Plenary Talk PV I Tue 9:00 Audimax

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

Quantum circuits with Josephson junctions are phenomenologically modelled by non-linear oscillators. These models 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, suitably scaled sums of microscopic quantum degrees of freedom provide collective quantum degrees able to support Josephson currents. Their temperature dependence will be compared with the one provided by Ambegaokar and Baratoff starting form the BCS model.

Plenary Talk PV II Tue 9:45 Audimax

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 hierarchy of quantum resources is established for quantum states with both discrete and continuous variables, answering the quest for the most fundamental resource. Finally, a quantification of necessary quantum resources to observe a certain Bell nonlocality will be presented.

Plenary Talk PV III Wed 9:00 Audimax

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 IV Wed 9:45 Audimax

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

Research on complex vector light has recently seen an explosion of activity, both from a fundamental and applied viewpoint. It mimics properties of quantum entanglement, can be focused below the conventional diffraction limit, and allows us to explore the vectorial nature of light-matter interactions.

In this talk, I will present our techniques to generate and analyse arbitrary vector fields and demonstrate their use in applications ranging from one-shot polarimetry to the detection of magnetic field alignment in an "atomic compass".

Plenary Talk PV V Thu 9:00 Audimax

Potential energy surfaces and Berry phases from the exact factorization — •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, or laser-induced structural phase transitions occur in the so-called non-adiabatic regime where the coupled motion of electrons and nuclei beyond the Born-Oppenheimer approximation is essential. The Born-Oppenheimer approximation is among the most fundamental ingredients of condensed-matter theory and theoretical chemistry. It not only makes computations feasible, it also provides us with an intuitive picture of chemical reactions. Yet it is an approximation. To go beyond it is notoriously difficult because one has to start from the full many-body Hamiltonian of interacting electrons and nuclei. We deduce an exact factorization 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 develop efficient algorithms for the study of non-adiabatic phenomena. The successful prediction of laser-induced isomerization processes, the ab-initio description of decoherence, calculations of the molecular Berry phase beyond the Born-Oppenheimer approximation and accurate predictions of vibrational dichroism will demonstrate the power of the new approach.

Plenary Talk PV VI Thu 9:45 Audimax

Atoms in a Propagating Light Field – be Prepared for the Unexpected — •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 governed by conceptually simple equations and has been extensively studied. Nevertheless, the vectorial properties of light combined with the multilevel structure of real atoms and their collective response yield rich and surprising physics. In our group, we are investigating this topic using nanophotonic components, such as subwavelength-diameter optical fibers and whispering-gallery-mode resonators, to couple light and atoms. I will present three effects that we have 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 significantly from the actual position. Third, an ensemble of atoms can change the photon statistics of laser light transmitted through the ensemble, yielding pronounced bunching or anti-bunching. Interestingly, these effects are not limited to a nanophotonic setting and even occur for freely propagating light fields.

Evening Talk PV VII Thu 19:00 PEL

Messen und wägen: Vom Urkilogramm zur Quantenphysik als das Maß aller Dinge — •Joachim Ullrich — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Brauschweig, Germany — Laureate of the Stern Gerlach Medal 2021

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 VIII Fri 9:00 Audimax

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 IX Fri 9:45 Audimax

Precision metrology of molecular hydrogen for tests of fundamental physics — •Wim Ubachs — Department of Physics and Astronomy, VU University Amsterdam, Netherlands

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. A variety of results are obtained: (1) Dissociation limits of H2 and D2 are measured to 10-digit accuracy; (2) Measurement of H2 shape resonances lead to an accurate determination of the scattering length of H + H collisions; (3) Measurements are being extended to radioactive tritium species; (4) Measurement of a vibrational splitting in the HD+ molecular ion yield the most accurate value for the proton-electron mass ratio.