Plenary Talk PV I Mon 9:00 Audimax 1

Inference and Mitigation of COVID-19 — •Viola Priesemann — MPI for Dynamics and Selforganization, Göttingen

How can we infer the spread of SARS-CoV-2 in a population, and how can we derive effective mitigation measures? How do non-pharmaceutical interventions, the vaccination progress and the emergence of new variants impact the viral spread? We recapitulate the basic principles of spreading dynamics, and highlight their implications for collective dynamics. On this basis, we investigate different COVID-19 mitigation strategies. In particular, we demonstrate a tipping point for the test-trace-isolate system, which incurs (transient) supra-exponential growth. We then show how the pace of lifting restrictions is determined by the progress of vaccination, and finally investigate the emergence of novel variants. With this work, we contribute to the basic understanding of spreading dynamics in populations, and provide approaches, which may guide mitigation policies.

Plenary Talk PV II Mon 9:00 Audimax 2

Quantum thermodynamics - superconducting circuit approach — •Jukka Pekola — QTF Centre of Excellence, Aalto University, Helsinki, Finland

I start by introducing ideas and principles of how to realize thermodynamic phenomena and devices in circuits composed of superconducting elements, including qubits, combined with heat baths formed of on-chip electronic reservoirs. This way we have demonstrated quantum limited heat transport by microwave photons [1,2], quantum heat valves [3] and rectifiers [4] and ultrasensitive calorimetric detectors [5]. Towards the end of the talk I present progress in realizing quantum heat engines and refrigerators based on thermodynamic cycles [6], and results on ultimate energy resolution of nanocalorimeters [5,7,8].

[1] M. Meschke, W. Guichard, and J. P. Pekola, Nature 444, 187 (2006). [2] A.V. Timofeev, M. Helle, M. Meschke, M. Möttönen, and J.P. Pekola, Phys. Rev. Lett. 102, 200801 (2009). [3] A. Ronzani, B. Karimi, J. Senior, Y.-C. Chang, J. T. Peltonen, C. Chen, and J. P. Pekola, Nat. Phys. 14, 991 (2018). [4] J. Senior, A. Gubaydullin, B. Karimi, J. T. Peltonen, J. Ankerhold, and J. P. Pekola, Comm. Phys. 3, 40 (2020). [5] B. Karimi, F. Brange, P. Samuelsson, and J. P. Pekola, Nat. Commun. 11, 367 (2020). [6] B. Karimi and J. P. Pekola, Phys. Rev. B 94, 184503 (2016). [7] Bayan Karimi, Jukka P. Pekola, Phys. Rev. Lett. 124, 170601 (2020). [8] B. Karimi, D. Nikolic, T. Tuukkanen, J. T. Peltonen, W. Belzig, and J. P. Pekola, Phys. Rev. Appl. 13, 054001 (2020).

Plenary Talk PV III Mon 16:30 Audimax 1

Complex networks with complex nodes — •Raissa D'Souza — University of California, Davis CA, USA

Real world networks – from brain networks to social networks to critical infrastructure networks – are composed of nodes with nonlinear behaviors coupled together via non-trivial network structures. Approaches from statistical physics study how behaviors arise in collections of simple elements connected together in complex structures such as modular or scale-free networks. They provide understanding about massive networks, revealing implications that network structure can have on network function and resilience. In contrast, approaches from dynamical systems and control theory typically study small systems of nonlinear nodes connected together in simple networks. This talk presents recent work bridging the gap of complex networks with complex nodes. First is considering nonlinear phase-amplitude oscillators coupled together by simple ring networks and how the interplay of nodal dynamics and coupling structure gives rise to emergent long-range order. Next is increasing the structural complexity from dyadic networks to hypergraphs to capture higher-order interactions and study cluster synchronization. The focus will then turn to social networks, starting from modeling humans as nodes with underlying attributes coupled in complete graphs, and moving on to real-world multiplex social networks in macaque monkey societies. We reveal the tensions between the forces of homophily and social balance, and show how the competition between rewarding talent and rewarding social reputation can cause cascading rank rearrangements in established social hierarchies.

Plenary Talk PV IV Mon 16:30 Audimax 2

Functional Three Dimensional Mesostructures as Bioelectronic Interfaces — •John Rogers — Northwestern University, Evanston, USA

Complex, three dimensional (3D) assemblies of micro/nanomaterials form naturally in biological systems, where they provide sophisticated function in even the most basic forms of life. In spite of their broad potential utility in man-made devices, design options for analogous abiotic 3D mesostructures are severely constrained by the comparatively primitive capabilities that are available with established techniques for materials growth, assembly and 3D printing. This talk summarizes progress on strategies that rely on geometric transformation of preformed 2D functional micro/nanostructures into 3D architectures by controlled processes of actively induced compressive buckling. The emphasis is on the foundational materials and mechanics principles, computational approaches that enable inverse designs, and examples of applications in areas ranging from thermoelectrics to microelectromechanical systems to biologically inspired open mesoscale microfluidic/electronic networks as functional interfaces to 3D cell cultures, including spheroids, organoids, assembloids and mini-brains.

Evening Talk PV V Mon 18:30 PEL

Die Rolle des Wasserstoffs im Energiesystem — •Robert Schlögl — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Deutschland

Wasserstoff ist die einzige Möglichkeit erneuerbare Energien global auszutauschen und damit den Bedarf an erneuerbarer Energie mit den Erzeugungsmöglichkeiten der Sonne zu verbinden. Eine zügige Umsetzung der Energiewende setzt nun voraus, dass wir die technischen und organisatorischen Hindernisse überwinden um zu einem globalen Markt für erneuerbare Energie zu gelangen. Der Beitrag adressiert einige technische Herausforderungen und beschreibt die politischen Maßnahmen zur Einführung einer Wasserstoffwirtschaft.

Plenary Talk PV VI Tue 9:00 Audimax 1

Correlated electrons with knots — •Silke Bühler-Paschen — TU Wien, Vienna, Austria

Strongly correlated quantum materials are fertile ground for new physics and offer numerous opportunities for discovery. To explore how the landscape of correlated quantum phases is enriched in the presence of nontrivial electronic topology, characterized by topological knots (or nodes) in momentum space, represents a new frontier. After a general discussion of this background, I will present our recent results on a Weyl semimetal driven by strong correlations, and highlight its giant topological responses as well as the ease to achieve genuine topology control. I will close by discussing the prospect of finding further correlation-driven topological phases and their potential for quantum applications.

Plenary Talk PV VII Tue 9:00 Audimax 2

Cuprous oxide: the ultimate material for studying excitons? — •Manfred Bayer — Experimentelle Physik, TU Dortmund

Excitons determine the optical properties of semiconductors. They are currently attracting intense renewed interest due to their large binding energies in novel materials such as transition metal dichalkogenides. Excitons are typically described by the hydrogen model. The highest observed principal quantum number n has been five or less in almost any semiconductor. The only exception is cuprous oxide, Cu_2O, in which excitons were demonstrated for the first time in 1952. Recently, the combination of high resolution laser spectroscopy and high crystal quality allowed the extension of the exciton series up to n=28, showing also the exceptional position of cuprous oxide for studying exciton physics. This contribution discusses the status achieved in the assessment of excitons in Cu_2O: (i) About 60 quantum number combinations (n, orbital angular momentum L), defining different shells, have been observed spectroscopically, also by applying electric or magnetic fields. (ii) Not only the optically active states that are allowed in different orders of light-matter coupling, but also the optically forbidden states could be detected up to $n = 6$. (iii) In the fine structure of the excitons pronounced deviations from the hydrogen model are found, which arise from breaking of the rotational into discrete symmetries in the crystal. (iv) Due to the large size of excitons with high principal quantum numbers, pronounced interaction effects with other excitons are observed. A consequence is the Rydberg blockade, where the presence of one exciton blocks excitation of another one in its surrounding.

Plenary Talk PV VIII Tue 16:30 Audimax 1

The Structural Origins of Wood Cell Wall Toughness — •Cynthia Volkert[1], Mona-Christin Maass[1], Salimeh Saleh[1], and Holger Militz[2] — [1]Institute of Materials Physics, University of Göttingen, Göttingen, Germany — [2]Wood Biology and Wood Products, University of Göttingen, Göttingen, Germany

Properties that are determined by structure - rather than by composition - are the basis of synthetic architected and meta-materials and of almost all natural materials. One remarkable example is wood. Despite being composed of only polymers, its hierarchical structure leads to specific strengths and stiffnesses that compete with those of high-performance engineering alloys.

The study presented here relates cellulose microfibril arrangements to splitting fracture toughness in pine wood cell walls using in-situ electron microscopy and reveals a previously unknown toughening mechanism [1]. The splitting cracks propagate along the direction of the microfibrils, and are steered to and trapped at highly tough interfaces, where the microfibrils change direction. This previously unexplained arrangement of the microfibrils can now be understood as a natural adaptation of living wood to enhance its toughness.

The microfibril structure can be mimicked to provide a powerful, new tactic for designing tough engineering composites by arranging fibers and layers to introduce tough interfaces that attract and trap delamination cracks. Perspectives for the application of this tactic to several technological problems will be discussed.

[1] M.-C. Maaß et al. Adv. Mater. 2020, 32, 1907693

Plenary Talk PV IX Tue 16:30 Audimax 2

Microscopic polarization and magnetization fields: Towards a 'post modern' theory — •John Sipe — Department of Physics, University of Toronto, 60 St. George St., Toronto, ON M5S 1A7 Canada

The response of solids to incident electromagnetic fields is often heuristically formulated in terms of macroscopic polarization and magnetization fields. The 'modern theory of polarization,' and its extension to magnetization, gives this a new level of rigour for time independent and uniform applied fields. We review the philosophy and main results of this strategy, and report on a new approach based on introducing microscopic polarization and magnetization fields. This 'post-modern' strategy can be used to address the response to electromagnetic fields varying arbitrarily in space and time. We connect it to earlier work on atoms and molecules, identifying important similarities and differences.

Plenary Talk PV X Wed 9:00 Audimax 1

Revealing the topological nature of transport at mesoscopic scales with quantum interferences — •Helene Bouchiat, A. Bernard, A. Murani, B. Dassonneville, A. Kasumov, M. Ferrier, R. Deblock, and S. Guéron — Laboratoire de Physique des Solides, University Paris Saclay, 91405 Orsay, France

A mesoscopic conductor is characterized by its size smaller than the phase coherence length of electronic wave-functions (typically one micrometer at low temperature). Mesoscopic electronic transport depends strongly on the nature of interferences between these wave functions determined by the scattering disorder potential which tends to localize electronic states at low dimension. Moreover, these interferences can be modulated by a magnetic flux through the Aharonov-Bohm effect giving rise to orbital persistent currents in ring geometries. These interferences also determine the Josephson supercurrent of a mesoscopic normal conductor when connected to superconducting electrodes. We show that these basic fundamental properties of mesoscopic quantum interferences can be used to reveal the existence and the physical location of 1d protected states in topological insulators. This method is illustrated in the case of crystalline bismuth nanowires which were found to belong to a class of newly discovered higher order topological insulators with helical ballistic hinge states coexisting with trivial bulk and surface diffusive states. In particular we discuss SQUID like periodic magnetic oscillations observed in Bi based Josephson junctions.

Plenary Talk PV XI Wed 9:00 Audimax 2

Quantum choreography to the beat of light — •Rupert Huber — Department of Physics and Regensburg Center for Ultrafast Nanoscopy (RUN), University of Regensburg, Regensburg, Germany

Lightwave electronics has pushed the control of condensed matter to unprecedented time scales. By harnessing the carrier wave of intense light as an alternating voltage, electrons can be driven faster than a cycle of light, opening a fascinating quantum world full of promise for future quantum technologies.

We will discuss prominent examples of lightwave-driven dynamics in solids, ranging from dynamical Bloch oscillations to lightwave valleytronics and super-resolution all-optical band structure reconstruction. In topological insulators, ballistic and quasi-relativistic electron motion leads to a new quality of non-integer high-harmonic generation, unveiling the Berry curvature of the surface state. Moreover, we combine lightwave electronics with low-temperature scanning tunneling microscopy to take atom-scale slow-motion movies of an individual vibrating molecule. Lightwaves inside the tunnelling junction can even serve as femtosecond atomic forces to choreograph a coherent structural motion of a single-molecule switch. This concept offers a radically new way of directly watching and controlling key elementary dynamics in nature and steer (bio)chemical reactions or ultrafast phase transitions, on their intrinsic spatio-temporal scales.

Plenary Talk PV XII Thu 9:00 Audimax 1

Quantum networks - from dreams to reality — •Jian-Wei Pan — University of Science and Technology of China, 96 Jinzhai Road, Hefei 230026, China

Photons, the fast flying qubits which can be controlled with high precision using linear optics and have weak interaction with environment, are the natural candidate for quantum communications. By developing a quantum science satellite Micius and exploiting the negligible decoherence and photon loss in the out space, practically secure quantum cryptography, entanglement distribution, and quantum teleportation have been achieved over thousand kilometer scale, laying the foundation for future global quantum internet. Surprisingly, despite the extremely weak optical nonlinearity at single-photon level, an effective interaction between independent indistinguishable photons can be effectively induced by a multi-photon interferometry, which allowed the first creation of multi-particle entanglement and test of Einstein's local realism in the most extreme way. By developing high-performance quantum light sources, the multi-photon interference has been scaled up to implement boson sampling with up to 76 photons out of a 100-mode interferometer, which yields a Hilbert state space dimension of 10^30 and a rate that is 10^14 faster than using the state-of-the-art simulation strategy on supercomputers.

Plenary Talk PV XIII Thu 9:00 Audimax 2

Status and Perspectives of Concentrating Solar Power Technologies — •Robert Pitz-Paal — DLR, Institut für Solarforschung, Cologne, Germany

In CSP technology concentrating collectors are used to generate high temperature heat that drives a conventional power cycle. As heat can be stored simpler and cheaper than electricity the concept is very suitable to provide electricity according to the demand in particular covering the load peak after sunset typical in many Sunbelt countries. CSP electricity costs have dropped approx. by half since the beginning of the commercial implementation phase in 2007 along with the implementation of 6,2 GW of CSP plants worldwide. They range today from 12 €cents/kWh down to 6 €cents/kwh depending on size of the power plant, solar resource and financing conditions. Further cost reduction is driven by mass production effects but also through technical innovations that lead to higher system efficiencies, resulting in more electricity output per sqm of concentrator surface. The talk will provide background information on the current market and cost situation. It will highlight new technology concepts and report on the progress of research projects that target to increase system efficiency through higher operation temperature in the heat transfer fluid of the system.

Plenary Talk PV XIV Thu 16:30 Audimax 1

Wanderings at the Crossroad between Nonlinear Dynamics and Systems Biology — •Alain Karma — Northeastern University, Boston, USA

Insights into biological systems have been historically obtained by two very different approaches. Nonlinear dynamics has primarily focused on understanding the temporal behavior of specific sub-systems at a single level of biological organization using mathematical models, often represented by a set of differential equations with fixed parameters such as those describing gene regulatory circuits, metabolic networks, or intra- and inter-cellular signaling and communication pathways. While this approach can shed light on the behavior of specific subsystems, it does not generally describe the coupling between different levels of biological organizations, which severely limits its scope. Systems biology, in contrast, attempts to understand biological systems globally by using high-throughput technologies and bioinformatics to probe the interaction of large ensembles of genes, proteins, and small molecules acting across different levels of biological organization. This approach has proven useful to identify genes and signaling pathways underlying diseases but does not predict how living organisms maintain their function and adapt to changing environments. This talk will describe recent progress to combine those two approaches to understand the dynamical coupling between different levels of biological organizations in the context of cardiac excitable dynamics. The results provide a fundamental basis for personalized therapies of heart rhythm disorders and other human diseases.

Plenary Talk PV XV Thu 16:30 Audimax 2
Cavity Magnonics — •Can-Ming Hu — University of Manitoba, Winnipeg, Canada

Cavity Magnonics (also known as Cavity Spintronics and Spin Cavitronics) is an emerging field that studies the light-matter interactions involving cavity photons and magnons [1-3]. Via the quantum physics of spin-photon entanglement on the one hand, and classical electrodynamic coupling on the other, magnon-photon coupling connects some of the most exciting modern physics, such as quantum information and quantum optics, with one of the oldest science on the earth, the magnetism.

This talk aims to introduce this frontier to the general audience of condensed matter physics. Starting with the intuitive example of coupled harmonic oscillators, I will explain the concepts of coherent and dissipative coupling, based on which two streams of research will be presented: (i) The development of diverse quantum transducers utilizing coherent coupling. (ii) The study of dissipative coupling governed by a non-Hermitian Hamiltonian, which leads to intriguing effects such as level attraction, nonreciprocal microwave transmission, exceptional points, and bound state in continuum. Students who are looking for frontier research opportunities are encouraged to attend.

[1] C.-M. Hu, Phys. in Canada, 72, No. 2, 76 (2016); arXiv: 1508.01966 (2015).
[2] D. Lachance-Quirion, et al., Appl. Phys. Express 12, 070101 (2019).
[3] Babak Zare Rameshti, et al., arXiv: 2106.09312 (2021).

Evening Talk PV XVI Thu 18:30 MVL
Max von Laue Lecture: What physicists can do to improve international security? — •Steve Fetter — University of Maryland, College Park, USA

After developing nuclear weapons, physicists were at the forefront in alerting policymakers and the public to the dangers of nuclear war. National academies, non-governmental organizations, and individual scientists helped conceive and promote arms control concepts and develop verification technologies which formed the foundation for treaties that enhanced international security and stability. That foundation is now crumbling, as treaties are discarded and a new generation of nuclear weapon systems is under development. Moreover, new security challenges are arising from emerging technologies, including quantum sensors and computing; artificial intelligence, machine learning, and robotics; cybersecurity; small satellites; and gene synthesis and editing. The physics community can play an important role in educating policymakers and the public about these risks and how they can be reduced.

Plenary Talk PV XVII Fri 9:00 Audimax 1
Superconductivity near room temperature — •Mikhail Eremets — Max-Planck-Institut fur Chemie (Otto-Hahn-Institut) Hahn-Meitner Weg 1 55128 Mainz Germany

Superconductivity at ambient conditions is one of the most challenging and long-standing problems in condensed-matter physics. Recently, superconductivity at 203 K was discovered in H3S at high pressure (Drozdov,Eremets et al. 2015), breaking archaic paradigms on conventional superconductivity. In the last years, many other superconductors were discovered and Tc of 250 K (Drozdov, Kong et al. 2019, Somayazulu, Ahart et al. 2019, Flores-Livas, L et al. 2020) was reached in a superhydride LaH10. Even higher critical temperatures were predicted theoretically (Sun, Lv et al. 2019). These record-breaking superconductors model atomic metallic hydrogen where high-temperature superconductivity was predicted 50 years ago (Ashcroft 1968, Ashcroft 2004). In this respect, I will show the most recent efforts on seeking the superconducting phase of pure hydrogen (Eremets, Drozdov et al. 2019). The progress towards room temperature superconductivity at moderate and ambient pressure is likely to be related to light-elements materials with strong covalent bonding.

Plenary Talk PV XVIII Fri 9:00 Audimax 2
Machine Learning meets Quantum Physics — •Klaus-Robert Müller — TU Berlin, Germany, Korea University, Seoul, Korea and MPII, Saarbrücken, Germany

The talk will first briefly introduce machine learning (ML) concepts, before applying them in Quantum chemistry and materials. This will include kernel-based learning methods and deep neural networks. A particular focus will lie on the challenge of interpreting nonlinear machine learning models. In other words, given that we have an excellent predictor of quantum chemical properties, how can we gain an understanding of the physics or chemistry that this learning machine has implemented? I will show selected examples of ML applied for predicting properties of small molecules and also for materials.

Plenary Talk PV XIX Fri 15:15 Audimax 1
Scalable semiconductor quantum and classical photonic systems — •Jelena Vuckovic — Stanford University

Classical and quantum photonics with superior properties can be implemented in a variety of photonic materials (silicon, diamond, silicon carbide) by combining state of the art optimization and machine learning techniques (photonics inverse design) with new fabrication approaches.

Plenary Talk PV XX Fri 15:15 Audimax 2
From Self-Assembled Soft Matter to Mesostructured Quantum Materials — •Ulrich Wiesner — Cornell University, Ithaca, NY 14853, US

Block copolymer (BCP) self-assembly (SA), a hallmark of soft condensed matter physics, continues to attract substantial academic and industrial interest. The dependence of SA structures and length scales on macromolecular characteristics like block fractions and molar mass allows for exquisite control over mesoscale lattice symmetry and parameters uncommon to the atomic lattice scale. This talk will provide an overview of polymer solution-based approaches that have been developed in recent years to translate this structure control to electronic materials, from energy conversion and storage devices all the way to quantum materials. Emphasis will be on fundamental understanding of structure formation principles, that can be generalized to a host of material classes from all-organic materials to carbons, oxides, semiconductors and metals all the way to superconductors, and resulting structure-property correlations. These solution-based SA approaches enable systematic studies of the influence of mesostructure on materials properties, resulting in what is often referred to as metamaterials. Mesostructured superconductors, in particular, are a fertile recent area for exploration of the impact of mesoscale order and porosity on the properties of correlated electron systems leading to quantum metamaterials. First examples will be discussed suggesting a fruitful convergence of soft matter self-assembly with condensed matter physics.