Plenary Talk PLV I Mon 9:00 HS 1+2

The Entanglement Frontier in Quantum Networks — •Gerhard Rempe — Max Planck Institute of Quantum Optics, Hans-Kopfermann Str. 1, 85748 Garching, Germany

Is a large-scale quantum internet realistic? Perhaps not, as quantum physics has been developed for the microscopic world. However, if a quantum internet becomes available, it will open up unimagined possibilities for communication. For example, a quantum search engine will provide answers to questions that even the machine cannot remember. In addition, the development of a quantum internet will provide us with new technologies to network quantum processors into a larger quantum computer. Perhaps most intriguingly, the pursuit of a quantum internet will lead to a better understanding of the abstract concept of entanglement and its topology in distributed quantum systems with many qubits. Last but not least, in our classical world the realization of a quantum internet, even in its simplest form, constitutes a gigantic challenge that will help us grow and mature. The talk will discuss the quantum optics toolbox and highlight recent experimental achievements that may have brought us a step closer to the grand dream of a quantum internet.

Plenary Talk PLV II Mon 9:45 HS 1+2

Atomic cooperative arrays in bio-inspired geometries — •Susanne Yelin — Harvard University, Cambridge, MA 02138, USA

What is the potential of dense – cooperative – emitter arrays? These arrays, already known for their use in metrology and quantum information as efficient waveguides and mirrors, are now being studied in alternative geometries. Inspired by nature, we investigate chiral and helical structures, as well as ring-shaped arrays.

Plenary Talk PLV III Tue 9:00 HS 1+2

Interferometric gravitational wave detection - a (quantum-) metrological challenge — •Michèle Heurs — Leibniz Universität Hannover, Hannover, Germany — Deutsches Zentrum für Astrophysik (DZA) in Gründung, Görlitz, Germany — Deutsches Elektronen-Synchrotron DESY, Zeuthen, Germany

Since the first direct detection of gravitational waves in 2015, we have gained a new observation window into the universe, complementary to the electromagnetic spectrum, neutrinos, and cosmic rays.

The sensitivity of current gravitational wave detectors is so incredible that the quantum effects of the employed laser light have become limiting. Ultra-precisely stabilised lasers do not suffice; non-classical (“squeezed”) light is already routinely employed in the current second generation of detectors (e.g., aLIGO & AdVirgo). Other noise sources, such as seismic and thermal noise, pose further challenges for third-generation detectors (e.g., the European Einstein Telescope, a planned underground gravitational wave observatory).

To achieve ever-higher detection rates for meaningful gravitational wave astronomy, ever-greater detection sensitivity is required. I will introduce the principle of interferometric gravitational wave detection and highlight some of the advanced technologies implemented, focusing on squeezed light. I will conclude my talk by showing some further possibilities related to this, as well as options for quantum noise reduction in laser interferometry and the broader field of quantum optics.

Plenary Talk PLV IV Tue 9:45 HS 1+2

Three Pillars of Ultrafast Molecular Sciences: Time, Phase, Intensity — •Albert Stolow — University of Ottawa & National Research Council, Canada

Three fundamental coupled characteristics of ultrashort laser pulses are their duration (Time), coherence (Phase) and Intensity. All three have played a key role in the development of Ultrafast Molecular Sciences. Using the narrative device of 'three pillars', we discuss: (i) Time: ultrafast wavepacket dynamics and its application to non-adiabatic electronic dynamics in molecules, the fundamental physics underlying charge transfer; (ii) Phase: perturbative and non-perturbative quantum control of molecular dynamics using shaped laser fields; (iii) Intensity: the complex, driven multielectron dynamics of polyatomic systems in strong (ionizing) laser fields.

Plenary Talk PLV V Wed 9:00 HS 1+2

Watching Ultrafast Processes in Single Molecules using Synchrotrons and X-Ray Free-Electron Lasers — •Till Jahnke — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Recording ”real-time movies” of ultrafast dynamical processes in molecules has been a driving force across numerous disciplines in the fundamental sciences over the recent decades. More recently, techniques targeting single gas-phase molecules with coincident single-particle detection have emerged. For instance, Coulomb explosion imaging uses ultrashort light pulses to fragment molecules, revealing their geometry through the breakup pattern. Electron emission patterns measured in coincidence provide additional insights into ultrafast processes. X-ray free-electron lasers (XFELs) excel at exploring the ultrafast time regime. These light sources are especially suited for time-resolved studies using pump-probe schemes, by adding, e.g., synchronized ultrashort UV pulses. Intriguingly, this time domain can also be accessed with synchrotron light sources (which produce light pulses with durations on the order of several 100 picoseconds) by employing coincident momentum imaging with so-called COLTRIMS reaction microscopes. This talk will offer an introduction to the topic and highlight the current state-of-the-art in related experiments. It will showcase various examples, spanning from ”relatively slow” dynamics, such as photo-induced molecular rearrangements occurring over several hundred femtoseconds, to the attosecond regime (and beyond) of electronic processes in molecules.

Plenary Talk PLV VI Wed 9:45 HS 1+2

High-precision Penning Trap Mass Measurements of Rare Isotopes — •Georg Bollen — Facility for Rare Isotope Beams, Michigan State University, East Lansing, MI, USA

The mass of an atom and its inherent connection with the atomic and nuclear binding energy is a fundamental property of the atomic nucleus. Precise mass values of rare isotopes far away from the valley of beta-stability provide important insight into nuclear structure, are critical for the understanding of nucleosynthesis, and contribute to the test of fundamental interactions. Penning traps have become important instruments for mass determination of such isotopes. They were first introduced at ISOLTRAP at the Isotope Mass Separator On-Line facility (ISOLDE) at CERN. ISOLTRAP's success led to Penning trap mass spectrometers now being in operation at several facility worldwide, where isotopes are produced with different means. LEBIT at the Facility of Rare Isotope Beams (FRIB) at Michigan State University (MSU) is the only instrument that allows rare isotopes produced through fragmentation of stable isotopes at half the speed of light to be captured in a Penning trap for precision mass measurements. I will provide an overview of Penning trap mass measurement activities for rare isotopes and their science motivation, discuss technical advances towards broader application and higher sensitivity, present examples of results achieved with LEBIT, and give my perspective on developments in this field.

Plenary Talk PLV VII Thu 9:00 HS 1+2

Spin Qubits in Semiconductors for Scalable Quantum Computers — •Daniel Loss — Department of Physics, University of Basel, Switzerland

Semiconductor spin qubits offer a unique opportunity for scalable quantum computation by leveraging classical transistor technology [1]. This has triggered a worldwide effort to develop spin qubits, in particular, in Si and Ge based quantum dots, both for electrons and for holes [2-5]. Due to strong spin orbit interaction, hole spin qubits benefit from ultrafast all-electrical qubit control and sweet spots to counteract charge and nuclear spin noise. In this talk I will present an overview of the state-of-the art in the field and focus, in particular, on recent developments on hole spin physics in Ge and Si nanowires, Si FinFETs, and Ge/SiGe heterostructures [6-15], as well as strategies for maximizing valley splitting crucial for scalability of electron spin qubits in Si [16] and long-distance entanglement via magnetic domain walls in race tracks [17].

[1] D. Loss and D.P. DiVincenzo, Phys. Rev. A 57 120 (1998); Milestone paper of Phys. Rev. A (1970-2020)
[2] C. Kloeffel and D. Loss, Annu. Rev. Condens. Matter Phys. 4, 51 (2013)
[3] A. Chatterjee, et al., Nat. Rev. Phys. 3, 157 (2021)
[4] P. Stano and D. Loss, Nat. Rev. Phys. (2022)
[5] G. Burkard, et al., Rev. Mod. Phys. 95 (2023)
[6] S. Bosco, B. Hetényi, and D. Loss, PRX Quantum 2, 010348 (2021)
[7] L. C. Camenzind, et al., Nat. Electr. (2022)
[8] S. Bosco and D. Loss, Phys. Rev. Lett. 127, 190501 (2021)
[9] G. Scappucci, et al., Nat. Rev. Mater. 6, 926 (2021)
[10] S. Bosco, P. Scarlino, J. Klinovaja, and D. Loss, Phys. Rev. Lett. 129, 066801 (2022)
[11] O. Malkoc, P. Stano, and D. Loss, Phys. Rev. Lett. 129, 247701

(2022)
[12] B. Hetényi, S. Bosco, and D. Loss, Phys. Rev. Lett. 129, 116805 (2022)
[13] S. Bosco, et al., Phys. Rev. Lett. 131, 197001 (2023)
[14] S. Geyer, et al., Nat. Phys. 20, 1152 (2024)
[15] S. Bosco, J. Zou, and D. Loss, PRX Quantum 5, 020353 (2024)
[16] C. Adelsberger, S. Bosco, J. Klinovaja, and D. Loss, Phys. Rev. Lett. 133, 037001 (2024)
[17] J. Zou, S. Bosco, B. Pal, S. S. P. Parkin, J. Klinovaja, and D. Loss, Phys. Rev. Research 5, 033166 (2023)

Plenary Talk PLV VIII Thu 9:45 HS 1+2

Nuclear laser spectroscopy and the optical nuclear clock — •Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Recently, three experiments have obtained resonant laser excitation of a low-energy nuclear transition, from the ground state of Th-229 to its isomeric state at 8.4 eV, using table-top laser systems at a wavelength of 148 nm in the vacuum-ultraviolet. The thorium nuclei have been prepared as dopant ions in VUV-transparent crystals, like calcium fluoride. This opens a new field for experiments that connect nuclear physics with atomic physics, where a nuclear transition occurs in the energy range that is typical for transitions of atomic valence electrons. Among several possible applications, the development of an optical nuclear clock seems particularly attractive. This clock would offer high accuracy, especially with laser cooled trapped Th-229 ions, high stability, because of the high number of nuclei that can be interrogated in Th-229-doped solids, and high sensitivity in clock-based tests of fundamental principles of physics, involving the strong interaction in addition to electromagnetism. A detailed microscopic picture of why Th-229 possesses these nearly degenerate levels is an open question, but studies of the hyperfine structure of the nuclear and electronic transitions provide information on the relevant nuclear properties like the magnetic moment and the charge distribution.

Plenary Talk PLV IX Fri 9:00 HS 1+2

Building the Cathedral of Quantum Mechanics — •Michel Janssen — University of Minnesota, Minneapolis, MN, USA

The upheaval in quantum theory in the mid-1920s is often seen as a paradigmatic example of Kuhn's account of scientific revolutions, in which new buildings are erected on the ruins of the old ones, brought down by an accumulation of anomalies. In our book Constructing Quantum Mechanics, Anthony Duncan and I use a different building metaphor to characterize the emergence of quantum mechanics. As suggested by the subtitles of the two volumes of our book, The Scaffold: 1900-1923 and The Arch: 1923-1927, we see the architects of the new quantum mechanics using parts of the old quantum theory as scaffolds to build the arch of the new one. In this talk, after sketching the underlying alternative to Kuhn's account of scientific revolutions in general, I will give an overview, as non-technical as possible, of the genesis of quantum mechanics in the period 1900-1927.

Plenary Talk PLV X Fri 9:45 HS 1+2

German Energy Transition - Joint Efforts for Ambitious Goals — •Dirk Stenkamp[1], Xenia Gieseler[2], Alexander Ohff[2], Silvio Konrad[2], Hans Koopman[2], and Maik Tiedemann[3] — [1]TÜV NORD AG, Am TÜV 1, 30519 Hannover, Germany — [2]TÜV NORD EnSys GmbH, Große Bahnstraße 31, 22525 Hamburg, Germany — [3]DMT GmbH, Am TÜV 1, 45307 Essen, Germany

In the beginning of the 2000s, Germany's electricity generation was heavily reliant on fossil fuels and nuclear power - a clear contrast to today's evolving landscape marked by the rise of renewable energy sources. This transformation, known as the German energy transition or "Energiewende", is a significant shift towards sustainable energy systems, aiming to reduce carbon emissions while maintaining energy security and affordability. This presentation provides a concise overview of the current status of the energy transition in Germany and examines technical aspects while addressing economic and political challenges. We will cover the integration of renewables into a changing energy landscape and discuss the emerging role of hydrogen as a key energy carrier. Finally, this presentation will discuss whether joint efforts can successfully achieve Germany's ambitious goals for the energy transition.