in vielfältiger Weise für hochgenaue sensorische Anwendungen für verschiedene Messgrößen wie Temperatur, Wellenlänge oder Konzentration von Biomolekülen nutzen. Eine weitere Form der Wechselwirkung ist das Auftreten optischer Kräfte bei starker Fokussierung. Holographisch-optische Pinzetten erlauben dabei nicht nur die berührungslose simultane Manipulation und Ausrichtung von Partikeln; mit entsprechenden Molekülen beschichtete Partikel können auch als Grundbausteine für ein neuartiges optisch basiertes Assemblierungsverfahren für Mikrosysteme verwendet werden. Ähnlich wie bei makroskopischen Montageverfahren können mit dieser Technologie kleinste Bauteile zugeführt, sortiert und verbunden werden.

Plenary Talk PV V Wed 9:15 V53.01

Ultracold polar molecules — •Silke Ospelkaus — Institut für Quantenoptik & QUEST, Universität Hannover, Germany — JILA, University of Colorado, Boulder, USA

Tremendeous progress in the preparation and control of ultracold molecular gases in the quantum regime promises to open exciting new research opportunities. Molecules rotate and vibrate and therefore offer many more quantum degrees of freedom than their atomic counterparts. Polar molecules interact via strong and long-range anisotropic interactions. These unique molecular properties combined with precise control over external molecular quantum degrees of freedom at temperatures close to absolute zero promise to provide largely unexplored novel opportunities. These range from the control of ultracold chemical reactions, precision measurements, strongly correlated novel quantum many-body systems and quantum phase transitions to novel systems for quantum information processing.

In this talk, I will take you on a tour through preparation and control of molecular quantum systems. We will see how ultracold all ground state molecular quantum systems can be efficiently created by means of a controlled chemical reaction at ultracold temperature; we will discuss how these molecular ensembles can be used to probe chemistry in a novel regime where even the smallest chemical reaction barrier exceeds the available thermal energy in the ensemble and how chemical reactions can then be controlled and understood by simple laws of quantum mechanics. Finally, we will discuss prospects of these systems as novel dipolar quantum many-body systems.

Plenary Talk PV VI Wed 10:30 V53.01

Laser Spectroscopy of Hydrogen — •Theodor Hänsch — Faculty of Physics, University of Munich (LMU), Schellingstr. 4, IIIrd floor, D-80799 Munich — Div. Laserspectroscopy, Max Planck Institute of Quantum Optics, Hans-Kopfermann-Str. 1, D-85748 Garching

Spectroscopy of the simple hydrogen atom has provided the rosetta stone for deciphering the strange rules of quantum physics during the first half of the 20th century. Doppler-free laser spectroscopy opened a new chapter in the exploration of hydrogen 4 decades ago. Recent precision measurements of the absolute frequency of the sharp 1S-2S two photon resonance have reached an uncertainty of 4 10-15. The frequency comb technique is enabling a direct comparison with Germany's primary cesium frequency standard at the PTB in Braunschweig via a 900 km optical fiber link. However, the determination of fundamental constants and stringent tests of fundamental physics laws have long been limited by our insufficient knowledge of the rms charge radius of the proton. Recently, a laser measurement of the 2S-2P Lamb shift in muonic hydrogen has yielded an independent precise new value of the proton radius which is 4% smaller than the presently accepted CODATA value. This "proton size puzzle" remains so far unsolved. Planned future spectroscopy of hydrogen and of hydrogen-like muonic helium may uncover some mistake or reveal a dent in the armor of quantum electrodynamic.

Prize Talk PV VII Wed 11:45 V53.01

The quantum way of doing computations — •Rainer Blatt — Institut für Experimentalphysik, Universität Innsbruck, Innsbruck, Österreich — Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Österreich — Laureate of the Stern-Gerlach-Medal

Since the mid nineties of the 20th century it became apparent that one of the century's most important technological inventions, computers in general, and many of their applications could possibly be further enormously enhanced by using operations based on quantum physics.

Computations, whether they happen in our heads or with any computational device, always rely on real physical processes, which are data input, data representation in a memory, data manipulation using algorithms and finally, the data output. Building a quantum computer then requires the implementation of quantum bits (qubits) as storage sites for quantum information, quantum registers and quantum gates for data handling and processing and the development of quantum algorithms.

In this talk, the basic functional principle of a quantum information processor will be reviewed and the ion trap technology for its implementation will be highlighted. In particular, quantum information processing will be illustrated by showing how entanglement is generated and used for computational processes. Aside from their use as quantum computers, such quantum information processors open wide perspectives for applications in many research areas. Examples will be presented for quantum enhanced metrology and quantum simulations.

Prize Talk PV VIII Wed 14:00 V53.01

3D Anderson localization of ultracold atoms in an optical disordered potential — •Alain Aspect — Institut d'Optique, Palaiseau, France — Laureate of the Herbert-Walther-Prize

Anderson localization (AL) is a quantum interference phenomenon proposed to understand how disorder can lead to the total cancelation of electron conduction. Its classical waves counterpart has been studied in acoustics or electromagnetism, but direct observation with particles remains a challenge. I will report on our observation of three dimensional (3D) localization of ultra-cold atoms, in a disordered potential created by a speckle laser field. A phenomenological analysis of our data allows us to identify a localized component and a diffusive component. The localization we observe can be interpreted neither as classical trapping of particles with energy below the classical percolation threshold in the disorder, nor as quantum trapping in local potential minima. In contrast, our data are compatible with the self-consistent theory of AL applied to our specific situation, provided we introduce a heuristic energy shift whose interpretation remains to be elucidated. We will discuss how experimental progress will allow us to have a genuine cold atoms quantum simulator, allowing us to shed light on an emblematic problem of Condensed Matter Physics for which no microscopic exact theory exists.

Prize Talk PV IX Wed 14:45 V53.01

Quantum Effects in Biology — •Martin B Plenio — Institut für Theoretische Physik, Universität Ulm — Blackett Laboratory, Imperial College London — Laureate of the Max-Born-Prize

The determination, description and explanation of physical phenomena in biological systems at the molecular and supra-molecular level represents one of the major challenges in modern science. In this lecture I touch upon two aspects of this problem.

I will explain how quantum control techniques may be used to achieve high performance sensing and imaging devices with atomic scale resolution that may be capable of probing the structure and dynamics of individual proteins under physiological conditions. This in turn may allow us to address unsolved challenges of fundamental research. Amongst these the role of quantum mechanics in biological organisms represents one of the important open questions in modern biology and I will discuss on which level quantum phenomena may be expected to play an important role. In this respect the interplay between quantum coherent evolution and the vibrational environment is of fundamental importance to the quantum dynamics of bio-molecular systems and I will present concrete examples for biological systems where such effects may play a role.

Prize Talk PV X Wed 15:30 V53.01

The size of the proton from laser spectroscopy of an exotic hydrogen atom — •Randolf Pohl[1,3] and Aldo Antognini[2,3] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]ETH Zürich, Switzerland — [3]Laureate of the Gustav-Hertz-Prize

The proton has a finite size because it is a composite system of quarks and gluons. The charge radius Rp of the proton has so far been known only with a low precision of about 1% from both electron scattering and precision spectroscopy of hydrogen.

We have recently determined Rp by means of laser spectroscopy of the exotic "muonic hydrogen" atom [1]. Here, the muon, which is the 200 times heavier cousin of the electron, orbits the proton with a 200 times smaller Bohr radius. This enhances the sensitivity of the muonic atom energy levels to the proton's finite size tremendously. Our new value Rp = 0.84184 (67) fm is ten times more precise than the generally accepted CODATA value, but it differs by 5 standard deviations from it.

A lively discussion about this discrepancy has started, considering bound-state QED, proton shape and structure, the value of the Rydberg constant and even new physics.

[1] R. Pohl, A. Antognini et al., Nature 466, 213 (2010)

Plenary Talk PV XI Thu 8:30 V53.01

THz Spectroscopy: A Novel Experimental Tool to Study Water Network Dynamics — •Martina Havenith — Physikalische Chemie II, Ruhr-Universität Bochum, NC7/74, 44780 Bochum

In recent years a new frequency window has been opened: The THz range. We could demonstrate that THz absorption spectroscopy is a new tool to study waternetwork motions [1]. Thus THz absorption spectroscopy probes sensitively the fast (sub-psec) solvation dynamics around solutes. Accompanying ab initio MD simulation unravel the underlying molecular motions: In contrast to the mid infrared regime -where the absorption peaks can be assigned to intramolecular motions- in the frequency regime below 1000 cm-1 intermolecular motions with concerted particle motions dictate the spectrum [2]. Precise measurements of absorption coefficients of solvated solutes in the THz regime allow now a detailed view on the role of the water for biological function [3].

[1] S. Ebbinghaus, S.J. Kim, M. Heyden, X. Yu, U. Heugen, M. Gruebele, D.M. Leitner, M. Havenith, PNAS USA, 104, 20749 (2006).

[2] M. Heyden, J. Sun, S. Funkner, G. Mathias, H. Forbert, M. Havenith, D. Marx, PNAS 107, 12068 (2010).

[3] M. Grossmann, B. Niehues, M. Heyden, D. Tworowski, G.B. Fields, I. Sagi, M. Havenith (2010), Nature Structural & Molecular Biology, 18(10), 1102 (2011).

Plenary Talk PV XII Thu 9:15 V53.01

Synthetic Quantum Matter under the Microscope — •Markus Greiner — Harvard University

Ultracold atoms in optical lattices enable experimenters to create and study synthetic quantum matter, opening a window into the fascinating world of many-body quantum physics. With quantum gas microscopy we are now able to take the control of atoms in an optical lattice to the next, the ultimate, level of being able to address, manipulate and measure single particles with high fidelity. I will present microscopic studies of strongly correlated quantum matter and the first realization of quantum magnetism in an optical lattice. This work opens a wide range of new possibilities and brings the realization of exotic states of matter within experimental reach.

Evening Talk PV XIII Thu 20:00 V53.01

Superflüssige Gase nahe dem absoluten Temperatur-Nullpunkt — •Wolfgang Ketterle — MIT, Cambridge, USA

Warum kühlen Physiker Materie zu extrem niedrigen Temperaturen? Warum ist es wichtig, Temperaturen zu erreichen, die mehr als eine Milliarde mal kälter sind als der interstellare Raum? In diesem Vortrag werde ich über neue Formen der Materie berichten, die nur bei extrem tiefen Temperaturen existieren. Tiefe Temperaturen öffnen ein Fenster in die Quantenwelt, in der Teilchen sich wie Wellen verhalten und im Gleichschritt marschieren können. Im Jahr 1925 sagte Einstein eine solche neue Form der Materie voraus, aber sie konnte erst 1995 in Labors in Boulder und am MIT verwriklicht werden. Superfluide Atompaare verhalten sich ähnlich wie Elektronen in supraleitenden

Metallen, obwohl ihre Dicht eine Milliarde mal geringer ist. Kalte Atome machen es möglich, Phänomene der Festkörperphysik in Reinform zu simulieren.

Plenary Talk PV XIV Fri 8:30 V53.01

Dynamical and thermal evolution of turbulent interstellar plasmas — •Dieter Breitschwerdt — Zentrum für Astronomie und Astrophysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin

The evolution of most spiral and irregular galaxies is driven by star formation, and therefore depends sensitively on the physical and chemical state of the interstellar medium (ISM). Stars are formed from molecular clouds, representing a gigantic and well-controlled fusion reactor during most of their lifetime. Massive stars end their lives, however, in a catastrophic core collapse supernova event, expelling chemically enriched material into the ISM, and depositing about 10^{44} J in hydrodynamic energy. As a result, the structure of the ISM is thoroughly changed, thereby closing a feedback loop between star formation and the ISM, called the galactic matter cycle. We will show, that the ISM, despite assertions in previous decades, is distributed not into separate phases, but covers a large range of densities and temperatures. As it turns out, high Reynolds number turbulence profoundly affects the ISM state and structure. It will further be shown that the ionization structure is in general out of equilibrium, leading to a spatially and temporally varying cooling function and to emission spectra, sometimes characterized by so-called delayed recombination, which manifests itself by X-ray emission from gas with temperatures as low as 10^4 K. It is argued, that turbulence is the key to our understanding of the ISM plasma in general, and to star formation in particular, and may thus help us to solve one of the long standing problems in astrophysics.

Plenary Talk PV XV Fri 9:15 V53.01

Quantum Opto-Mechanics: How to extend quantum experiments to massive mechanical objects — •Markus Aspelmeyer — Vienna Center for Quantum Science and Technology (VCQ), Faculty of Physics, University of Vienna, Austria

Massive mechanical objects are now becoming available as new systems for quantum science. Quantum optics provides a powerful toolbox to generate, manipulate and detect quantum states of motion of such mechanical systems – from nanomechanical waveguides of some picogram to macroscopic, kilogram-weight mirrors of gravitational wave detectors. Recent experiments, including laser-cooling of massive mechanical devices into their quantum ground state of motion, and demonstrations of the strong coupling regime provide the primary building blocks for full quantum optical control of mechanics, i.e. quantum optomechanics.

This has fascinating perspectives for both applications and for quantum foundations: For example, the on-chip integrability of nano- and micromechanics, together with their flexibility to couple to different physical systems, offers a novel perspective for solid-state quantum information processing architectures. At the same time, the mass of available mechanical resonators provides access to a hitherto untested parameter regime of macroscopic quantum physics via the generation of superposition states of massive systems and of optomechanical quantum entanglement, which is at the heart of Schrödinger's cat paradox. Finally, due to the large mechanical mass, table-top quantum optomechanics experiments even allow to test experimental consequences of theories of quantum gravity.