Plenary Talk PV I Mon 8:30 B Audimax
Learning and artificial intelligence in the quantum domain — •Hans J. Briegel — Institut für Theoretische Physik, Universität Innsbruck

Quantum mechanics has changed the way we think about the scope and possibilities of information processing, and the foundations of computer science. Recently researchers have started to apply ideas from quantum information to machine learning, and even commercial companies are pursuing research efforts in this direction.

In this talk, I will discuss possible future roles of quantum information for artificial intelligence, and vice versa. These include the use of learning agents in quantum physics laboratories, as well as the use of quantum information in machine learning and artificial-agent design. I will focus on the model of projective simulation (PS), which employs random-walk processes in the agent's memory for learning and decision-making. Projective simulation has been applied, e.g., in autonomous robotic playing and in the design of quantum experiments. The PS model can be naturally quantized, allowing for a quantum speed-up of the agent's decision process. I will review some recent results of our research on (classical and) quantum-enhanced learning agents, including applications in quantum experiment and quantum foundations.

Plenary Talk PV II Mon 9:15 B Audimax
On the road towards an Optical Nuclear Clock: What do we know about the elusive 229-Thorium isomer ? — •Peter G. Thirolf — Ludwig-Maximilians-Universität München, Garching, Germany

Today's most precise time and frequency measurements are performed with optical atomic clocks. However, it has been proposed that they could potentially be outperformed by a nuclear clock, which employs a nuclear transition instead of an atomic shell transition. There is only one known nuclear state that could serve as a nuclear clock using currently available technology, namely, the isomeric first excited state of 229Th. Since 40 years nuclear physicists have targeted the identification and characterization of the elusive isomeric ground state transition of 229mTh. Evidence for its existence until recently could only be inferred from indirect measurements, suggesting an excitation energy of 7.8(5) eV. Thus the first excited state in 229Th represents the lowest nuclear excitation so far reported in the whole landscape of known isotopes. Recently, the first direct detection of this nuclear state could be realized via its internal conversion decay branch, which confirms the isomer's existence and lays the foundation for precise studies of its decay parameters, in particular its half-life, excitation energy and nuclear structure. This would pave the way towards an all-optical control and thus the development of an ultra-precise nuclear frequency standard. Moreover, a nuclear clock promises intriguing applications in applied as well as fundamental physics, ranging from geodesy and seismology to the investigation of possible time variations of fundamental constants.

Plenary Talk PV III Tue 8:30 B Audimax
Rydberg Dipole-Dipole Energy Transfer from 300K to 300μK — •Thomas Gallagher — University of Virginia

A gedanken experiment, tuning the energy levels of two atoms to observe sharply resonant energy transfer, can be realized using Rydberg atoms, due to their large electric dipole moments. The dipole moments provide large Stark shifts, for tuning, and a strong coupling between the interacting atoms, allowing energy transfer to occur. The basic notions of these dipole-dipole interactions are illustrated by collision experiments with thermal, ~300K, beams of atoms. Collisions with cross section σ~109 Å2 and duration τ~1 ns are observed, a time long enough that we can easily perturb the atoms during a collision. Reducing the temperature to ~1 K, leads to even larger cross sections, but more interesting, to collisions of duration τ ~1 μs, a time long enough that we can know when individual collisions start and end. The use of a magneto optical trap, with τ ~ 300 μK, takes the atoms into a new regime, in which the atoms do not move on the 1 μs time scale of interest. The interactions are between static atoms, as in an amorphous solid. More generally, the strong dipole-dipole interactions of cold Rydberg atoms have suggested many fascinating new avenues of research.

Plenary Talk PV IV Tue 9:15 B Audimax
The dimer-approach to characterize opto-electronic properties of organic semiconductors — •Bernd Engels — Institut für Physikalische und Theoretische Chemie, Universität Würzburg

Spectroscopic approaches are essential for an understanding of the electronic structure and properties of organic semi-conductors but the information are often ambiguous. Hence, for the assignment of the spectra theory is necessary but depending on the underlying approach, the simulations are contradictory too. In this talk, we will describe the so-called dimer-approach [1] and provide a few examples in which this approach could successfully assign absorption as well as emission spectra [2,3] and could delivered an atomistic picture of photo-induced relaxation effects in perylene-based materials. The model Hamiltonians of standard monomer-based approaches are also briefly discussed to reveal the differences between both methods and to shed some light on their strengths and shortcomings. Finally, we will compare both approaches in their description of amorphous materials.[4]

[1] B. Engels, V. Engel PCCP 2017, 19, 12604-12619.

[2] D. Bellinger, J. Pflaum, C. Brüning, V. Engel, B. Engels PCCP 2017 19, 2434

[3] V. Settels, A. Schubert, M. Tafipolski, W. Liu, V. Stehr, A. K. Topczak, J. Pflaum, C. Deibel, R. F. Fink, V. Engel, B. Engels J. Am. Chem. Soc. 2014, 136, 9327-9337

[4] C. Brückner, M. Stolte F. Würthner, J. Pflaum, B. Engels J. Phys. Org. Chem. 2017; 30; e3740

Lunch Talk PV V Tue 13:00 K 2.020
Vom Doktorhut zum Vorstandshemd: Physiker können auch Unternehmer — •Wilhelm Kaenders — Gründer und Vorstand TOPTICA Photonics AG, Lochhamer Schlag 19, 82166 Graefelfing

Der promovierte Physiker leitet mit einem Partner seit zwanzig Jahren ein mittleres Unternehmen und vertreibt Lasergeräte für die Forschung und industrielle Anwendung. Dass gerade die Physik der kalten Atome en vogue war oder dass er sein Unternehmen in Boomzeiten der New Economy startete, begünstigten den anfänglichen Geschäftserfolg. Die TOPTICA Photonics AG (230 Mitarbeiter) nutzt die dt. Forschungslandschaft für Laserpräzisionstechnologie in globalen Märkten. Angetrieben durch die Physik-Nobelpreise hat sich ein weltweiter Markt entwickelt: Ionen- und Atomfallen, interferierende Atomwolken und Quantencomputer werden weltweit mit TOPTICA-Produkten erzeugt und gebaut. Wo zuerst Frequenzen "geteilt" wurden, werden sie heute zunehmend mit TOPTICA-Lasern "gekämmt". Unsere Laser sind beteiligt an der Spektroskopie von Antimaterie, aber auch der Suche nach der Supersymmetrie. Die Firma erzielt Wachstumsraten von etwa 15%/Jahr und beschäftigt alleine in Deutschland 65 Physiker.

Evening Talk PV VI Tue 18:30 B Audimax
Physik und Medizin: von einzelnen Atomen im Vakuum zu einzelnen Proteinen in lebenden Zellen — •Vahid Sandoghdar — Max-Planck-Institut für die Physik des Lichts, Erlangen — Friedrich Alexander Universität, Erlangen

Proteine sind allgegenwärtige und bilden einige der wichtigsten Bestandteile einer biologischen Zelle. Ihre Struktur und Dynamik spielen eine entscheidende Rolle für ihre Funktion. Diese Prozesse können auf einer Zeitskala zwischen Nanosekunden bis hin zur Minuten oder Stunden ablaufen. Die Untersuchung von einzelnen Proteinen mit sehr hoher räumlicher als auch zeitlicher Auflösung verspricht dabei viele neue Erkenntnisse. In diesem Vortrag werfen wir einen Blick auf die aktuellen Entwicklungen verschiedener optischer Methoden der letzen zwei Jahrzehnte ein, die neue Einblicke im Bereich der Life Sciences ermöglicht haben. Häufig werden hierbei die Methoden und Konzepte der experimentellen Physik genutzt um aufregenden und noch offene Fragestellungen aus der medizinischen Grundlagenforschung zu beantworten. Anhand neuester Ergebnisse aus unserem eigenen Labor zeige ich wie wir Techniken der Tieftemperatur-Mikroskopie und der Interferometrie nutzen, um neues Licht auf die Struktur und Dynamik von Proteinen zu werfen.

Plenary Talk PV VII Wed 8:30 B Audimax
Ultrafast nonlinear optics in the mid-infrared: Expanding the realm of optical physics — •Aleksei Zheltikov — Physics Department, International Laser Center, M. V. Lomonosov Moscow State University — Department of Physics and Astronomy, Texas A&M University — Russian Quantum Center

Motivated and driven by numerous applications and long-standing challenges in strong-field physics, molecular spectroscopy, semiconductor electronics, and standoff detection, ultrafast optical science is rapidly expanding toward longer wavelengths. Recent breakthroughs in laser technologies enable the generation of few- and even single-cycle mid-IR field waveforms within a broad range of oeak oiwers and central wavelengths. Experiments with such mid-IR sources help understand complex interactions of high-intensity ultrashort mid-IR pulses with matter, giving rise to unique regimes of laser-matter interactions and revealing unexpected properties of materials in the mid-infrared. High-power mid-IR soliton transients and laser filaments in air demonstrated in recent experiments set new milestones in the 1000-year history of atmospheric optics, opening new horizons in high-power laser signal transmission and remote sensing of the atmosphere. Below-the-bandgap high-order harmonics generated by ultrashort mid-infrared laser pulses are shown to be ideally suited to probe the nonlinearities of electron bands, enabling an all-optical mapping of the electron band structure in bulk solids. This talk will offer an overview of recent discoveries in this field of research, which lead us to rethink the limits of the rapidly expanding realm of nonlinear optical physics.

Plenary Talk PV VIII Wed 9:15 B Audimax

Quantum metrology gets real — •Konrad Banaszek — Centre of New Technologies, University of Warsaw, Warsaw, Poland

Quantum physics holds the promise of enhanced performance in metrology and sensing by exploiting non-classical phenomena such as multiparticle interference. Specific designs for quantum-enhanced schemes need to take into account noise and imperfections present in real-life implementations. This talk will review selected recent results in realistic quantum metrology, starting from interferometric phase estimation with common impairments, such as photon loss, and ending with general scaling laws implied by the geometry of quantum channels. In many practical situations, although qualitatively improved asymptotic scaling of ideal noise-free protocols is lost, quantum physics can offer performance beyond the standard shot noise limit. As a concrete example, the fundamental quantum interferometry bound is compared with the recently achieved sensitivity of the squeezed-light-enhanced GEO600 gravitational wave detector, indicating nearly optimal operation given the present amount of optical loss. Finally, the potential of mode-engineering techniques for quantum-enhanced sensing is highlighted.

Prize Talk PV IX Wed 11:20 B Audimax

Gravitational Wave Astronomy: Listening to the sounds of the dark universe! — •Karsten Danzmann — Albert-Einstein-Institut, Hannover

For thousands of years we have been looking at the universe with our eyes. But most of the universe is dark and will never be observable with electromagnetic waves. Since September 14th, 2015, everything is different: Gravitational waves were discovered! We have obtained a new sense and finally we can listen to the dark side of the universe. The first sounds that we heard were from unexpectedly heavy Black Holes and Neutron Stars. But nobody knows what other dark secrets are waiting for us out there.

Prize Talk PV X Wed 12:00 B Audimax

New theoretical challenges in quantum optics and quantum information — •Ignacio Cirac — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

In the last years, quantum optics and quantum information have merged with other areas of science, like condensed matter or high-energy physics. This opens various scientific questions and poses new theoretical challenges. In this talk I will give a brief overview of some of the areas of resarch that have emerged in that context, like the study and applications of emitters close to structured baths, and the development of theoretical tools to address many-body quantum problems.

Prize Talk PV XI Wed 12:40 B Audimax

Focusing Light — •Gerd Leuchs — Universität Erlangen-Nürnberg, Erlangen, Germany

Concentrating light to the smallest possible spot is at the heart of classical and quantum optics. This requires manipulating all parameters of the electromagnetic vector field and experimentally characterizing the resulting field structure. Strongly focused light fields produce non-trivial distributions, involving, e.g., transverse angular momentum of light, which in turn allows for demonstrating a nano beacon. Another example is optimizing the interaction of light with an atom in free space. Goals are the experimental demonstrations that a single photon can excite an atom with certainty, - or that it can act as a localized dielectric medium producing a 180° phase shift of a beam of light. Some guidance can be taken from time-reversal symmetry of the underlying quantum dynamics. Experimental challenges are e.g. the fabrication of diffraction-limited deep parabolic mirrors and the shaping of a single-photon wave packet in time using a nonlinear whispering gallery mode resonator in combination with ghost imaging in the time domain. Even when studying the seemingly most trivial case, the efficient focusing of light in vacuum, i.e. in the absence of any real matter, there are still open questions and challenges.

Plenary Talk PV XII Thu 8:30 B Audimax

From rotons to quantum droplets: Dipolar quantum gases echo He superfluid phenomena — •Francesca Ferlaino — Universität Innsbruck, Institut für Experimental Physik, Austria — Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Innsbruck, Austria

With the tremendous advances in cooling and manipulation techniques, ultracold atomic gases have consolidated themselves as an ideal system to address fundamental questions in quantum few- and many-body physics. Recently, we have reached Bose-Einstein condensation and Fermi degeneracy with ultracold Erbium atoms. This *exotic* atomic species combines unusually rich atomic spectra and a large magnetic moment. In the quantum regime, bosonic Er atoms feature interactions of genuinely different nature. The more ordinary and magnetically-tunable contact interaction combines with the long-range and anisotropic magnetic dipolar interaction. The mere existence and competition between these two sources of interactions dictate the physics at play, disclosing a variety of intriguing phenomena in close connection to superfluid He. This talk will provide an overview of some fascinating dipolar phenomena from the Innsbruck perspective, including the first observation of rotons in the gas and quasi-self-bound quantum droplets.

Plenary Talk PV XIII Thu 9:15 B Audimax

Device-independent quantum cryptography — •Renato Renner — ETH Zurich, Switzerland

Quantum cryptography provides, in principle, perfect security, based solely on the correctness of physical laws. Nevertheless, recent successful hacking attacks have revealed that such strong security is not warranted by actual implementations. This mismatch between theory and practice is due to a fundamental incompleteness of models for real-world devices such as photon sources and detectors.

A clean and elegant approach to overcome this problem is “device-independent” quantum cryptography. The idea is to establish security claims that hold independently of the details of the devices used for their implementation. This is achieved by the use of techniques originally proposed for experiments on the foundations of quantum theory, such as loophole-free Bell tests.

Lunch Talk PV XIV Thu 13:00 K 2.020

Erneuerbare Energien und elektrisches Energiesystem – ein Platz für Physiker? — •Bernd Utz — Senior Innovation Manager bei Siemens AG, Erlangen

Nach Studium und Promotion an der TU München als Entwicklungsingenieur zu Siemens über die Leitung des Projektes ”Desertec” bei Siemens Renewable Energies ins Management. Auch so kann der Lebenslauf eines Physikers aussehen. Der Referent wird über seinen Werdegang und die Möglichkeiten für Physiker im Bereich erneuerbarer Energiesysteme berichten.

Evening Talk PV XV Thu 18:30 B Audimax

Lise-Meitner-Lecture: From Materials to Cosmology: Studying the early universe under the microscope — •Nicola Spaldin — ETH Zurich

What happened in the early universe just after the Big Bang? This is one of the most intriguing basic questions in all of science, but it is extraordinarily difficult to study because of insurmountable issues associated with replaying the Big Bang in the laboratory. I will explore one way in which scientists are trying to find the answer, by using laboratory materials as testbeds for physical laws proposed to describe the formation of early-universe structures known as cosmic strings. I will show that a so-called “multiferroic” material, with its coexisting magnetic and electric dipoles, generates structures that are equivalent to cosmic strings, and will present results of measurements on the material suggesting that cosmic strings indeed formed as cosmologists think.

Evening Talk PV XVI Thu 20:00 B Audimax

Max-von-Laue Lecture: Scientific Work in Support of Bans on Nuclear Testing: Lessons for Science Advice — •Paul G.

Richards — Lamont-Doherty Earth Observatory of Columbia University

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) was finalized in 1996, but cannot enter into force until a few more key signatures and ratifications are obtained. In practice this treaty has stopped nuclear testing by all but North Korea. The CTBT is associated with a complex verification system. Several different approaches combine to give excellent capability to monitor for nuclear explosions.

The talk will review the principal monitoring methods. Some of the most important are provided by seismology. The presentation also describes how most methods of explosion monitoring evolved, mainly from 1945 to 1996 when more than 2000 nuclear test explosions were conducted. The goal then was to monitor ongoing weapons development by potential adversaries. Today the treaty context is nuclear arms control, involving very different agencies, different objectives, and different attitudes to technical issues. The talk also describes several difficulties in giving valid science advice, eventually accepted, that was not initially welcomed by sponsoring organizations.

Plenary Talk PV XVII Fri 8:30 B Audimax

Quantum Key Distribution - An Overview — •Harald Weinfurter — Fakultät für Physik, LMU München, Deutschland — Max Planck Institut für Quantenoptik, Garching, Deutschland

The security of our communication is of utmost importance, yet, on the long run it is threatened by attacks using quantum computers. Quantum key distribution is the only method known already today, which is robust against such attacks. Even better, in strong contrast to mathematics based methods, it enables to evaluate the maximum information a potential eavesdropper could have gained.

This overview shows the state-of-the-art in QKD technology, ranging from commercial products and large scale trusted node networks to high-rate prototypes without the need of dark fibers. For free-space systems it describes the flexibility enabling a series of application scenarios from short range authentication all the way to global distribution of secure keys using satellites.

Plenary Talk PV XVIII Fri 9:15 B Audimax

The Role of Spin in the Photo-induced Ultrafast Dynamics of Transition Metal-based Chromophores — •James McCusker — Department of Chemistry, Michigan State University, East Lansing, Michigan USA

From fundamental issues concerning the interplay between geometric and electronic structure to their applications in energy conversion and chemical transformation strategies, the excited-state properties of transition metal complexes constitutes a very dynamic area of chemical research. This presentation will examine the role of spin and its influence on the photophysics of transition metal complexes through a discussion of three chemical systems. First, variable-temperature ultrafast time-resolved spectroscopic data acquired on a series of Fe(II) polypyridyl complexes will be presented that provide quantitative insights into the reorganization energies and electronic coupling involved in a conversion that is characterized by a two-quantum spin flip (i.e., $\Delta S = 2$); in this case, the dynamics are clearly dominated by the doubly spin-forbidden nature of this relaxation pathway. The role of spin becomes less well-defined when it comes to ultrafast excited-state evolution. This will be explored through a discussion of two chemical platforms that we have developed, one based on Fe(II) in which changes in spin-state appear to play no role whatsoever in dictating the kinetics of excited-state evolution, and a second based on Cr(III) in which spin not only influences these kinetics but can be controlled systematically through synthetic means. The possibility of leveraging these ideas toward problems in energy science will also be discussed.