Plenary Talk PV I Mon 8:30 Audimax

Meeting the Energy Challenge — •Steve Chu — Stanford University

Science and technology has profoundly transformed the lives of much of humanity. The industrial and agricultural revolutions are also changing the future destiny of the world. I will discuss the necessity, challenges, and opportunities in innovation and policy that will be needed to transition to a sustainable future.

Plenary Talk PV II Mon 9:15 Audimax

Reverse-engineering quantum theory: (anti-)matter waves, interferometry, and clocks — •Holger Müller — University of California, Berkeley

Interpreting quantum mechanics still holds profound mysteries. Finding alternative formulations is one way to improve our understanding. We will discuss the "clock picture": Matter-wave packets are viewed as oscillators at the Compton frequency mc^2/h that are red-shifted and time-dilated by gravity and relative motion (m is the particle mass). From this picture, one may use path integrals to obtain the Schrödinger equation for spinless, slow particles in weak gravity. Starting with a relativistic ansatz, however, should be a way to obtain a relativistic result. We will extend the clock picture and derive the Dirac equation for particles with spin, of any velocity, in curved-space time, with and without electromagnetic fields. All results are shown to agree with quantum mechanics. The clock picture is not just valid, but indeed powerful enough to re-derive the theory.

The talk will give an overview of experiments that were inspired by this picture: tests of the equivalence principle at 10^{-9} accuracy; a clock that measures time by the Compton frequency of cesium atoms; and a realization of the unit of mass with state of the art precision. Moreover, I will present our ongoing measurement of the fine structure constant. At 2×10^{-9} accuracy, it has been the world's third best. We have since reduced the leading systematic error about 8-fold and the statistical error about 10-fold. As an outlook, we will discuss atom interferometry in space, with antimatter, and for gravitational wave detection.

Plenary Talk PV III Tue 8:30 Audimax

Research Data Infrastructures – Challenges, Desires, Incentives — •Maik Thomas — Helmholtz-Centre Potsdam, GFZ German Research Centre for Geosciences

New scientific instruments, such as sensor networks, satellites, telescopes and supercomputers, are generating vast amounts of data providing one of the most important pillars for scientific findings and supporting progressively decision-making processes. Although research data acquisition is generally associated with large technical, staff, and thus financial investments, the information content of resulting data products is often not fully exploited due to restricted access, deficiencies in documentation, or limited availability. After a long lasting fragmentation of science into more and more specialized research fields, present scientific challenges increasingly demand overcoming of frontiers separating scientific disciplines. In particular, substantial progress in modern information technologies supports this linking and, in principle, promotes the achievement of new synergetic effects. However, multi-disciplinary synergies and improvement in efficiency imply that research data are easily accessible and comprehensibly documented in order to be usable for a broad community outside of the specific subject area. This gains in importance considering that the spectrum of transdisciplinary benefit of research data is generally not obvious at the time of their generation. Although scientists are becoming more and more aware of the need for sustainable data handling and numerous data policies and strategies have been developed, the realization mainly depends on appropriate incentives for parties involved in data generation.

From the perspective of a scientist producing large amounts of data the talk outlines requirements concerning the development of future research data infrastructures and tries to identify prospects for the motivation of scientists to make their contribution to sustainable handling of research data.

Plenary Talk PV IV Tue 9:15 Audimax

Isotopic Microprobe Mass Spectrometry — •Michael J. Pellin — Materials Science Division, Argonne National Laboratory, IL, USA

Technological advances in analytical methods enable discovery. Lippershey and Janssen's conversion of their telescopes to optical microscopes enabled Hooke and van Leeuwenhoek to investigate biological structures and to discover micro-organisms. Similar statements can be made about the electron and scanning probe microscopes. Microprobe mass spectrometry instrumentation has undergone a similar transformation with the advent of new, bright, stable ion sources that allow probing ever smaller voxels of matter. We will review these advances focusing on a unique application - the study or presolar grains. These mesoscale refractory grains are thought to have condensed around dying stars and were trapped in primitive meteorites during our solar systems formation. The objects are challenging to investigate since each tells a unique story of its original star and analysis is atom limited, requires high lateral resolution, and needs isotopic precision. These smallest objects are our only samples of other stars and the research again connects astronomy and microscopy.

Evening Talk PV V Tue 20:00 Audimax

Das Higgs-Teilchen: Unsichtbares sichtbar und Unmögliches möglich machen — •Felicitas Pauss — ETH Zurich, Switzerland — Lise-Meitner-Lecture

Nach jahrzehntelangen Anstrengungen ist es 2012 gelungen, das Higgs Teilchen, eines der meist gesuchten Teilchen in der Wissenschaftsgeschichte, mit den ATLAS und CMS Experimenten am Large Hadron Collider (LHC) am CERN in Genf nachzuweisen. F. Englert und P. Higgs wurden für ihre theoretischen Arbeiten auf diesem Gebiet, die sie vor ungefähr 50 Jahren durchführten, 2013 mit dem Nobelpreis in Physik ausgezeichnet.

Die Entdeckung dieses Teilchens - ein Meilenstein in der Physik - könnte ein Kapitel der Physik schliessen, das vor einem halben Jahrhundert begann. Aber es könnte auch eine völlig neue Ära in unserem Verständnis des Universums eröffnen.

Der Vortrag beleuchtet den gegenwärtigen Stand und die Zukunftsperspektiven dieser faszinierenden Forschung und illustriert auch die Bedeutung des Higgs Teilchens. Der Zusammenhang zwischen Grundlagenforschung und Innovation spielt dabei eine genauso wichtige Rolle wie grosse internationale Kollaborationen.

Plenary Talk PV VI Wed 8:30 Audimax

Sharp versions of Heisenberg's error-disturbance trade-off — •Reinhard Werner — Institut für Theoretische Physik, Leibniz Universität Hannover

Quantum mechanics textbooks usually explain and prove the uncertainty relation as an inequality on the variances of two canonically conjugate observables in the same state. However, this does not cover the scenario which is most prominent in Heisenberg's 1927 paper: a "gamma ray microscope" in which an approximate position measurement disturbs the conjugate momentum. In this talk I will show how to set up and prove a quantitative and general uncertainty relation for error and disturbance in Heisenberg's scenario and for more general joint measurements of canonically conjugate observables. This is in apparent contradiction to a recent claim by Ozawa and coworkers, of having experimentally refuted Heisenberg's relation, so I will comment on the different approaches.

The talk emphasizes conceptual issues: One should not think of "the uncertainty relation" in the singular, but rather in the plural, as a group of results differing in the scenario they address, but also in the mathematical terms employed to quantify "uncertainty". Quantitative relations, as opposed to hand waving order of magnitude arguments, are increasingly of interest as more and more experiments approach the uncertainty-limited regime. As an example I will discuss the use of entropic uncertainty relations with side information in security proofs of quantum cryptography

Plenary Talk PV VII Wed 9:15 Audimax

Resolving and manipulating attosecond processes via strong-field light-matter interactions — •Nirit Dudovich — Weizmann Institute of Science, Departement of Physics of Complex Systems, Rehovot, 76100, Israel

The interaction of intense light with atoms or molecules can lead to the generation of extreme ultraviolet (XUV) pulses and energetic electron pulses of attosecond (10-18) duration. The advent of attosecond technology opens up new fields of time-resolved studies in which transient electronic dynamics can be studied with a temporal resolution that was previously unattainable. I will review the main challenges and goals in the field of attosecond science. As an example, I will focus on recent experiments where the dynamics of tunnel ionization, one of the most fundamental strong-field phenomena, were studied. Specifically, we were able to measure the times when different electron trajectories exit from under the tunneling barrier created by a laser field and the atomic binding potential. In the following stage, subtle delays in ionization times from two orbitals in a molecular system were resolved. These experiments provide an additional, important step towards achieving the ability to resolve multielectron phenomena – a long-term goal of attosecond studies.

Plenary Talk PV VIII Wed 12:10 Audimax

Quantum Nano-Optics — •Jelena Vuckovic — Stanford University

By embedding a single quantum emitter inside a nanoresonator that strongly localizes optical field, it is possible to achieve a very strong light-matter interaction. The strength of this interaction is characterized by the coherent emitter-field coupling strength (g), which increases with reduction in the optical mode volume and which also sets the limit on the operational speed of such a system. While in systems consisting of a single neutral atom coupled to a cavity maximum $g/(2\pi) = 20$ MHz has been demonstrated, quantum dots inside photonic crystal cavities have reached $g/(2\pi) = 40$ GHz. Such a quantum dot-nanocavity platform has also been employed in a series of quantum and nonlinear optics experiments at the single or few photons level, that are of importance for applications ranging from all optical computing and optical interconnects, to bio-sensors and quantum repeaters.

Considering that the speed of each of these elements is ultimately limited by g, it is worthwhile building structures that localize light into volumes even smaller than those of photonic crystal cavities (typically on the order of a cubic optical wavelength). In nano-metallic and metamaterials cavities, light can be squeezed into volumes that are a few orders of magnitude times smaller than those of photonic crystal cavities, opening a new field of quantum metaphotonics. As an example, a silver nano-cavity was used to demonstrate a strong interaction with a single quantum dot, with coherent coupling strengths exceeding 100GHz.

Evening Talk PV IX Wed 20:00 Audimax

Wege durch die Quantenwelt – neue Experimente zur Welle-Teilchen Dualität massiver Materie — •Markus Arndt — Fakultät für Physik der Universität Wien

Es wird zuweilen behauptet, die Welt der Atome und Moleküle sei seltsam, denn dort regiere die Quantenphysik. Dort können Objekte in Zustände geraten, die uns im Alltag logisch verboten erscheinen.

Ein Schlüsselphänomen der Quantenmechanik ist die Dualität der Materie: sie erscheint uns oft in Form wohldefinierter Teilchen, die man unter dem Mikroskop sichtbar machen kann. Jedes von ihnen für sich muss aber auch unter geeigneten Umständen durch eine weit delokalisierte Quantenwelle beschrieben werden, die auch Orte „erkunden“ kann, die nach klassischer Logik nie erreichbar wären.

Was bedeuten dann aber Logik, Realität, Raum oder Zeit? Warum tun wir uns mit diesen Begriffen im Laborexperiment so schwer, wenn uns doch die Alltagswelt so „normal“ erscheint? Sind das alles rein akademische Fragen oder haben die Besonderheiten der Quantenphysik auch praktische Anwendungen?

Wir werden beim virtuellen Rundgang durch ein modernes Labor der Molekülinterferometrie versuchen, zu verstehen, wie man sich experimentell der Frage nähern kann, was die Quantenphysik der Materie bedeutet, ob es denn überhaupt eine fundamentale Grenze zwischen Mikrokosmos und Alltagswelt gibt und welche modernen Anwendungen sich aus der Quantendualität von Welle und Teilchen ergeben.

Plenary Talk PV X Thu 8:30 Audimax

Atomic and Molecular Reactions in Slow-Motion: Time-Resolved Experiments with XUV and IR Laser Pulses — •Robert Moshammer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Advances in IR laser-technology and in the generation of intense XUV and X-ray radiation open new avenues for experiments on the dynamics of atoms and molecules in ultra-short light pulses. At present, laser pulses with durations of only a few femtoseconds (5-20 fs) down to the attosecond regime can be produced. The combination of these new sources with many-particle imaging spectrometers (so-called reaction microscopes) for the coincident detection of ions and electrons enable detailed studies at light intensities of 10^{14} W/cm^2 or more and thus reveal insight into the coupling of light with matter. How does an atom absorb two or more photons from an intense laser pulse, and how is the energy released after the interaction? This and other fundamental processes are subject of ongoing research. Pump-probe experiments with molecules allow the observation of rotational, vibrational and electronic excitations with unprecedented resolution and in real time, and time-resolved experiments with molecules using intense fs XUV Laser pulses are very first steps towards the visualization of fundamental molecular reactions. The general physical and technical concepts will be discussed and recent results will be presented.

Plenary Talk PV XI Thu 9:15 Audimax

Relativistic Geodesy with Optical Clocks — •Tanja E. Mehlstäubler — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Time and frequency are the most accurately measurable quantities today. In particular, optical atomic clocks, which have the potential to reach relative frequency inaccuracies as low as 10^{-18} [1,2], open up new fields of fundamental and applied research. The dependence of the atomic frequencies on the gravitational potential makes atomic clocks ideal candidates for the search for deviations in the predictions of Einstein's general relativity, tests of modern unifying theories and the development of new sensors for gravity.

In my talk, I will introduce the concepts of optical clocks and present the current status of international clock development and comparison. Further on, I will discuss the status of some fundamental tests of our standard model by means of high-precision spectroscopy and future applications of time and frequency metrology. Besides further improvement in stability and accuracy of today's best clocks, a large effort is put into increasing the reliability and technological readiness for field missions with compact, portable devices. In the near future, optical clocks are foreseen to contribute together with satellite missions to the precise determination of the Earth's geoid [3] with a height resolution on the *cm*-level.

[1] C.W. Chou, D.B. Hume, J.C.J. Koelemeij, D.J. Wineland, and T. Rosenband: Frequency Comparison of Two High-Accuracy Al$^+$ Optical Clocks, *Phys. Rev. Lett.* **104**, 070802 (2010).
[2] B. J. Bloom, T. L. Nicholson, J. R. Williams, S.L. Campbell, M. Bishof, X. Zhang, W. Zhang, S. L. Bromley, and J. Ye: An Optical Lattice Clock with Accuracy and Stability at the 10^{-18} Level, arXiv:1309.1137 (2013).
[3] E. Mai: Time, Atomic Clocks, and Relativistic Geodesy, *DGK*, Reihe A, **124** (Beck, München 2013), http://dgk.badw.de/_leadmin/docs/a-124.pdf

Evening Talk PV XII Thu 20:00 Audimax

The Scientists Go to War: Questions, Contexts and Consequences, 1914-1918 — •Roy MacLeod — University of Sydney — Max-von-Laue-Lecture

In August 2014, the world will commemorate the outbreak of the Great War of 1914-18. The occasion will cause many to rethink the causes and the consequences of the war for our time. For many, the war was a catalyst of modernity, and in the popular phrase, 'the cause of nowadays'. Looking back, it was also the first installment of what historians have come to call the Great World War, 1914-45. From the global struggle, emerged one great idea among many: victory was destined to favor those best able to communicate, cooperate, and innovate in the mobilization and management of resources and the applications of science.

This task fell largely, and most often, to a generation of scientists and scholars who saw a role for science and culture in nationalism and nation-building. The first international war to engage the entire industrial world quickly challenged established Enlightenment ideals of fraternity, internationality, and communality. Crusading, often ahead of their political and military leadership, scientists won praise for their patriotic service. Afterwards, many saw the war – all war – as a heart-rending waste of talent and resources; for others, however, it was an opportunity to show what science could do. As Emil Fischer put it, 'modern warfare draws its means from the progress of the sciences'. And for George Ellery Hale, Foreign Secretary of the US National Academy of Sciences, the war was 'the greatest chance we ever had to advance research'.

This presentation will outline leading features of the 'scientific war' between 1914-1918 and will reflect on the war's effect on redrawing the scientific landscape, revising pre-war hegemonies, and inaugurating a vision of scientific internationalism that was, in the end, to fail before it could succeed. It is in this wider context that we find the war's most enduring contributions to the changing social role of modern science.

Plenary Talk PV XIII Fri 8:30 Audimax

From Astrophysics to Life: The Making of Habitable Planets — •Manuel Güdel — University of Vienna, Vienna, Austria

More than one thousand extrasolar planets have been firmly detected, and the search is on for Earth-like planets potentially maintaining conditions conducive to the formation and evolution of life. But what makes a planet habitable? In search of life-friendly conditions on other planets, we follow the water, the all-important liquid for life as we know it. Where does this water come from, how does it get onto Earth-like planets, and how long does it stay there? Our search takes us back to the earliest moments of planet formation in protoplanetary gas and dust disks around young stars where water abounds. Liquid water needs to be incorporated into growing planets, probably necessitating complex transport mechanisms in disks. But even so, planetary surfaces are at the mercy of hostile conditions in a stellar environment dominated by plasma flows, high-energy particles, ultraviolet and X-ray radiation orders of magnitude stronger than seen around our present-day Sun. A delicate balance between properties of the host star, the planet, its interior, and its atmosphere may pave the way to habitability, or else a hostile planetary environment will prevail. Understanding astrophysical conditions for planetary habitability has only just begun.

Plenary Talk PV XIV Fri 9:15 Audimax

Quantum networks based on diamond spins: from long-distance teleportation to a loophole-free Bell test — •Ronald Hanson — Delft University of Technology

The realization of a highly connected network of qubit registers is a central challenge for quantum information processing and long-distance quantum communication. Diamond spins associated with NV centers are promising building blocks for such a network as they combine a coherent optical interface (similar to that of trapped atomic qubits) with a local register of robust nuclear spin qubits [1]. At the same time, the excellent control of NV centers allows for testing and demonstrating fundamental concepts in physics such as qubit steering by adaptive partial measurements [2].

Here we present our latest progress towards scalable quantum networks. We have recently realized deterministic teleportation between long-lived qubits residing in independent setups [3]. The teleportation exploits entanglement between distant NV electronic spins that is generated through spin-photon entanglement and subsequent photon detection [4]. By encoding the source state in a separate qubit (a single nuclear spin) we realize a Bell state measurement that distinguishes between all four outcomes in a single shot. Analysis shows that the obtained fidelities are in principle high enough for a loophole-free violation of Bell's inequalities.

[1] T. H. Taminiau et al., Nature Nanotechnology (in press), see arXiv:1309.5452.
[2] M.S. Blok et al., Nature Physics (in press), see arXiv:1311.2899.
[3] Pfaff et al., in preparation.
[4] H. Bernien et al., Nature 497, 86 (2013).