Plenary Talk PV I Mon 9:35 PV-Rooms

Fifty years of revolutions in atomic physics and quantum optics — •Serge Haroche — Collège de France, Laboratoire Kastler Brossel, Paris, France

The last fifty years have witnessed tremendous progresses in atomic physics and in optics, largely triggered by the development of lasers as unique tools to probe and manipulate matter. What we can achieve now, in high resolution spectroscopy and time measurement precision, in atomic motion control, in single quantum particle manipulation or in ultra-fast atomic or molecular processes observation, could not even have been dreamed about when I started my life as a physicist, half a century ago. In my talk, I will reflect on some of these major advances, analyse how the perspective of an atomic physicist has changed over this period of time, and try to guess what the future holds for this physics.

Plenary Talk PV II Tue 9:00 PV-Rooms

Exploring the QCD Phase Diagram at the LHC — •Johanna Stachel — Physikalisches Institut, Universitaet Heidelberg

The theory of strong interaction, quantum-chromo-dynamics, predicts for high temperature and density a new state of matter in which the confinement of quarks and gluons is lifted. This state, the quark-gluon-plasma, existed in the early universe after the electro-weak phase transition up to about 10 microseconds. In the past 25 years accelerator-based experiments have been conducted in order to recreate this state of matter for a short time. The ideal tool are collisions of heavy nuclei at energies as high as possible. Now with the Large Hadron Collider (LHC) at CERN an entirely new energy regime is accessible.

Two aspects of the data will be explored: (i) Experimental knowledge about the phase bounary between ordinary hadronic matter and the quark-gluon plasma. This is based on the measured yields of various hadronic species. Here a direct link can be made to the full statistical operator of QCD including it's fluctuations. (ii) Evidence for deconfinement. This comes from the production of charmonia as a function of center of mass energy and centrality of the collision. The LHC data will be put into perspective vis-a-vis the results from lower energies.

Plenary Talk PV III Tue 9:45 PV-Rooms

Precision Electroweak Physics — •William Marciano — BNL Brookhaven

An overview of precision electroweak measurements and their comparison with Standard Model predictions is given. Agreement is used to constrain "New Physics" speculations. The current status of lepton anomalous magnetic moments is considered in some detail, particularly the muon, where a 3.5sigma difference between experiment and theory exists.

Evening Talk PV IV Tue 20:00 Neue Aula

Klimawandel: Zu spät für 2°C? — •Thomas Stocker — Klima- und Umweltphysik, Physikalisches Institut, Universität Bern, Schweiz

Die CO_2 Konzentrationen in der Atmosphäre sind heute über 30% höher als je zuvor in den letzten 800'000 Jahren und steigen über 100 Mal schneller an als je in den letzten 20'000 Jahren. Die Ursache dafür ist die Verbrennung fossiler Energieträger und die Abholzung tropischer Regenwälder. Der Anstieg der Treibhausgase, allen voran CO2, hat zu einer Aufnahme von Energie im Erdsystem geführt: ca. $270 \cdot 10^{21}$ J seit 1970. Der neuste Sachstandsbericht *Climate Change 2013: The Physical Science Basis* des Weltklimarats IPCC dokumentiert ein sich rasch und tiefgreifend änderndes Erdsystem und liefert wissenschaftliche Informationen über künftige Änderungen. Eine Einschränkung des Klimawandels erfordert umfangreiche und langfristige Reduktionen der Treibhausgasemissionen. Trotz aller Komplexität des gekoppelten physikalisch-biogeochemischen Erdsystems gibt es einen überraschend einfachen, linearen Zusammenhang zwischen der Summe der CO_2 Emissionen seit der industriellen Revolution und der erwarteten Erwärmung im 21. Jahrhundert. Ein gesellschaftlich vereinbartes Klimaziel impliziert deshalb ein limitiertes CO_2 Budget. Für das 2°C Ziel wurden bereits 2/3 dieses Budgets konsumiert; bei gegenwärtigen Emissionen ist es in weniger als 25 Jahren aufgebraucht.

Plenary Talk PV V Wed 9:00 PV-Rooms

Science at the Timescale of the Electron: The Quantum Nonlinear Optics of High Harmonic Generation — •Margaret M. Murnane — JILA, University of Colorado, Boulder, CO 80309-0440, USA

The same revolution that visible lasers underwent in the 1960s is now happening for tabletop coherent X-ray sources. In nonlinear optics, the high electric fields that are present in a focused laser beam can drive electrons in a highly irregular (anharmonic) motion, re-radiating harmonics of the driving laser light at much shorter wavelengths. Although its physical manifestation is very different, high harmonic generation (HHG) can be thought of as a coherent laser-driven version of the Rontgen X-ray tube. In HHG, the laser field intensity is sufficient to ionize the atom. For the few-femtosecond time interval during which this is happening, the laser-driven quantum wavefunction of the electron can radiate coherent high harmonic X-ray beams, which have spectacular temporal and spatial coherence. This is because of the ultra-precise timing relationship between the laser and X-ray fields, and the acceleration of the electron quantum wavefuction, that are all synchronized to less than an attosecond (or $<10^{-18}$ seconds).

Very recently, the full power of extreme nonlinear optics for manipulating the quantum wavefunction of a radiation electron has been realized. Simply by changing the color and polarization of the driving laser, the HHG spectrum, pulse duration and polarization can be exquisitely controlled.[1-4] One recent surprising finding is that *longer* wavelength mid-infrared lasers can generate *shorter* wavelength bright X-ray beams. Using 4μm driving lasers for example, HHG emerges as a broad coherent supercontinuum, spanning the entire electromagnetic spectrum from the ultraviolet (UV) to the soft X-ray keV region of the spectrum, to wavelengths < 8 Å. Moreover, these X-rays emerge as isolated attosecond bursts, that are predicted to scale to the sub-attosecond (i.e. zeptosecond) regime using longer wavelength lasers. In contrast, using intense UV driving lasers, HHG emerges as a series of bright narrow-band peaks, with ≈ 10 fs pulse duration. Finally, by manipulating the electron wavefuction using bi-chromatic (two-color) circularly polarized counter-rotating laser beams, it is now possible to produce bright circularly polarized harmonics (ideal for studying chiral media), to complement the bright linearly polarized HHG beams available for 20 years. The powerful quantum coherence of HHG make it ideal for imaging the fastest dynamics relevant to function in atoms, molecules, nanosystems and materials, at multiple atomic sites simultaneously. [5-10]

[1] Popmintchev et al., Science, vol. **336**, pp. 1287-1291 (2012)
[2] Chen et al., PNAS, vol. **111**, pp. E2361-E2367 (2014)
[3] Kfir et al., Published online, Nature Photonics, *DOI: 10.1038/NPHOTON.2014.293* (2014)
[4] Hernandez-Garcia et al., Physical Review Letters **111**, 033002 (2013)
[5] Mathias et al., PNAS **109**, 4792 (2012)
[6] Rudolf et al., Nat. Comm. **3**, 1037 (2012)
[7] Turgut et al., Physical Review Letters **110**, 197201 (2013)
[8] Seaberg et al, Optica **1**, 39 (2014)
[9] Siemens et al., Nature Materials **9**, 26 (2010)
[10] Nardi et al., Postdeadline presentation, Conf. on Ultrafast Phenomena, Japan (2014)

Plenary Talk PV VI Wed 9:50 PV-Rooms

A Bose-Fermi Double Superfluid Mixture — •Christophe Salomon — LKB, Physics Department of ENS, 24 rue Lhomond, 75005 Paris

In recent years, ultra-cold atoms have established a very fruitful connection with condensed matter physics, nuclear physics, and astrophysics. Thanks to the tunability of atomic systems, Bose and Fermi gases can be brought to the strongly correlated regime and simulate outstanding problems in quantum many-body physics. One of them deals with the possibility to produce a mixture of Bose and Fermi superfluids, a long-standing challenge in Helium 4 -Helium 3 mixtures. Using lithium 7 and lithium 6 isotopes, we have produced a quantum gas mixture where both the Bose species and the Fermi species are superfluid [1]. We probe the collective dynamics of this system by exciting center-of-mass oscillations that exhibit extremely low damping below a certain critical velocity. Using high precision spectroscopy of these low-lying modes we observe coherent energy exchange and measure the coupling between the two superfluids. We have also measured the critical velocity for superfluid counterflow. In in the phonon-dominated regime and for weak Bose-Fermi coupling, the critical velocity is predicted to be given by the sum of the sound velocities in the Bose gas and in the Fermi gas [2]. In some parameter range of the BEC-BCS crossover, our observations are consistent with this prediction.

[1] I. Ferrier-Barbut, M. Delehaye, S. Laurent, A.T. Grier, M. Pierce, B.S. Rem, F. Chevy, C. Salomon, Science 345, 1035 (2014)

[2] Y. Castin, I. Ferrier-Barbut, and C. Salomon, ArXiv 1408.1326

Evening Talk PV VII Wed 20:00 C/gHS

Astronomie: Exegese kosmischen Lichts — •Hans-Walter Rix — Max-Planck-Institut für Astronomie, Heidelberg

Das Labor der Astrophysik ist das Universum, ein Labor welches eine unglaubliche Vielfalt von phsikalischen Phänomenen bietet, die aber nur aus der Entfernung "passiv" beobachtet und nicht manipuliert werden können. Fast alle Aspekte der Astronomie lassen sich deswegen letztendlich auf die physikalische Interpretation, oder Exegese, der Beobachtungen von Licht aus dem Kosmos zurückführen. Es gibt gute Gründe viele Himmelsrichtungen mit mit immer höherer Auflösung und Empfindlichkeit bei vielen Wellenlängen zu beobachten. Dies treibt die Entwicklung neuer Teleskope und Messinstrumente. Ich werde skizzieren welche technischen und wissenschaftlichen Möglichkeiten sich für Beobachtungen mit höchster Bildschärfe durch heutige und zukünftige Observatorien bieten, insbesondere durch adaptive Optik und Interferometrie.

Plenary Talk PV VIII Thu 9:00 PV-Rooms

Plutonium in the Environment: Can we Predict its Subsurface Behavior? — •Annie Kersting — Glenn T. Seaborg Institute, Lawrence Livermore National Laborartory, CA USA

There is an acute need to expedite progress toward a permanent storage facility that can safely isolated long-lived radionuclides from the biosphere. Significant uncertainty remains on how to safely store long-lived radionuclides that will make up the majority of the dose after a few hundred years.Plutonium (Pu) is of particular interest because of its high toxicity and long half life (t1/2 239Pu 2.4 x104 yrs). The chemical interactions of Pu are dependent on its oxidation state, which in turn control its stability and solubility. Understanding the interplay (the bio-geo-chemistry) between Pu and the repository environment is necessary to predict the conditions for which Pu will either migrate or remain immobile. A mechanistic understanding of the surface structure and reactivity of coupled Pu*mineral, Pu*organic ligand, and Pu*microbe interfacial processes is needed to advance our understanding Pu. To elucidate the mechanisms controlling Pu transport, we have investigated Pu desorption rates from montmorillonite and other mineral colloids. These data suggest that Pu desorption rates are slow enough that colloid-facilitated transport of adsorbed Pu is possible at the field scale (km distances and decade timescales). Additional experiments show that the presence of organic matter plays an important role in stabilizing Pu both in solution and on mineral surfaces. Our experiments are helping to develop a conceptual model of Pu subsurface behavior.

Plenary Talk PV IX Thu 9:45 PV-Rooms

Atom Trap, Krypton-81, and Global Groundwater — •Zheng-Tian Lu — Argonne National Laboratory, Lemont, USA — The University of Chicago, Chicago, USA

The long-lived noble-gas isotope ^{81}Kr is the ideal tracer for water and ice with ages of 10^5 - 10^6 years, a range beyond the reach of ^{14}C. ^{81}Kr-dating, a concept pursued over the past five decades by numerous laboratories employing a variety of techniques, is finally available to the earth science community at large. This is made possible by the development of the Atom Trap Trace Analysis (ATTA) method, in which individual atoms of the desired isotope are captured and detected. ATTA possesses superior selectivity, and is thus far used to analyze the environmental radioactive isotopes ^{81}Kr, ^{85}Kr, and ^{39}Ar. These three isotopes have extremely low isotopic abundances in the range of 10^{-16} to 10^{-11}, and cover a wide range of ages and applications. In collaboration with earth scientists, we are dating groundwater and mapping its flow in major aquifers around the world. We have also demonstrated for the first time ^{81}Kr-dating of old ice.

This work is supported by U.S. DOE, Office of Nuclear Physics, under contract DE-AC02-06CH11357.

Evening Talk PV X Thu 20:00 C/gHS

Nanoskopie mit fokusiertem Licht — •Stefan W. Hell — Max-Plank-Institut für biophysikalische Chemie, Göttingen

Während des gesamten 20. Jahrhunderts war es eine weithin akzeptierte Tatsache: ein Lichtmikroskop, das herkömmliche Linsen verwendet und somit im optischen Fernfeld arbeitet, kann keine feineren räumlichen Details auflösen als ungefähr die halbe Lichtwellenlänge (>200 nm). In den 1990er Jahren jedoch wurde entdeckt, dass eine Überwindung der klassischen Beugungsgrenze in der Tat möglich ist und dass fluoreszente Probenstrukturen mit einer Auflösung nahe der molekularen Skala untersucht werden können.

In diesem Vortrag werden die einfachen und gleichzeitig sehr mächtigen Prinzipien erläutert, die es erlauben, die auflösungsbegrenzende Rolle der Beugung im optischen Fernfeld zu neutralisieren [1,2]. Im Kern geht es darum, Probenmoleküle, die näher beieinander liegen als der durch die Beugungsgrenze diktierte Mindestabstand in unterschiedliche (Quanten-)Zustände zu überführen, damit sie für ein kurzes Zeitintervall zur Detektion unterscheidbar gemacht werden. Im Ergebnis wird die alte Auflösungsgrenze radikal überwunden, und das Innere transparenter Proben wie zum Beispiel Zellen und Gewebe kann nun nichtinvasiv, mit fokussiertem Licht und in 3D, auf der Nanoskala abgebildet werden.

Neben den Grundlagen werden einige der neueren Fortschritte in diesem Forschungsgebiet aufgezeigt. Konkret wird die massive Parallelisierung der RESOLFT- und STED-Verfahren mithilfe einfacher Lichtverteilungen um mehr als das Hunderttausendfache [3] beschrieben. Die Relevanz der „fernfeldoptischen Nanoskopie“ für verschiedene Bereiche, darunter die Lebens- und Materialwissenschaften, wird ebenfalls an Beispielen verdeutlicht.

[1] Hell, S.W. Far-Field Optical Nanoscopy. *Science* **316**, 1153-1157 (2007).
[2] Hell, S.W. Microscopy and its focal switch. *Nature Methods* **6**, 24-32 (2009).
[3] Chmyrov, A. *et al.* Nanoscopy with more than 100,000 ‘doughnuts’. *Nature Methods* **10**, 737-740 (2013).

Plenary Talk PV XI Fri 9:00 PV-Rooms

The Oceans in a Warming World: How are the oceans changing and what role do they play in climate change? — •John Marshall — Massachusetts Institute of Technology, Cambridge, MA, USA

Due to its enormous heat capacity and ability to move heat around the globe, the ocean plays an out-sized role in climate and climate change. The ocean is at the center of contemporary questions such as:
- Why have global-mean surface temperatures not warmed in the last decade, despite CO_2 continuing to rise in the atmosphere?
- Why is the Arctic losing sea-ice but not the Antarctic?
- Will ocean currents such as the Gulf Stream change?
- How much might sea-level rise this century?
- How might life respond to the ocean becoming ever more acidic as CO_2 dissolves into it?

In this discussion we will touch on some of the above questions and review how scientists observe patterns of warming propagating down in to the ocean's interior, how the ocean is responding to that warming, what we think the future holds and why.

Plenary Talk PV XII Fri 9:45 PV-Rooms

Quantum Measurements — •Berge Englert — Centre for Quantum Technologies and Department of Physics, National University of Singapore

We gather information about physical systems by observation. In the realm of quantum physics, the experiments give us probabilistic data with natural statistical fluctuations that cannot be reduced by better instrumentation. What do such data tell us about the quantum system under study? A systematic and reliable answer can be given with the methods of quantum state estimation and quantum parameter estimation. I will review recent developments.