**Sunday Evening Lecture** PLV I Sun 18:45 H 0105

**Next exit future: Is it them or us?** — •Ranga Yogeshwar — science journalist and presenter, Hennef, Germany

Artificial intelligences already outperform humans in some fields such as playing Go or identifying tumors within X-rays. They often excel by developing whole new ways of seeing, or even thinking and recent findings suggest that they attain superhuman performances even without the need of learning from human experiences. AI is set to play an increasingly significant role in our professional and personal lives with applications within financial businesses, communication, medicine or autonomous cars.

But as machine learning becomes more and more powerful and complex, the field's researchers increasingly find themselves unable to account for what their algorithms really know. We experience a transition from causality, the basic foundation of the enlightenment, to an opaque world of correlations and statistical probabilities. The impact on our society is huge and this raises a number of questions: Just how much can and should we trust these intelligent systems? How much responsibility are we prepared to hand over to AI? How should we respond to the steadily growing capabilities of many areas of deep learning?

Society as a whole needs to have a broad-based discussion on the applications and implications of AI.

**Plenary Talk** PLV II Mon 8:30 H 0105

**Imaging Topological Electrons in Low Dimensions: from the Inorganic to the Organic** — •Michael F. Crommie — UC Berkeley Physics Dept., Berkeley, CA, USA — Lawrence Berkeley National Laboratory, Materials Sciences Division, Berkeley, CA, USA

The idea of classifying materials by their topological properties is useful for predicting their behavior, especially at interfaces. Materials belonging to different topological classes exhibit conducting states at the interfaces between them, even when the materials are insulators to begin with. But what do these topologically-protected electrons look like? Somewhat ironically, electrons in low-dimensional topological systems (such as 1D molecular chains and 2D quantum wells) that have long been studied are quite difficult to image, whereas newer 3D topological systems are much more accessible to imaging via scanning tunneling microscopy (STM). I will discuss recent developments that have resulted in new low-dimensional topological systems that are increasingly accessible to microscopists who image electrons. The first is a 2D class of inorganic material, the transition metal dichalcogenides (TMDs). Single TMD layers in the 1T(prime) phase are 2D topological insulators. I will discuss our recent efforts to image electrons that inhabit topologically protected edge-states in this new quantum spin Hall insulator. The second system is molecular: graphene nanoribbons are 1D topological insulators. I will discuss our recent efforts to engineer the topological properties of this organic system, and to image resulting electronic behavior at sub-nm lengthscales.

**Plenary Talk** PLV III Mon 14:00 H 0105

**Imaging and controlling nanoscale crystal growth in the transmission electron microscope** — •Frances M. Ross — IBM T. J. Watson Research Center, Yorktown Heights, NY, USA

Building functional nanostructures with atomic level precision requires a detailed understanding of materials growth and the physics of self-assembly at the nanoscale. *In situ* imaging in the transmission electron microscope can provide unique information here, because measurements can be made on individual nanostructures while they grow. Here we will describe examples in which *in situ* electron microscopy helps to explore growth mechanisms and can even suggest strategies to build new types of structure. We will show nanocrystal epitaxy on graphene, electrochemical deposition processes in aqueous solutions and the formation of semiconductor structures from catalytic droplets. We will conclude with a perspective on the exciting recent developments in electron microscopy and how these will advance *in situ* experiments in the future.

**Plenary Talk** PLV IV Mon 14:00 H 0104

**Fast Parametric Interactions Between Superconducting Quantum Circuits** — •Raymond W Simmonds — The National Institute of Standards & Technology, Boulder, CO USA

The need to develop robust schemes for providing fast, reliable qubit-qubit interactions for logical gates is generic to all physical approaches for implementing a large-scale quantum information processor. The Advanced Microwave Photonics Group at NIST, Boulder, Colorado USA has been developing non-resonant, parametrically induced coupled interactions between transmon-based superconducting quantum bits for providing fast, high fidelity gate operations. We use a flux-biased direct-current Superconducting Quantum Interference Device (dc-SQUID) to generate tunable interactions between transmon qubits. By modulating the flux to the dc-SQUID, we can create variable coupling rates from zero to greater than 100 MHz. Parametric coupling is important for constructing larger coupled systems, also useful for producing quantum simulators. In addition, our Group has been developing quantum-limited parametric amplifiers that use a nonreciprocal network for qubit readout. Our amplifiers have been designed to eliminate the back-action caused by noise in the amplification chain and to increase measurement efficiency by retaining most of the information carrying microwave photons. The coupling between our circuit components within the measurement network is controlled through tunable parametric interactions, in a similar way to the techniques used for coupling qubits.

**Plenary Talk** PLV V Tue 8:30 H 0105

**Upside-Down and Inside-Out: Biomechanics of Cell Sheet Folding** — •Raymond Goldstein — University of Cambridge, UK

Deformations of cell sheets are ubiquitous in early animal development, often arising from a complex and poorly understood interplay of cell shape changes, division, and migration. In this talk I will describe an approach to understanding such problems based on perhaps the simplest example of cell sheet folding: the "inversion" process of the algal genus *Volvox*, during which spherical embryos literally turn themselves inside out through a process hypothesized to arise from cell shape changes alone. Through a combination of light sheet microscopy and elasticity theory a quantitative understanding of this process is now emerging.

**Plenary Talk** PLV VI Tue 17:30 H 0105

**Resonant Inelastic X-Ray Scattering** — •Lucio Braicovich and Giacomo Claudio Ghiringhelli — Dipartimento di Fisica, Politecnico di Milano, 20133 Milano — EPS Condensed Matter Division Europhysics Prize

**Plenary Talk** PLV VII Wed 8:30 H 0105

**Nanoscale thermal imaging of dissipation in quantum systems** — •Eli Zeldov — Weizmann Institute of Science, Rehovot, Israel

Imaging energy dissipation in quantum systems by existing thermal imaging methods is currently impossible due to limited sensitivity and low temperature incompatibility. We developed a scanning SQUID-on-tip nanothermometer with sub 50 nm diameter that provides cryogenic thermal imaging with four orders of magnitude improved sensitivity of below 1 $\mu$K/Hz1/2 [1]. The non-contact non-invasive thermometry allows thermal imaging of minute energy dissipation down to the fundamental Landauer limit of 40 fW for continuous readout of a single qubit at 1 GHz at 4.2 K. By varying potential between the SQUID-on-tip and the sample a spectroscopic analysis of the dissipation process is attained. Using this scanning nanothermometry we visualize and control phonon emission due to inelastic electron scattering off individual atomic defects in graphene [2], which occurs, however, only when the Fermi level comes into resonance with the quasi-bound states at the defects. The atomic defects are very rare in the bulk but abundant at the edges, acting as switchable atomic-scale phonon emitters that establish the dominant dissipation mechanism in graphene.

[1] D. Halbertal, J. Cuppens, M. Ben Shalom, L. Embon, N. Shadmi, Y. Anahory, H.R. Naren, J. Sarkar, A. Uri, Y. Ronen, Y. Myasoedov, L.S. Levitov, E. Joselevich, A.K. Geim, and E. Zeldov, Nature 539, 407 (2016). [2] D. Halbertal, M. Ben Shalom, A. Uri, K. Bagani, A.Y. Meltzer, I. Marcus, Y. Myasoedov, J. Birkbeck, L.S. Levitov, A.K. Geim, and E. Zeldov, Science 358, 1303 (2017).

**Plenary Talk** PLV VIII Wed 14:00 H 0105

**Quantum photonics using van der Waals heterostructures** — •Atac Imamoglu — ETH Zurich

Transition metal dichalcogenide (TMD) monolayers represent a new class of two-dimensional (2D) valley semiconductors, exhibiting features such as a valley pseudospin degree of freedom, ultra-strong Coulomb interactions and Berry curvature with novel optical signatures. Since the first experiments in 2010, exploration of the electronic and optical properties of TMD monolayers has resulted in a number of ground-breaking achievements, including the observation of valley Hall effect and many-body optical excitations termed exciton-polarons.

Concurrently, there has been an impressive improvement in sample quality, culminating in observation of radiative-lifetime broadened exciton resonances and realization of an atomically thin mirror using a TMD monolayer. Most of these advances rely on unique features of 2D materials with no counterpart in conventional semiconductors such as GaAs. In this talk, I will describe novel quantum optical and many-body phenomena in van der Waals heterostructures composed of TMD monolayers, boron nitride and graphene. The emphasis will be on strong interactions between electrons and excitons or polaritons.

**Plenary Talk** PLV IX Wed 14:00 H 0104

**Hairy Hydrodynamics** — •Anette Hosoi — Massachusetts Institute of Technology, Cambridge, MA, USA

Flexible slender structures in flow are everywhere. While a great deal is known about individual flexible fibers interacting with fluids, considerably less work has been done on fiber ensembles - such as fur or hair - in flow. These hairy surfaces are abundant in nature and perform multiple functions from thermal regulation to water harvesting to sensing. Motivated by these biological systems, we consider three examples of hairy surfaces interacting with flow. In the first example, we take inspiration from semi-aquatic mammals which have specially adapted fur that serves as an effective insulator both above and below water. Many of these animals have evolved pelts that naturally entrap air when they dive. Here we investigate diving conditions and fur properties which amplify air entrainment. In the second example we consider viscous dipping, a feeding method utilized by many nectar drinking animals, whereby fluid is viscously entrained on the surface of a tongue. Finally, we consider a fundamental component in hydraulic systems, the flow rectifier. In particular we propose a design that allows the operator to modulate the relative resistances in the rectifier and that can be achieved using only solid state components.

**Evening Talk** PLV X Wed 20:00 Urania

**Kollektive Dynamik in Sozialen Systemen: Netzwerke, Emotionen und Big Data** — •Frank Schweitzer — Chair of Systems Design, ETH Zurich, Switzerland

Die statistische Physik stellt Methoden bereit, um kollektive Phänomene in physikalischen Systemen zu beschreiben. Neue Systemeigenschaften, wie die Leitfähigkeit in einem Festkörper, enstehen aus der Wechselwirkung einer grossen Zahl von Elementen, etwa der Atome. Schon Aristoteles wusste, dass das Ganze mehr ist als die Summe seiner Teile. Was ist damit für das Verständnis der kollektiven Dynamik in sozialen Systemen gewonnen? Können wir die Entstehung kollektiver Emotionen aus der Interaktion einer Vielzahl von Internet-Usern erklären? Oder die virale Verbreitung von YouTube Videos und die Popularität von Internet-Phänomenen wie Boxxy? In der Tat lassen sich solche kollektiven Prozesse mithilfe von Agenten-basierten Modellen beschreiben, die die Systemdynamik sehr gut wiedergeben. Mehr noch: die Flut sozialer Daten erlaubt auch Performance-Analysen. Das Ganze ist mehr als die Summe seiner Teile - aber wieviel mehr? Ist ein Team 2x, 3x oder 1.5x so produktiv, wenn die Zahl der Mitarbeiter verdoppelt wird? Eine Erklärung liefert uns die Analyse des sozialen Netzwerkes. Um die kollektive Dynamik in sozialen Systemen zu verstehen, lassen sich also verschiedene Ansätze kombinieren: stochastische Modelle, Netzwerkanalysen und datengetriebene Methoden.

**Plenary Talk** PLV XI Thu 8:30 H 0105

**Emergent properties and functions of topological magnets** — •Yoshinori Tokura — RIKEN Center for Emergent Matter Science, Japan — Department of Applied Physics, University of Tokyo, Japan

Magnetism meets topology. The topology of spin texture either in momentum space and real space can generate emergent electromagnetic fields acting on the conduction and valence electrons in solid, produce intriguing properties and responses. One archetypical example is a magnetic skyrmion, a spin swirling object with integer winding number. Its topology protects the skyrmion from external perturbation, forming a robust metastable state. Skyrmions and accompanied magnetic monopoles provide a fertile research field not only for topology physics but also for new spintronic functions.

One other important example of topological magnets is magnetic topological insulators, in which the spin-momentum locking as well as the magnetization-induced mass-gap shows up to form the ideal 2D Weyl fermion system at surface. With control of the magnetizations on the top and bottom surfaces, quantum anomalous Hall state and quantum magnetoelectric (axion insulator) state can be formed. Therein, the topological magneto-optical effects also show up and the quantized chiral edge conduction is realized on the reconfigurable magnetic domain walls.

These momentum-space or real-space topological spin textures are overviewed with perspectives of exploration for new quantum materials and functions.

**Plenary Talk** PLV XII Thu 14:00 H 0105

**From Atomistic Simulations into the Mouse: Learning how to exploit bacterial adhesives as nanoscale probes to map the mechanical strain of tissue fibers.** — •Viola Vogel[1], Simon Arnoldini[1], Alessandra Moscaroli[2], Mamta Chabria[1], Manuel Hilbert[2], Samuel Heritig[3], Roger Schibli[2], and Martin Behe[2] — [1]ETH Zurich — [2]PSI Villigen — [3]Hertig Visualizations

Many novel mechanisms have emerged how mechanical forces can regulate protein and cell functions. This was made possible by an increasingly large toolbox of nano- and microtechnologies to quantify forces and mechanical strains at the molecular and cellular levels. Yet, how to extend those insights towards the tissue level is unclear, due to the lack of force or tissue fiber strain probes. It is thus not known how cell-generated forces acting on tissue fibers might tune the structure*function relationships of proteins and whether this might ultimately regulate spatially directed tissue growth, regeneration, homeostasis, or disease progression. To address this major need, we took advantage of the evolution of bacterial adhesives that specifically target the extracellular matrix protein fibronectin. In wounds or sites of inflammation, tissue fibers are cleaved, either mechanically or enzymatically, which leads to the structural relaxation of tensed tissue fibers. After we had discovered that these bacterial adhesives tightly bind to relaxed but not to highly tensed fibers, we next illustrated that they can be exploited as nanoscale mechanical strain probes at the tissue level.

**Plenary Talk** PLV XIII Thu 14:00 H 0104

**A significant raw material of the 21$^{st}$ century** — •Claudia Draxl — Physics Department and IRIS Adlershof, Humboldt-Universität zu Berlin — Fritz Haber Institute of the Max Planck Society, Berlin

The growth of data from simulations and experiments is expanding beyond a level that is addressable by established scientific methods. The so-called “4 V challenge” of Big Data – Volume (the amount of data), Variety (the heterogeneity of form and meaning of data), Velocity (the rate at which data may change or new data arrive), and Veracity (uncertainty of quality) – is clearly becoming eminent also in materials science. An issue, for example, is understanding errors in both experiment and theory; related to this, assigning error bars and trust levels to high-throughput screening results, as obtained by density-functional theory. Controlling our data, however, sets the stage for explorations and discoveries. Novel data-mining technology can find patterns and correlations in data that can’t be seen by a human eye. In fact, data-driven materials research is adding a new research paradigm to our scientific landscape.

**Evening Talk** PLV XIV Thu 18:00 H 0105

**Lise-Meitner-Lecture: Multiferroic Materials for a New Age** — •Nicola Spaldin — ETH Zürich

Every advance in human civilization, from the Stone Age to today’s Silicon Age, has been driven by a development in materials. I will present a new class of materials – multiferroics – that are both a playground for exploring exciting fundamental physics, and a potential enabler of transformative beyond-silicon technologies.

**Plenary Talk** PLV XV Fri 8:30 H 0105

**How photons change the properties of matter: QED-TDDFT an ab initio framework for modeling Light-Matter interaction** — •Angel Rubio — Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany — Center for Computational Quantum Physics (CCQ), The Flatiron Institute, 162 Fifth avenue, New York NY 10010, USA — Laureate of the Max-Born-Prize

Computer simulations that predict the light-induced change in the physical and chemical properties of complex systems, molecules, nanostructures and solids usually ignore the quantum nature of light. Recent experiments at the interface between materials science and quantum optics have uncovered situations where both the molecular system and the photon field have to be treated in detail. In this talk, we show how the effects of quantum-photons can be properly included in the newly developed quantum electrodynamics density-functional formalism (QED-TDDFT). We provide an overview of how well-established concepts in the fields of quantum chemistry and material sciences have to be adapted when the quantum nature of light becomes important in correlated matter-photon problems. We identify fundamental changes in Born-Oppenheimer surfaces, conical intersections, spectroscopic quantities, and quantum control efficiency. We also show how periodic driving of many-body systems allow to design Floquet states of matter with tunable electronic properties on ultrafast time scales.

Work done in collaboration with: H. Appel, M. Ruggenthaler, H, Hübener, U. de Giovannini, M. Sentef, N. Park, J. Flick, C. Schaefer, V. Rokaj, D. Welakuh