Plenary Talk PV I Mon 8:30 HSZ 01

The Ring of Brownian motion: the good, the bad and the simply silly — •Peter Hanggi — University of Augsburg, 86135 Augsburg, Germany

Since the turn of the 20-th century Brownian hiss has continuously disclosed a rich variety of phenomena in and around physics. The understanding of this jittering motion of suspended microscopic particles has undoubtedly helped to reinforce and substantiate those pillars on which the basic modern physical theories are resting: Its formal description provided the key to great achievements in statistical mechanics, the foundations of quantum mechanics and even astrophysical phenomena, to name only a few [1]. – Brownian motion determines the rate limiting step in most transport phenomena via escape events that help to overcome obstructing bottlenecks [2], or triggers oscillatory dynamics in excitable media [3]. Although noise is usually thought of as the enemy of order it in fact also can be of constructive influence. The phenomena of Stochastic Resonance [4,5] and Brownian motors [6,7] present two such archetypes wherein random Brownian dynamics together with unbiased nonequilibrium forces beneficially cooperate in enhancing detection and/or in facilitating directed transmission of information. The applications range from innovative information processing devices in physics, chemistry, and in physical biology to new hardware for medical rehabilitation. Particularly, those additional non-equilibrium disturbances enable the rectification of haphazard Brownian noise so that quantum and classical objects can be directed around on *a priori* designed routes (Brownian motors). Despite its thrilling manifold successes Brownian motion nevertheless is not the “Theory of Everything”, as is revealed by some more doubtful applications.

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Plenary Talk PV II Mon 9:15 HSZ 01

Plasmonics: Photons at the Nanoscale Yield Physics, Metamaterials, and Devices — •Harry A. Atwater — Thomas J. Watson Laboratories of Applied Physics, California Institute of Technology MS 128-95, Pasadena, CA

Plasmonics is a rapidly emerging photonics discipline that enables unusual dispersion engineering and mode localization, and which is having an impact in the development of metamaterials and active nanophotonic devices. Dispersion control and active materials integration have yielded plasmonic components, including i) three-dimensional single layer plasmonic metamaterials ii) all-optical, electro-optic and field effect modulation of plasmon propagation iii) plasmon-enhanced absorption in solar cells. We expand upon recently re-ported work on direct observation of two-dimensional negative refraction in the visible fre-quency range to develop a general approach to realization of three-dimensional single-layer, all-angle, polarization-independent plasmonic metamaterials exhibiting negative refraction. Full wave simulations and dispersion calculations are used to demonstrate that metal-dielectric-metal plasmonic structures are characterized by negative wave vectors and negative refractive indices. Metal-dielectric plasmon waveguides can serve as active switching elements when the dielectric refractive index can be actively modulated. We demonstrate elec-tro-optic refractive index modulation in metal-dielectric-metal plasmon waveguides using low-voltage electro-optic modulation of both silicon and perovskite oxide dielectric layers. The efficiency and cost effectiveness of photovoltaic cells can both be increased by reduction of the active semiconductor absorber layer thickness and ability to fabricate ultrathin absorber layers opens up new possibilities for solar cell device design. The strong mode localization of surface plasmon polaritons at metal-dielectric interfaces leads to strong absorption in semi-conductors thin films, enabling a dramatic reduction in the semiconductor absorber physical thickness needed to achieve an optically thick film. Modal analysis in full wave simulation allows us to determine the fraction of power absorbed by the solar cell for both dielectric and plasmonic modes.

Plenary Talk PV III Mon 17:00 HSZ 01

Nature’s Materials – hierarchical structure and mechanical properties — •Peter Fratzl — Max Planck Institut of Colloids and Interfaces, Potsdam

A large variety of natural materials with outstanding mechanical properties have appeared in the course of evolution. This includes wood, grasses, bone, sea shells or glass sponges. Biological materials are generally composites of different types of polymers and – sometimes – mineral. They are built in a hierarchical fashion, which allows the material to be optimized for its function at many different structural levels.

Bone, for example, consists in about equal amounts of a collagen-rich matrix and calcium-phosphate nano-particles. These components are joined in a complex hierarchy of fibres and lamellar structures to a material with exceptional fracture resistance. Studying bone using methodologies borrowed from materials physics improves the basic understanding of its hierarchical structure and in relation to its properties and function, but it may also help in understanding the effect of diseases and therapies, e.g., in the context of osteoporosis or bone healing.

Glass sponge skeletons are another example where a minimum amount of protein dramatically reduces the inherent brittleness of glass. Plant cell walls, on the contrary, are almost fully polymeric composites which are able to generate considerable stresses and even complex movements with changing humidity. These actuation capabilities are based on intricate cellulose fibre architectures and the water swelling of hemicelluloses. Unravelling the structural principles of these unexpected material properties may help in the understanding of these biological systems but also indicate ways on how to develop new types of biomimetic materials with exceptional properties.

Plenary Talk PV IV Tue 8:30 HSZ 01

Quantum Hall Phases “seen” as Quantum Liquids — •Aron Pinczuk, T.D. Rhone, J. Yan, Y. Gallais, J. Groshaus, I. Dujovne, C. Hirjibehedin, L.N. Pfeiffer, and K.W. West — Dept. of Appl. Physics & Appl. Mathematics and Dept. of Physics, Columbia University, New York, NY

Electron fluids in semiconductor quantum structures support remarkable quantum phases that emerge from fundamental interactions in two-dimensions. The benchmark semiconductor system is that of the well-known ultra-high mobility 2D electron gas in GaAs-AlGaAs heterostructures. Atomic layers of graphene with linear dispersion of the electron bands and density tunable by electric field doping are of enormous current interest.

Inelastic light scattering methods at very low temperatures (reaching below 50 milliKelvin degrees) are experimental venues to study excitations of electron fluids in the low dimensional systems. The light scattering experiments access directly low-lying “quasiparticle” excitation modes that take the fluids above its ground states and that express key properties of emergent quantum phases.

This talk presents a brief introduction to inelastic light scattering methods for studies of exotic quantum phases in quantum Hall regimes. These results are examples that demonstrate the power of light scattering experiments to study the low-lying excitations. These are the excitations that express quantum phases of the electron liquids. The measurements of these modes uncover key insights on the physics of interactions that drive the emergence of novel quantum phases.

Recent inelastic light scattering studies explore excitations of the quantum Hall fluids that reside in the second Landau level at filling factors such as ν=5/2 and ν=7/3. The quantum Hall fluids in higher Landau levels are of great current interest for applications in topologically protected quantum computations. The recent light scattering results will be evaluated to show how these experiments directly reveal properties not currently accessible by other methods, and seek to elucidate the interplay among competing non-quantum-Hall phases that occur in higher Landau levels. [1]

Work supported by the U.S National Science Foundation, by the U.S. Department of Energy, and by the U.S. Office of Naval Research.

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Prize Talk PV V Tue 13:00 HSZ 01

Lévy Random Walks: From the Dispersal of Dollar Bills to New Models for the Forecast of Epidemics — •Theo Geisel — MPI für Dynamik und Selbstorganisation und Fakultät Physik der Universität Göttingen — Träger des Gentner-Kastler-Preises

Since their introduction in chaotic systems that exhibit anomalous diffusion [1], Lévy random walks have been discovered and modeled in various scientific contexts for more than two decades. In a recent application we have suggested their use for the description of human dispersal on geographical scales, a key factor for the spatiotemporal modeling of epidemics. While the *local* infection dynamics is well understood for many diseases, the efficiency of epidemic forecasts has suffered in the past from a poor description of the *spatial* dynamics, as little was known about the statistical laws by which humans and their pathogens disperse.

How can one obtain reliable information on traveling statistics, if people can travel using very different means of transportation from bikes to planes? We have studied this problem empirically using the dispersal of bank notes as a proxy [2]. Dollar bills were tracked based on the dataset of the internet game wheresgeorge.com. Their dispersal can be described very accurately in terms of an ambivalent super- and subdiffusive process in a model very similar to the one introduced in Ref. [1]. The model needs 3 parameters only and predicts a spatiotemporal scaling law for the time dependent probability density in very good agreement with the empirical data.

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Plenary Talk PV VI Wed 8:30 HSZ 01

Developing Physical Tools for Biology: From the Quantitative Understanding of Life Processes to Applications in Medicine — •X. Sunney Xie — Harvard University, Cambridge, MA U.S.A.

Advances in biology in the last half-century, from the discovery of the structure of DNA, to unraveling the human genome, to structures of macromolecular machines, were facilitated by developments of physical tools, such as X-ray crystallography and DNA sequencers. In recent years, single-molecule spectroscopy and nonlinear optical imaging have changed the way many biological problems are addressed. New knowledge from these experiments continues to emerge, revealing how biomolecules work in real time, individually, together, and ultimately, how they work inside living cells. These studies in biochemistry and molecular biology yield not only deeper understanding of the physical underpinnings of life processes, but potential applications to medicine as well.

Prize Talk PV VII Wed 13:00 HSZ 01

Optomechanics — •Florian Marquardt — Department of Physics, Center for NanoScience, and Arnold Sommerfeld Center for Theoretical Physics, Ludwig Maximilians Universität München, Theresienstrasse 37, 80333 München — Träger des Walter-Schottky-Preises

In this talk I will review recent progress in understanding the physics of the interaction between radiation and mechanical motion. The paradigmatic system in this field of 'optomechanics' consists of an optical cavity with a movable mirror attached to a cantilever. I will discuss how the coupled dynamics of the light field inside the cavity and the cantilever motion gives rise to a series of interesting effects. On the level of classical dynamics, I will present the theory of nonlinear oscillations and the corresponding attractor diagram. Furthermore, it is possible to cool the cantilever by irradiating the cavity with a red-detuned laser beam. I will present the quantum theory of optomechanical cooling and discuss the prospects for reaching the ground state of the cantilever's center-of-mass motion. This could open the door to the observation of quantum jumps between Fock states of a macroscopic object, and I will illustrate this by presenting a setup where a quantum-non-demolition measurement of the cantilever's phonon number could be achieved. Finally, I comment on the opportunities opened up by various recent developments in this field, such as the connection with cold atom physics.

Evening Talk PV VIII Wed 20:00 HSZ 01

Wie Kooperation unter Egoisten entsteht — •Martin Nowak — Harvard University, Boston, USA

Menschen sind Weltmeister, wenn es um Kooperation (und Betrug) geht. Sie haben kooperative Unternehmungen gegründet, die den gesamten Globus umspannen. Aber wir helfen anderen auch, wenn es mit Kosten für uns verbunden ist. Solches altruistisches Verhalten ist im Gegensatz zu dem, was man aufgrund des Prinzips der natürlichen Auslese erwarten würde. Warum sollten wir potenziellen Konkurrenten helfen?

Ich werde fünf Mechanismen vorstellen, die zur Entstehung von Kooperation führen: genetische Verwandtschaft, direkte und indirekte Gegenseitigkeit, Vernetzung, und Konkurrenz zwischen Gruppen. Direkte Gegenseitigkeit meint Situationen, in denen dieselben Individuen mehrmals miteinander interagieren und wo das eigene Verhalten davon abhängt, wie sich die anderen einem gegenüber verhalten haben. Indirekte Gegenseitigkeit betrifft Situationen mit wiederholten Interaktionen, wo das eigene Verhalten auch davon abhängt, wie sich jemand gegenüber anderen verhalten hat, also von seiner Reputation. Direkte und indirekte Gegenseitigkeit sind die Schlüsselmechanismen für das Verständnis sozialen Verhaltens unter Menschen. Indirekte Gegenseitigkeit hat insbesondere den Selektionsdruck erzeugt, der die Evolution sozialer Intelligenz und der menschlichen Sprache bedingt hat. Ich werde ausserdem ausführen, dass Bestrafung kein effizienter Mechanismus ist, um die Entstehung von Kooperation unter Egoisten zu erreichen.

The emergence of cooperation:
Humans are the world champions of cooperation (and defection). We help others even if costs are involved. We have established cooperative enterprises that span the entire globe. Such "altruistic behavior" should be at variance with natural selection. Why should we help potential competitors? I will present five mechanisms for the evolution of cooperation: kin selection, group selection, graph selection, direct reciprocity and indirect reciprocity. Direct reciprocity means there are repeated interactions between the same two individuals and my behavior towards you depends on what you have done to me. Indirect reciprocity means there are repeated interactions within a group and my behavior towards you also depends on what you have done to others. Direct and indirect reciprocity are the key mechanisms for understanding any pro-social behavior among humans. Indirect reciprocity has provided the selection pressure for the evolution of social intelligence and human language. I will also show that costly punishment is not an efficient mechanism for the evolution of cooperation.

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Plenary Talk PV IX Thu 8:30 HSZ 01

Self-healing rubbers and glasses from supramolecular assembly — •Ludwik Leibler — Matière Molle et Chimie, CNRS – ESPCI ParisTech (UMR 7167), 10 rue Vauquelin, 75005 Paris, France

Supramolecular chemistry can help to solve the dilemma of making easily processable materials with good polymer-like properties and thereby contribute to alleviate some important social issues of 21st century. It can also allow synthesis of materials with unique hitherto unimaginable properties. My lecture will try to answer the question of how small molecules can exhibit polymer-like properties thanks to direction interactions. I will also show how direction interactions say multiple parallel hydrogen bonds and dynamic correlation effects can be harnessed to lead to self-healing supramolecular rubbers and glasses. Such materials when broken or cut can be simply mended and basically recover their initial mechanical properties by bringing together fractured surfaces to self-heal at room temperature. The process of breaking and healing can be repeated many times and healing does not require heating or using chemical reactions. Interestingly, the discovery of self-healing rubbers could shed new light on physics of association.

The discovery of self-healing rubbers opens challenging questions about unusual glassy-like dynamics, physics of fracture and adhesion but also interestingly it could shed new light on physics of simple liquids such as water or water/alcohol mixtures.

Prize Talk PV X Thu 13:00 HSZ 01

The Route toward Sub-Å and 0.1eV Analytical Electron Microscopy — •Harald Rose — Institute of Applied Physics, Darmstadt University of Technology, 64289 Darmstadt, Germany — Träger des Robert-Wichard-Pohl-Preises

The ultimate goal of analytical electron microscopy is the elucidation of the atomic structure, the chemical composition, and the local electronic states of real objects. Sub-Å resolution at voltages below 300kV can only be achieved for a large field of view by correcting the spherical aberration and the coma of the objective lens. In order to obtain precise information on the inter-atomic bonding, an energy resolution of about 0.1 eV is necessary. To satisfy these conditions, the electron microscope must be equipped with (a) a quasi-monochromatic electron source, (b) a corrector compensating for spherical aberration, chromatic aberration and off-axial coma, and (c) a highly dispersive aberration-free imaging energy filter or spectrometer, respectively. We realize corrected systems by means of quadrupoles and octopoles or hexapoles. Feasible designs for both types of correctors will be presented together with a novel monochromator and imaging energy filter. The new electron microscopes are being realized within the US TEAM Project and the German SALVE Project. First results will be presented demonstrating atomic spatial and 50 meV energy resolution.

Plenary Talk PV XI Fri 8:30 HSZ 01

Spin Mapping and Spin Manipulation on the Atomic Scale
— •Roland Wiesendanger — Institute of Applied Physics and Interdisciplinary Nanoscience Center Hamburg, University of Hamburg, D-20355 Hamburg, Germany

A fundamental understanding of magnetic phenomena requires the determination of spin structures and spin excitations down to the atomic scale. The direct visualization of atomic-scale spin structures [1-4] has first been accomplished by combining the atomic resolution capability of Scanning Tunnelling Microscopy (STM) with spin sensitivity, based on vacuum tunnelling of spin-polarized electrons [5]. The resulting technique, Spin-Polarized Scanning Tunnelling Microscopy (SP-STM), nowadays provides unprecedented insight into collinear and non-collinear spin structures at surfaces of magnetic nanostructures and has already led to the discovery of new types of magnetic order at the nanoscale [6,7]. More recently, the development of subkelvin SP-STM has allowed studies of magnetic properties of individual magnetic adatoms on non-magnetic substrates as well as the magnetic interactions between them [8]. Based on SP-STM experiments performed at temperatures of 300 mK, indirect magnetic exchange interactions at the sub-milli-electronvolt energy scale between individual paramagnetic adatoms as well as between adatoms and nearby magnetic nanostructures could directly be revealed in real space up to distances of several nanometers. In both cases we have observed an oscillatory behavior of the magnetic exchange coupling, alternating between ferromagnetic and antiferromagnetic, as a function of distance. Moreover, the detection of spin-dependent exchange and correlation forces has allowed a first direct real-space observation of spin structures at surfaces of antiferromagnetic insulators [9]. This new type of scanning probe microscopy, called Magnetic Exchange Force Microscopy (MExFM), offers a powerful tool to investigate different types of spin-spin interactions based on direct-, super-, or RKKY-type exchange down to the atomic level. Finally, the combination of spin state read-out and spin state manipulation, based on spin-current induced switching across a vacuum gap by means of SP-STM [10], provides a fascinating novel type of approach towards ultra-high density magnetic recording without the use of magnetic stray fields.

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Plenary Talk PV XII Fri 9:15 HSZ 01

Redox-Based Switching – the Next Step of Moore's Law?
— •Rainer Waser — Department IFF, Forschungszentrum Jülich, 52425 Jülich — IWE2, RWTH Aachen University, 52056 Aachen, Section Fundamentals of Future Information Technology (JARA-FIT), Germany

After following Moore's law for more than four decades, the exponential performance increase of silicon based CMOS technology will run into inherent technological and physical limits by 2020. In particular, the Flash memory, widely spread used in MP3 players, cameras, and smart phones, suffers from limits in voltage scaling and endurance. A potential leap beyond these limits may emerge from redox-based switching effects encountered in oxides and higher chalcogenides. A range of systems exist in which ionic transport and redox reactions on the nanoscale provide the essential mechanisms for bistable resistive switching. One class relies on mobile cations which are easily created by electrochemical oxidation of the corresponding electrode metal, transported in the insulating layer, and reduced at the inert counterelectrode. Another important class operates through the migration of anions, typically oxygen ions, towards the anode, and the reduction of the cation sublattice in the layer locally providing metallically or semiconducting phases. In all systems, the defect structure turned out to be crucial for the switching process.

Despite exciting results obtained in recent years, huge challenges have to be met before these physical effects can be turned into industrial technology. This presentation will outline the fundamental principles, the prospects and challenges, as well as the open questions.