Plenary Talk PV I Mon 9:00 E415

Probing the quantum nature of gravity in table-top experiments — •Markus Aspelmeyer — University of Vienna, Faculty of Physics, Vienna, Austria — Austrian Academy of Sciences, IQOQI, Vienna, Austria

No experiment today provides evidence that gravity requires a quantum description. The growing ability to achieve quantum optical control over massive solid-state objects may change that situation – by enabling experiments that directly probe the phenomenology of quantum states of gravitational source masses. This can lead to experimental outcomes that are inconsistent with the predictions of a purely classical field theory of gravity. Such 'Quantum Cavendish' experiments will rely on delocalized motional quantum states of sufficiently massive objects and gravity experiments on the micrometer scale. I review the current status in the lab and the challenges to be overcome for future experiments.

Plenary Talk PV II Mon 9:45 E415

Quantum Chemistry on Quantum Computers: Challenges and New Directions — •Sabrina Maniscalco — Algorithmiq Ltd, Kanavakatu 3C, 00160 Helsinki, Finland — QTF Centre of Excellence, Department of Physics, Faculty of Science, University of Helsinki, Finland

Simulating electronic structure problems is one of the most attractive applications of quantum computers. Current devices, however, are limited: they are still operating with small number of qubits and high level of noise. Moreover, they are affected by a large number of both technical and fundamental problems. In my talk I will focus on one of the most studied applications of quantum computers, namely quantum chemistry simulations, and I will highlight both the current major roadblocks and a new framework to overcome them. As an example I will focus on three key steps, namely how to map optimally fermionic systems to qubits [1], how to initialise the quantum computers [3], and how to measure them in the most efficient manner [4,5].

References: [1] A. Miller, Z. Zimborás, S. Knecht, S. Maniscalco, G. García-Pérez, arXiv:2212.09731. [2] A. Nykänen, M. A. C. Rossi, E. Borrelli, S. Maniscalco, G. García-Pérez, arXiv:2212.09719. [3] A. Fitzpatrick, A. Nykänen, N. Talarico, A. Lunghi, S. Maniscalco, G. García-Pérez, S. Knecht, arXiv:2212.11405. [4] G. García-Pérez, M.A. C. Rossi, B. Sokolov, F. Tacchino, P. Kl. Barkoutsos, G. Mazzola, I. Tavernelli, S. Maniscalco, PRX Quantum 2, 040342 (2021). [5] A. Glos, A. Nykänen, E. Borrelli, S. Maniscalco, M. A. C. Rossi, Z. Zimborás, G. García-Pérez, arXiv:2208.07817.

Plenary Talk PV III Tue 9:00 E415

Educational Transformation at a Critical Time: The essential roles and promise of physicists — •Noah Finkelstein — University of Colorado, Boulder USA

Significant, perhaps unprecedented, attention is being paid to the needs for transformation within the fields of science, technology, engineering, and mathematics (STEM) education at the undergraduate level. This talk examines how higher education STEM disciplines, and physicists and physics departments in particular, are positioned to contribute to these discussions and address our challenges. I will review our own efforts in physics education transformation and the growth of work in physics education research (PER). Building from theory on student learning and educational environments, this talk will review examples of physicists' support of learning at the individual, course, and departmental scales. Examples will consider: how we can build on understanding of student reasoning to study and transform our introductory through upper division courses, studies of how our environments do and do not support identity formation in physics, and models for engaging in sustainable and scalable transformation.

Plenary Talk PV IV Tue 9:45 E415

New Lightwave Science with Photonic Crystal Fibres — •Philip Russell — MPI Science of Light, Erlangen, Germany

Photonic crystal fibres (PCFs), thin strands of glass with an array of hollow channels running along their length, offer light guidance in both hollow and solid glass cores. They permit unprecedented control over dispersion, birefringence and nonlinearity, and over the last three decades have ushered in a new era of linear and nonlinear fibre optics. Gas-filled hollow-core PCF provides low-loss diffraction-free transmission of light in a single transverse mode, and through pressure-adjustable dispersion provides a simple means of compressing pulses to single-cycle durations, as well reducing the threshold power for nonlinear effects by orders of magnitude. Operating on opposite sides of the gas-pressure-tuneable zero dispersion point permits a novel form of holography based on Raman coherence, which has been used for highly efficient state-preserving frequency up-conversion of single photons by 125 THz in hydrogen (doi.org//10.1126/science.abn1434). Chiral PCF, formed by spinning the preform during fibre drawing, provides circular and vortex birefringence, as well as permitting localization of light in core-less (i.e., defect-free) 2D lattices of chiral coupled cores (doi.org//10.1002/lpor.202200570). After a brief introduction, a number of recent developments will be covered in the talk.

Plenary Talk PV V Wed 9:00 E415

The device-independent scenario: quantum information information processing based on Bell Theorem — •Antonio Acin — ICFO - The Institute of Photonic Sciences

Bell theorem implies the existence of quantum correlations that cannot be explained by classical physics, this phenomenon often known as Bell non-locality. Despite its fundamental importance, the role of Bell non-locality in standard quantum information theory is, perhaps surprisingly, marginal. Bell non-locality is however the fundamental resource for device-independent quantum information processing, in which devices are seen as quantum black boxes processing classical information. The talk introduces the main concepts and tools of the device-independent scenario and its relevance for the certification of quantum systems and technologies.

Plenary Talk PV VI Wed 9:45 E415

Cavity-enhanced light-induced processes in aerosol droplets — •Ruth Signorell — Department of Chemistry and Applied Biosciences, ETH Zurich, CH-8093 Zurich, Switzerland

When light interacts with an aerosol particle, the light intensity can be greatly amplified inside the particle as the latter acts as a light-amplifying cavity. This optical phenomenon can be viewed as a dielectric analogue of plasmon resonances in metallic nanoparticles. The role these optical confinement effects play in aerosols are diverse. We report their influence in three different areas: (1) Photochemical processes have been identified as the main causes of degradation and oxidation of matter in atmospheric aerosol particles. Photochemistry in aerosol particles is accelerated by optical confinement effects compared with reactions in bulk condensed matter. We have studied and quantified the acceleration of in-particle photochemistry using photoacoustic spectroscopy and X-ray spectro-microscopic imaging of single aerosol particles. (2) Low-energy electron scattering in liquid water plays a crucial role in a variety of physical, chemical, and biological processes. However, the quantitative description of electron scattering has been hampered by the lack of scattering cross-sections for liquid water. By exploiting optical confinement effects in photoemission images of water droplets, we have contributed to solving this problem. (3) Optical confinement also affects ultrafast, laser-driven plasma formation from aerosol particles by structuring the internal light intensity. We report recent coherent diffraction imaging experiments during nanoplasma expansion of core-shell aerosol particles.

Evening Talk PV VII Wed 20:00 E415

Das Ende der klassischen Welt – Der Physik-Nobelpreis 2022 — •Reinhard Werner — Leibniz Universität Hannover

Der Physik-Nobelpreis 2022 ging an John Clauser, Alain Aspect und Anton Zeilinger „für Experimente mit verschränkten Photonen, den Nachweis der Verletzung der Bellschen Ungleichungen und Pionierarbeiten der Quanteninformationswissenschaft“. Dies ist nicht weniger als der experimentelle Nachweis für das Versagen aller klassischen Beschreibungen und Bilder in der Mikrophysik. Der Vortrag zeichnet die Ideengeschichte dieses Durchbruchs nach und geht auf häufige Missverständnisse ein, oft verbunden mit dem Ausdruck „spukhafte Fernwirkung“. Bemerkenswert ist, dass die Preisträger, ebenso wie Einstein (in Bezug auf Quantentheorie), Bell und die Theoretiker, die die Quanteninformationswissenschaft begannen, deutlich abseits des Mainstreams standen. Mehrfach sehen wir hier Entwicklungen, die von einer Handvoll Exoten begonnen wurden und Jahrzehnte später zum festen Bestandteil der Physik wurden. Der Vortrag endet mit ein paar Betrachtungen was gerade diese Exoten ausgezeichnet hat, und wie wir die Chancen verbessern können, dass ihre modernen unkonventionellen Kollegen Gehör finden.

Plenary Talk PV VIII Thu 9:00 E415

Highly charged helium droplets — •Paul Scheier — Institut für Ionenphysik und Angewandte Physik, Universität Innsbruck, Tech-

nikerstr. 25, A-6020 Innsbruck, Austria

Helium nanodroplets provide an inert matrix, free of walls with outstanding properties to grow complexes and clusters at sub-Kelvin temperatures. However, like for almost every existing method of cluster and nanoparticle formation pickup into neutral helium droplets leads to a wide distribution of dopant cluster sizes. Recently, we discovered that large helium droplets can become highly-charged. Micrometer sized droplets can reach charge states up to several 100. The charge centers self-organize as two-dimensional Wigner crystals at the surface of the droplets and act as seeds for the growth of dopant clusters. Cluster ions of a specific size and composition can be formed by this technique with unprecedented efficiency. Soft-landing of dopant clusters formed in highly-charged helium droplets can be achieved via collisions with a surface set on a retarding potential. Due to the fact that several hundred nanoparticles are formed simultaneously in one helium droplet and the suppression of splashing, the deposition time compared to neutral helium droplets can be reduced by more than two orders of magnitude.

Plenary Talk PV IX Thu 9:45 E415

Exploring fundamental interactions and constants with trapped ions — •Sven Sturm — Max Planck Institute for Nuclear Physics (MPIK), Heidelberg

Single ions in cryogenic Penning traps are almost ideal tools for exploring the validity of quantum electrodynamics (QED) as well as for determining the values of fundamental constants - the links that allow us to compare theories to actual measurements. We utilise the extraordinary control over the motion of the trapped ions, which are decoupled from any disturbing environment, to determine their mass, magnetic moment (g-factor) and transition spectrum with highest precision. This way, we have measured the masses of electron, proton, deuteron and helium. Furthermore, with highly charged ions we can explore the strongest electromagnetic fields and perform stringent tests of strong-field QED. Novel techniques have lately enabled a leap in precision, so that the comparison of experiment and theory allows searching for new physics beyond the Standard Model. Finally, the Penning-trap toolbox enables laser spectroscopy of otherwise difficult-to-access species, such as the molecular hydrogen ion. I will present the techniques as well as our previous and future campaigns.

Plenary Talk PV X Fri 9:00 E415

Lightwave electronics in trivial, topological, and strongly correlated solids — •Misha Ivanov — Max Born Institute, Berlin, Germany

Modern light generation technology has evolved to the point where a theorist may reasonably expect an experimentalist to generate light pulses where individual oscillations of the electric field are shaped almost at will. Control of the carrier-envelope phase of few-cycle pulses is now almost routine. One can also reliably generate complex polarization states in two and three dimensions, sculpting the Lissajous figures drawn by the electric field vector during a single optical cycle. As these fields can be made strong enough to compete with the internal electric fields in a medium, coherent electronic motion can be excited and shaped almost at will, at the time-scale of a single light oscillation. How can we use such opportunities? What happens to a crystal exposed to such light? Do we change its effective band structure and density of states? Can these changes be controlled?

I will address these questions by considering several examples, ranging from trivial to topological to correlated solids, showing how our ability to control light on the sub-cycle time-scale leads to interesting and often unexpected results.

Plenary Talk PV XI Fri 9:45 E415

Quantum Simulation using Ultracold Atoms and Molecules — •Immanuel Bloch — Max Planck Institute of Quantum Optics — LMU Munich

40 years ago, Richard Feynman outlined his vision of a quantum simulator for carrying out complex calculations of physical problems. Today, his dream has become a reality and a highly active field of resarch across different platforms. In my talk, I will delineate how ultracold atoms in optical lattices started this vibrant and interdisciplinary research field 20 years ago and now allow probing quantum phases in- and out-of-equilibrium with fundamentally new tools and single particle resolution. Ultracold polar molecules allow to significantly extend the simulation capabilities due to their more complex internal structure and strong dipolar interactions. So far, however, efficient and general techniques to cool them to quantum degeneracy have remained out of reach. In the talk, I will discuss how microwave shielding provides an efficient general solution that allows to cool three-dimensional bulk samples of polar molecules to deep quantum degeneracy as well as to provide a handle on controlling their scattering properties using novel 'field-linked' resonances. Realizing such full control over polar molecules promises to harness their full potential for quantum simulations.