TUT 1: Tutorial: Plasmonics (HL with O)

Organizer: Harald Giessen (Universität Stuttgart)

The tutorial Plasmonics and Nanooptics covers highly topical subjects in the fields of nanooptics and plasmonics. The topics include novel methods of bottom-up fabrications of functional plasmonic nanostructures with DNA-origami (Na Liu, University of Heidelberg und MPI for Intelligent Systems, Stuttgart), complex functional plasmonics with hybrid systems (Harald Giessen, University of Stuttgart), application as novel sensors (Hatice Altug, EPFL Lausanne, Switzerland), as well as infrared plasmonics with novel 2D materials such as graphene and hexagonal boron nitride (Rainer Hillenbrand, Nanogune San Sebastian, Spain).

The tutorial is aiming at students and postdocs who would like to get an overview of the fields of plasmonics and nanooptics, as well as at researchers who are interested in the most exciting new developments directly from leading scientists in the field.

Time: Sunday 16:00–18:30 Location: H15

Tutorial TUT 1.1 Sun 16:00 H15

Graphene and Metal Plasmonics for Mid-IR Biosensing — •Hatice Altug — Bionanophotonics Systems Laboratory, EPFL Lausanne, Switzerland

Mid-IR absorption spectroscopy is a powerful label-free biosensing technique enabling chemical identification of molecules through their vibrational fingerprints. However, the method is not effective in detecting nanometric biomolecules due to the large size-mismatch with several microns long Mid-IR light. By engineering on-chip plasmonic nano-antennas, we overcome this fundamental limitation and enhance intrinsic signals of molecules by many orders of magnitude. Using extreme field concentration we also monitor in real-time and in-situ biomolecular interactions from low quantities of molecules. Most recently we showed that graphene could revolutionize biosensing due to its exceptional opto-electronic properties. Graphene plasmons can be tuned by electrostatic gating, in contrast to conventional plasmonic materials such as noble metals. By exploiting this unique feature we demonstrated a dynamically tunable plasmonic Mid-IR biosensor that can extract complete optical properties of proteins over a broad spectrum.In addition, the extreme light confinement in graphene*up to two orders of magnitude higher than in metals*produces an unprecedentedly strong overlap with nanometric biomolecules, enabling superior sensitivity. The combination of tunable spectral selectivity and enhanced sensitivity of graphene opens exciting prospects for sensing, not only proteins but also a wide range of chemicals and thin films.

Tutorial TUT 1.2 Sun 16:45 H15

Active 3D plasmonics — •Na Liu — Kirchhoff Institute for Physics, University of Heidelberg — MPI for Intelligent Systems, Stuttgart, Germany

Active control of three-dimensional configuration is one of the key steps towards smart plasmonic nanostructures with desired functionalities. We lay out a multi-disciplinary strategy to create active 3D plasmonic nanostructures, which execute DNA-regulated conformational changes on the nanoscale.

Construction of 3D reconfigurable plasmonic nanostructures witnesses major technological limitations, arising from the required subwavelength dimensions and controlled 3D motion. There have been considerable efforts on integration of plasmonic nanostructures with active platforms using top-down techniques. Here we lay out and implement a multi-disciplinary strategy to create active 3D plasmonic nanostructures by merging plasmonics and DNA nanotechnology on the nanoscale. First, we show the creation of a reconfigurable plasmonic switch, which can execute DNA-regulated conformational changes. In one role, DNA works as molecular platform for organizing plasmonic nanoparticles into a 3D architecture. In the other role, DNA is used as fuel to drive the constructed 3D plasmonic switch along fully programmable routes. Simultaneously, the 3D plasmonic switch serves as optical reporter, which transduces its own conformational information into optical circular dichroism changes upon external stimuli in real time. We also demonstrate the first plasmonic walker.

Coffee Break

Tutorial TUT 1.3 Sun 17:30 H15

Infrared nanoscopy and nano-FTIR spectroscopy by elastic light scattering from a scanning probe tip — •Rainer Hillenbrand — CIC nanoGUNE, San Sebastian, Spain

With the development of scattering-type scanning near-field optical microscopy (s-SNOM) [1] and nanoscale FTIR spectroscopy [2,3], the analytical power of IR and THz imaging has been brought to the nanometer scale. The spatial resolution of about 10 - 20 nm opens a new era for modern nano-analytical applications such as chemical identification, free-carrier profiling and near-field mapping of plasmons.

s-SNOM and nano-FTIR spectroscopy are based on elastic light scattering from AFM tips. Acting as an optical antenna, the tip convert the illuminating light into strongly concentrated near fields at the tip apex, providing a means for localized excitation of molecule vibrations, plasmons or phonons in the sample surface. Recording the tip-scattered light yields nanoscale-resolved IR images and spectra, beating the diffraction limit by orders of magnitude.

After a brief overview of fundamentals and applications, recent achievements such as IR-spectroscopic nanoimaging of polymers and proteins [4] will be presented, as well as the launching and mapping of ultra-confined plasmons in graphene [5,6].

[1] F. Keilmann, R. Hillenbrand, Phil. Trans. R. Soc. Lond. A 362, 787 (2004) [2] F. Huth, et al., Nature Mater. 10, 352 (2011) [3] F. Huth, et al., Nano Lett. 12, 3973 (2012) [4] I. Amenabar, et al., Nat. Commun. 4:2890 (2013) [5] J. Chen et al., Nature 487, 77 (2012) [6] P. Alonso Gonzalez et al., Science 344, 1369 (2014)

Tutorial TUT 1.4 Sun 18:00 H15

Complex functional plasmonics: Ultrafast hybrid nonlinear plasmonics — •Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart

We are going to present several different concepts on ultrafast nonlinear hybrid plasmonics. Both second- and third-harmonic processes are studied. The first concept incorporates strong local nonlinearities such as nanocrystals of nonlinear materials like LiNbO3 and ITO into gaps of plasmonic nanoantennas [1]. The second concept investigates the nonlinearities of the metals itself, particularly the influence of the localized density of states in the d-band and its influence on the nonlinear optical processes [2]. The third concept uses Miller's rule to enhance the optical nonlinearity by tailoring the linear response such that the first order susceptibility is resonant with the second harmonic light [3]. This leads to a strong and reproducible enhancement of the nonlinear response. Our general method is particularly well suited to incorporate also localized quantum emitters into the gap and investigate nonlinear optical processes on the single particle level.

[1] B. Metzger et al., Nano Lett. 14, 2867 (2014). [2] B. Metzger et al., Opt. Lett. 39, 5293 (2014). [3] B. Metzger et al., Nano Lett. 15, 3917 (2015).

TUT 2: Tutorial: Evolutionary Dynamics and Applications to Biology, Social and Economic Systems (SOE with DY, BP, AGjDPG)

Current model approaches for collective phenomena in biological, social and economic systems widely employ methods from statistical physics. This sequence of tutorial talks demonstrates how physical concepts allow the formulation of appropriate microscopic models, the numerical and analytical treatment to obtain phase diagrams and macroscopic equations of motion. Host-virus coevolution, social opinion formation and systemic risk of the interbank network are research frontiers illustrating fruitful applications (Session compiled by J.C.Claussen)

Time: Sunday 16:00–18:30 Location: H16

Tutorial TUT 2.1 Sun 16:00 H16
Predicting evolution: statistical mechanics and biophysics far from equilibrium — •Michael Lässig — Institut für theoretische Physik, Zülpicher Strasse 77, D-50937 Köln

The human flu virus undergoes rapid evolution, which is driven by interactions with its host immune system. We describe the evolutionary dynamics by a fitness model based on two biophysical phenotypes of the virus: protein folding stability and susceptibility to human immune response. This model successfully predicts the evolution of influenza one year into the future, which has important consequences for public health: evolutionary predictions can inform the selection of influenza vaccine strains. Based on this example, we discuss the role of statistical mechanics and biophysics in making evolutionary biology a predictive science.

Tutorial TUT 2.2 Sun 16:50 H16
Voter models of social opinion formation. — •Katarzyna Sznajd-Weron — Department of Theoretical Physics, Wroclaw University of Technology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw

Among many different subjects, opinion dynamics is one of the most studied in the field of sociophysics. In my opinion there are at least two important reasons why physicists study this topic. The first motivation comes from social sciences and can be described as a temptation to build a bridge between the micro and macro levels in describing social systems. Traditionally, there are two main disciplines that study social behavior - sociology and social psychology. Although the subject of the study is the same for both disciplines, the usually taken approach is very different. Sociologists study social systems from the level of the social group, whereas social psychologists concentrate on the level of the individual. From the physicist's point of view this is similar to the relationship between thermodynamics and statistical physics. This analogy raises the challenge to describe and understand the collective behavior of social systems (sociology) from the level of interpersonal interactions (social psychology). The second motivation to deal with opinion dynamics is related to the development of non-equilibrium statistical physics, because models of opinion dynamics are often very interesting from the theoretical point of view. A good example of such an interesting model is a broad class of voter models, including linear voter model and nonlinear q-voter model introduced in along with its modifications.

Tutorial TUT 2.3 Sun 17:40 H16
Maximum-entropy methods for network reconstruction, systemic risk estimation, and early-warning signals — •Diego Garlaschelli — Lorentz Institute for Theoretical Physics, University of Leiden, The Netherlands

The global financial crisis shifted the interest from traditional measures of "risk" of individual banks to new measures of "systemic risk", defined as the risk of collapse of an entire interbank system. In principle, estimating systemic risk requires the knowledge of the whole network of exposures among banks. However, due to confidentiality issues, banks only disclose their total exposure towards the aggregate of all other banks, rather than their individual exposures towards each bank. Is it possible to statistically reconstruct the hidden structure of a network in such a way that privacy is protected, but at the same time higher-order properties are correctly predicted? In this talk, I will present a general maximum-entropy approach to the problem of network reconstruction and systemic risk estimation. I will illustrate the power of the method when applied to various economic, social, and biological systems. Then, as a counter-example, I will show how the Dutch interbank network started to depart from its reconstructed counterpart in the three years preceding the 2008 crisis. Over this period, many topological properties of the network showed a gradual transition to the crisis, suggesting their usefulness as early-warning signals of the upcoming crisis. By definition, these early warnings are undetectable if the network is reconstructed from partial bank-specific information.

TUT 3: Tutorial: Spin Hall Effect and Spin-Orbit Torques (MA)

Organizers: Karin Everschor-Sitte and Matthias Sitte (Johannes Gutenberg Universität Mainz)

In spintronics, magnetic textures are manipulated by spin-polarized currents. A traditional way to obtain a spin-polarized current is by sending an electric current through a ferromagnet. A different option is to exploit the spin Hall effect which is the generation of a spin current perpendicular to an applied charge current. This tutorial provides an introduction into the field of spin Hall effect and spin-orbit torques.

Time: Sunday 16:00–18:30 Location: H17

Tutorial TUT 3.1 Sun 16:00 H17
Introduction to Spin Hall Effect — •Christian Back — University of Regensburg, Regensburg, Germany

We give here an overview of the spin Hall effect. Since its discovery over a decade ago the spin Hall effect has been one of the most researched areas of spintronics, with multiple unexpected new phenomena arising from its studies. Its origins, both intrinsic and extrinsic, have been studied both theoretically and experimentally, giving us now a rich picture of this phenomena which is present in many branches of spintronics. It is connected of course to the anomalous Hall effect, but in recent years it is understood to be linked closely with magnetization dynamics as well as inverse spin Galvanic effect. The fields of Topological Insulators also arose from the spin Hall effect in the limit if large spin-orbit coupling. We summarise the recent review written on the subject that covers most of the developments over the last decade.

15 min. break

Tutorial TUT 3.2 Sun 17:00 H17
Magnetisation of ferromagnetic nanostructures manipulated by spin-orbit torques — •Stefania Pizzini — Institut Néel, CNRS, Grenoble, France

It has been shown recently that spin-orbit torques (SOT) associated to the spin-Hall effect, generated by the flow of an electrical current in the plane of a ferromagnetic/heavy metal bilayer, can be used as an efficient way to manipulate the magnetisation of nanostructures with broken inversion asymmetry.

After an introduction to the microscopic origins of the SOT, I will give a review of recent experimental work showing the use of this mechanism to obtain both deterministic switching of nanosized magnets, and efficient propagation of domain walls in nanotracks consisting of ultrathin ferromagnetic layers with perpendicular magnetic anisotropy and strong Dzyaloshinskii-Moriya interaction.

Tutorial TUT 3.3 Sun 17:45 H17

Spin Hall effect and spin-orbit torque from material-specific theory — •Yuriy Mokrousov — Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

The phenomena of spin Hall effect (SHE) in magnetic and nonmagnetic materials, and spin-orbit torque (SOT) in magnetic materials with broken inversion symmetry have become major sources of intensive interest for both theoreticians and experimentalists, owing to their importance for future technology based on relativistic effects. In my talk I will present an overview of recent progress in our understanding and description of the SHE and SOT based on the material-specific first principles theory. My particular focus will be both on the intrinsic Berry phase and impurity-driven origins of the SHE and its anisotropy in paramagnets, ferromagnets and antiferromagnets. I will then review the various origins of the SOT in magnetic bilayers, show how the SOT can be understood based on the non-trivial topology of the electronic bands, and outline the relation between the SOT and the spin currents originated in the non-magnetic substrate.

TUT 4: Tutorial: Hybrid and Perovskite Photovoltaics (CPP with DF, DS, HL)

Organizers: Lukas Schmidt-Mende (Universität Konstanz), Vladimir Dyakonov (Universität Würzburg) and Christoph Lienau (Universität Oldenburg)

Tremendous progress has been achieved in the performance of hybrid solar cells, with efficiencies now exceeding 20 % for devices based on organometallic halide perovskites. Aim of this tutorial is to introduce this topic of perovskite solar cells to prepare for the following symposium (SYHP) and allow vivid scientific discussions. A description of current state-of-the-art device fabrication methods and solar cell architectures will be given and their role on the device performance explained. The device physics will be discussed and charge carrier generation and recombination mechanisms in perovskite films explained and compared to other material systems. Additionally the important role of electronic structure of the different layers in hybrid perovskite will be covered.

Time: Sunday 16:00–18:30 Location: H18

Tutorial TUT 4.1 Sun 16:00 H18

Perovskite photovoltaics: Synthesis, structure and device architecture — •Pablo Docampo — LMU Munich, Germany

Recently, organic-inorganic hybrid perovskites have been proven to be excellent photovoltaic materials, exhibiting outstanding light absorption, high carrier mobility and facile solution processability. Besides the manufacturing low costs of perovskite thin-films, the power conversion efficiencies demonstrated for this class of materials is already at the same level as poly-crystalline silicon and other thin film photovoltaic technologies. The pursuit of efficiency in the field of metal halide perovskite solar cells has been achieved mainly through the improvement to perovskite deposition processing and optimization of the device architecture.

In this tutorial I will focus on three topics. Firstly, the evolution of the device architecture, starting from sensitized mesoscopic solar cells to planar heterojunction devices employing organic contacts. Secondly, the commonly employed perovskite deposition techniques with special emphasis on the morphological quality of the prepared perovskite films. Thirdly, the perovskite structure and its stability both towards moisture and other factors such as UV-light, temperature and atmosphere. I will link these different aspects with device performance characteristics and introduce recent developments in the field towards surmounting the challenges the technology is currently facing from a materials point of view.

Tutorial TUT 4.2 Sun 16:50 H18

Charge Carrier Generation and Recombination in Organic and Perovskite Solar Cells — •Andreas Baumann — Bayerisches Zentrum für Angewandte Energieforschung (ZAE Bayern), Magdalene-Schoch-Str. 3, D-97074 Würzburg

The new star on the photovoltaic (PV) horizon, are the so called organometal halide perovskite solar cells. This new kind of thin-film PV technology has experienced a tremendous, yet not seen increase in power conversion efficiency (PCE) compared to other types of PV technologies. Up to now the solar cell efficiency on lab scale could be improved from 3.8% in 2008 to above 20% in 2015 being already competitive with commercially available PV technologies. Especially this boost in PCE values has attracted attention of many researchers from all different PV research fields. Thereby, perovskite PV is one of the most promising thin film PV technologies regarding low-cost manufacturing combined with high PCE. However, the working principle of these solar cells is yet not completely understood and is strongly discussed in literature. Phenomena, such as the often observed anomalous hysteresis in the current-voltage characteristics or the giant dielectric constant and its impact on charge carrier generation and recombination are highly debated topics with so far different given possible explanations.

In this tutorial, the processes of charge carrier generation and recombination in perovskite solar cells will be highlighted and compared to those in well studied organic solar cells. Thereby, the aim is to give an overview of the published data on these processes in order to present the current status of research.

Tutorial TUT 4.3 Sun 17:40 H18

The electronic structure in hybrid perovskite layers and devices — •Selina Olthof — University of Cologne, Institute for Physical Chemistry, Luxemburger Straße 116, 50939 Köln, Germany

The performance of optoelectronic devices strongly depends on the appropriate energetic alignment of the participating transport levels which directly influence the charge transport through the different layers. In order to optimize these interfaces in a non-trial-and-error fashion, one needs to know the conduction band minimum and valence band maximum of the perovskites to be able to select ideal transport layers as well as contact materials. While commonly vacuum level alignment is assumed at the interface to the substrate, this is actually rarely found in devices. Interfacial states, interface dipoles, and band bending can (and do) significantly alter the energy level landscape.

In this tutorial I will discuss the electronic structure of perovskites and introduce common measurement techniques that can shed a light on their energetic properties as well as the interface alignment relevant for devices. Combining reports from literature with our own recent results on the versatile electronic nature of this material I will elucidate the interplay between electronic structure and overall device performance.

TUT 5: Tutorial: Correlations in Integrable Quantum Many-Body Systems (TT)

The tutorial is planned to present recent developments and ongoing activities in the theory of exact correlation functions of Heisenberg spin chains and their relatives, such as integrable bosonic and fermionic gases. Recent theoretical developments go beyond the calculation of just universal properties of many body systems as captured in Tomonaga-Luttinger liquid theory. By taking account of the full interactions of integrable Hamiltonians the complete correlations at large and short distances respectively small and large frequencies can be calculated. Due to substantial experimental advances integrable models of condensed matter physics can be realized for instance by ultra-cold quantum gases in traps.

Organizers: Hermann Boos and Andreas Klümper (Universität Wuppertal)

Time: Sunday 16:00–18:30 Location: H20

Tutorial TUT 5.1 Sun 16:00 H20

Correlation functions of integrable models — •Frank Göhmann — Bergische Universität Wuppertal

This introductory tutorial reviews some of the progress in the theory of integrable quantum systems that led to the exact calculation of correlation functions of Heisenberg spin chains and related integrable quantum field theories. I shall mostly focus on two subjects: the factorization property of correlation functions of integrable models, discovered about 15 years ago, and the exact calculation and summation of matrix elements appearing in Lehmann representations of their correlation functions. Special emphasis will be put on methods which allow us to take into account the temperature dependence and on methods for calculating the long-time large-distance asymptotic behaviour of correlation functions.

Tutorial TUT 5.2 Sun 16:45 H20

Non-Abelian anyons — •Holger Frahm — Institut für Theoretische Physik, Leibniz Universität Hannover

In this tutorial we shall discuss the construction and analysis of integrable many-body quantum systems built from non-Abelian anyons – objects with most exotic statistics under permutation whose states are protected against local perturbations by the existence of topological charges. They can appear as quasi-particle excitations in certain topological quantum liquids and are possibly realized in quantum Hall states at certain fractional filling factors or frustrated two-dimensional quantum magnets. Integrable models can provide unbiased insights into the nature of the collective states of many anyons formed in the presence of interactions.

We begin the tutorial with a brief review of the theoretical description of interacting many-anyon lattice models starting from the underlying fusion category. Within this framework a basis of operators for local interactions of anyons as well as the topological charges characterizing the many-anyon state are built. Finally, we show how by fine-tuning of the coupling constants the resulting models can be embedded into families of commuting operators and discuss strategies for the calculation of their spectral properties.

15 min. break

Tutorial TUT 5.3 Sun 17:45 H20

Quantum quenches and equilibration of lattice and continuum systems — •Michael Brockmann — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

In this tutorial we will discuss the problem of relaxation and equilibration in closed quantum systems which are prepared in an off-equilibrium initial state. Quantum quenches are examples of such out of equilibrium situations. The focus will be on one-dimensional integrable theories where additional conservation laws heavily restrict the dynamics of the system.

I will briefly present two examples for which the steady state can be investigated by means of exact methods. The first example is a quench protocol where the ground state of a free many-particle bosonic theory unitarily evolves in time under the Lieb-Liniger Hamiltonian of δ-interacting repulsive bosons. In the second example the antiferromagnetic Néel state, the ground state of the spin-1/2 Ising chain, is released into the anisotropic Heisenberg spin chain. Using a variational method, the so-called quench action approach (QAA), one obtains the exact non-thermal steady state of the system in the thermodynamic limit, which correctly reproduces expectation values of local observables. Besides being rare cases of exact solutions of quench situations in truly interacting theories, those two quench protocols represent examples where a naive implementation of the generalized Gibbs ensemble (GGE) fails.