Plenary Talk PV I Mon 9:00 e415

From Quantum Computers to New Physics Searches using trapped atomic ions — •Roee Ozeri — Weizmann Institute of Science, Rehovot , Israel

Trapped-ions are highly controlled quantum systems. Trapped-ion systems are one of the leading platforms for the realization of a quantum computer and also provide extreme spectroscopic precision and great optical clock-work. In this talk I will describe how methods which are borrowed from the world of quantum computing can be used to increase the coherence time of, sometimes highly correlated, atomic superpositions which in turn leads to greater measurement precision. I will further show how this great spectroscopic precision can be used for new-physics searches

Plenary Talk PV II Mon 9:45 e415

Superfluid Helium Droplets — •Andrey Vilesov — University of Southern California, Los Angeles

Free superfluid helium droplets constitute a versatile platform for diverse experiments in physics and chemistry. In many applications, He droplets serve as an ultracold matrix for spectroscopic interrogation of single molecules, radicals, or ionic species. More recently, superfluid droplets have emerged as unique nano-laboratories for the study of quantum vorticity in finite isolated systems.

In this talk, I will provide a brief historic account of experiments in helium droplets, an introduction to quantum vorticity, and a more detailed discussion of the rotational motion of superfluid helium droplets of a few hundreds of nm in diameter. The droplets are studied by ultrafast x-ray diffraction using a free electron laser. The diffraction patterns provide simultaneous access to the morphology of the droplets and the vortex arrays they host. The rotation of classical viscous and superfluid droplets will be compared.

Plenary Talk PV III Tue 9:00 e415

Potential energy surfaces and Berry phases from the exact factorization: A rigorous approach to non-adiabatic dynamics — •E.K.U. Gross — Fritz Haber Center for Molecular Dynamics, The Hebrew University of Jerusalem, Israel

Some of the most fascinating phenomena in physics and chemistry, such as the process of vision, as well as exciton dynamics in photovoltaic systems occur in the so-called non-adiabatic regime where the coupled motion of electrons and nuclei beyond the Born-Oppenheimer approximation is essential. To tackle the problem we deduce an exact factorization [Abedi et al, PRL 105, 123002 (2010)] of the full electron-nuclear wave function into a purely nuclear part and a many-electron wave function which parametrically depends on the nuclear configuration and which has the meaning of a conditional probability amplitude. The equations of motion for these two wave functions lead to a unique definition of exact potential energy surfaces as well as exact geometric phases and, hence, provide an ideal starting point to study non-adiabatic phenomena. The successful prediction of laser-induced isomerization processes [Agostini et al, JPCL 8, 3048 (2017)], the description of decoherence [Min et al, PRL 115, 073001 (2015)], calculations of the molecular Berry phase beyond the Born-Oppenheimer approximation [Min et al, PRL 113, 263004 (2014)] and accurate predictions of nonadiabaticity in vibrational spectroscopy [Scherrer et al, PRX 7, 031035 (2017); Requist et al, PRB 99, 165136 (2019)] will demonstrate the power of the new approach.

Plenary Talk PV IV Tue 9:45 e415

From Plasma Electrons to Electrons in Quantum Dots: Nanocrystal Growth in Plasmas — •Uwe Kortshagen — University of Minnesota, Mechanical Engineering, 111 Church Street SE, Minneapolis, MN 55455, USA

Chemically reactive nonthermal plasmas are an interesting environment for the growth of nanocrystals. Molecular precursors are dissociated by electron impact reactions and the resulting molecular fragments and radicals, many of them charged, nucleate to form clusters and nanocrystals. Energetic surface reactions can heat these initial clusters to temperatures that exceed the gas temperature by hundreds of Kelvin. This enables plasmas to form crystalline nanoparticles of strongly covalently bonded or ionically bonded materials, many of which require high temperatures for crystallization. This presentation briefly discusses the physics of the plasma nanocrystal growth mechanisms.

Plasmas can be used to produce high quality silicon nanocrystals, also called silicon quantum dots. With the proper surface functionalization such silicon quantum dots exhibit strong photoluminescence, different from bulk silicon material. Solar luminescent concentration is a potential application for these highly luminescent nanocrystals. We recently demonstrated that the indirect bandgap nature of the silicon nanocrystals virtually eliminates reabsorption losses in luminescent solar concentrators, making them a promising materials system for this application.

The ability of plasmas to produce doped nanocrystals has recently enabled new insights into the electronic transport in nanocrystal films, leading to the development of a new theory for the insulator-to-metal transition (IMT) in directly connected nanocrystal networks. This talk will discuss recent progress in achieving the IMT in plasma-produced nanogranular media.

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Prize Talk PV V Tue 18:45 e415

Quantum information processing with macroscopic objects — •Eugene Polzik — Niels Bohr Institute, University of Copenhagen, Denmark — Laureate of the Herbert Walther Award

Single atoms and atom-like particles have always been in the mainstream of quantum information processing and quantum technologies. However, as it has been realized for the first time about twenty years ago, collective quantum states of large many-body quantum systems can be generated and possess some unique properties and advantages. Examples of such systems span from collective spins of large atomic ensembles to motional degrees of freedom of mechanical oscillators. In the talk I will review some of the experiments with macroscopic quantum systems performed at my group over the past two decades. Those include generation of entanglement, quantum teleportation and quantum memory with large atomic ensembles. In the field of quantum sensing and measurement an atomic spin ensemble in magnetic field can play the role of a negative mass reference frame in which simultaneous measurement of position and momentum become possible. Applications of this principle to sensing of magnetic fields, acceleration and even gravitational waves will be briefly discussed.

Plenary Talk PV VI Wed 9:00 e415

On quantum resource theories — •Dagmar Bruss — Institute for Theoretical Physics III, Heinrich-Heine-University Düsseldorf, Germany

In the prospering field of quantum technologies one aims at employing quantum mechanical properties as resources for tasks such as quantum computing, sensing, communication and simulations. In recent years, so-called quantum resource theories have been developed. They provide an elegant tool for quantifying a quantum resource, and for analysing its conversion properties. An overview of the state of the art is given, and the general structure of a quantum resource theory is exemplified via purity and coherence, including an extension of the latter concept to generalised measurements. A direct connection between the resources of coherence and purity is pointed out, and a hierarchy of fundamental quantum resources is established, answering the quest for the most elementary quantum resource.

Plenary Talk PV VII Wed 9:45 e415

Quantum fluctuation mesoscopic approach to Josephson junctions — •Fabio Benatti — Department of Physics, University of Trieste, Strada Costiera 11, I-34151 Trieste, Italy

The quantum features of Josephson circuits are usually studied by modelling them as non-linear quantum oscillators. It will be discussed how such phenomenological approaches can be accounted for by means of the theory of quantum fluctuations applied to the so-called strong-coupling quasi-spin version of the BCS Hamiltonian.

Within this formulation suitable quantum fluctuations, namely sums of microscopic quantum degrees of freedom scaling differently from the classical mean-field limits, provide mesoscopic degrees of freedom. These latter are at the same time macroscopic and behave quantumly; moreover, they evolve in time according to a Hamiltonian able to support a Josephson current.

Evening Talk PV VIII Wed 20:00 e415

Messen und wägen: Vom Urkilogramm zur Quantenphysik als das Maß aller Dinge — •Joachim Ullrich — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Brauschweig, Germany

Von den Ägyptern, Chinesen und Sumerern über Alexander von Humboldt bis zur modernen Industriegesellschaft: Messungen sind die Grundlage einer quantitativen Beschreibung der Natur und insbesondere auch die Voraussetzung für Handel sowie für die Fertigung von Produkten aller Art.

Während früher jede Gesellschaft, jedes Königreich oder Fürstentum eigene Maßverkörperungen besaß, vereinheitlichten die Staaten der Meterkonvention seit 1875 diese „Sprache“. So wurde 1960 das internationale Einheitensystem (SI) eingeführt – eine fundamentale Voraussetzung für den sicheren globalen Warenaustausch.

Basierend auf den revolutionären Ideen von Max Planck und bahnbrechenden Fortschritten in der Metrologie in jüngster Zeit wurde dieses SI 2018 nochmals revidiert und trat im Mai 2019 in Kraft. Mit dem Übergang von Artefakten zu Quanten bildet dieses neue internationale Einheitensystem nun – in den Worten von Max Planck: „für alle Zeiten und Culturen“ – ein stabiles und zukunftweisendes Fundament für Industrie, Handel und Forschung.

Neben einer anschaulichen Vorstellung des revidierten SI gibt dieser Vortrag auch einen Ausblick auf die Zukunft der Zeit. Denn zahlreiche innovative Technologien drängen auf eine Neudefinition der Sekunde, die Wissenschaft, Wirtschaft und Gesellschaft gänzlich neue Perspektiven eröffnen könnte.

Plenary Talk PV IX Thu 9:00 e415

Structured light - structured atoms — •Sonja Franke-Arnold — Physics and Astronomy, University of Glasgow, UK

Complex vector light is recently receiving increased attention, both from a fundamental and applied view point. It formally shares properties of quantum entanglement, it can be focused below the conventional diffraction limit, and it allows us to explore and employ the full mode space available for light-matter interactions. In this talk I will present a simple and efficient method to generate arbitrary vector fields, introduce concurrence as a useful tool to analyse their 'vectorness', and demonstrate their interaction with cold atomic gasses.

Plenary Talk PV X Thu 9:45 e415

Imaging proteins with X-ray free-electron lasers — •Henry Chapman — CFEL DESY, Hamburg, Germany — Department of Physics, Universität Hamburg, Hamburg, Germany — Center for Ultrafast Imaging, Universität Hamburg, Hamburg, Germany

Free-electron lasers produce X-ray pulses with a peak brightness a billion times that of beams at a modern synchrotron radiation facility. A single focused X-ray FEL pulse completely destroys a small protein crystal placed in the beam, but not before that pulse has passed through the sample and given rise to a diffraction pattern. This principle of diffraction before destruction has given the methodology of serial femtosecond crystallography for the determination of macromolecular structures from tiny crystals without the need for cryogenic cooling. Consequently, it is possible to carry out high-resolution diffraction studies of dynamic protein systems with time resolutions ranging from below 1 ps to milliseconds. Even now, a decade after the first experiment at LCLS, we have not fully explored the limits of the technique, nor developed it to its full potential. I will discuss some of those potentials.

Plenary Talk PV XI Fri 9:00 e415

Physics beyond the Standard Model from hydrogen molecules — •Wim Ubachs — Department of Physics and Astronomy, Vrije Universiteit Amsterdam

The hydrogen molecule is the smallest neutral chemical entity and a benchmark system of molecular spectroscopy. The comparison between highly accurate measurements of transition frequencies and level energies with quantum calculations including all known phenomena (relativistic, vacuum polarization and self-energy) provides a tool to search for physical phenomena in the realm of the unknown: are there forces beyond the three included in the Standard Model of physics plus gravity, are there extra dimensions beyond the 3+1 describing space time ? Comparison of laboratory wavelengths of transitions in hydrogen may be compared with the lines observed during the epoch of the early Universe to verify whether fundamental constants of Nature have varied over cosmological time. Details of the precision laboratory experiments on molecular hydrogen, its stable and radioactive isotopic species, as well as the HD+ molecular ion, will be presented.

Plenary Talk PV XII Fri 9:45 e415

Revisiting Light–Matter Interaction at the Microscopic Scale — •Arno Rauschenbeutel — Department of Physics, Humboldt Universität zu Berlin, 10099 Berlin, Germany

The interaction of a single-mode light field with a single atom or an ensemble of atoms is described by a simple Hamiltonian and has been extensively studied. Still, the vector-properties of light in conjunctions with the multilevel-structure of real atoms and their collective response results in rich and surprising physics. In our group, we investigate this subject matter using nanophotonic components, such as subwavelength-diameter optical fibers and whispering-gallery-mode resonators, for interfacing light and atoms. I will present three effects that we recently observed in experiments with these systems and that go beyond the standard description of light–matter coupling. First, light which is tightly confined can locally carry transverse spin angular momentum which leads to propagation direction-dependent emission and absorption of light. Second, when imaging an elliptically polarized emitter with a perfectly focused, aberration-free imaging system, its apparent position differs from the actual position. Third, an ensemble of atoms can change the photon-statistics of light transmitted through the ensemble. There, depending on the number of coupled atoms, a collectively enhanced nonlinearity leads to pronounced bunching or anti-bunching.