TUT 1: Tutorial: Coherent Control (HL)

The term 'Coherent Control of Quantum Systems' comprises a variety of closely related ideas from different branches of physics. They all have the common goal of exploiting coherence properties of laser light or long-wavelength radiation to create quantum mechanical interferences of matter waves that can steer a quantum system into a certain pre-defined target channel. Coherent control techniques are very general and can be applied to virtually any quantum system. This Tutorial provides an introduction to coherent control concepts and discusses recent applications of such ideas in solid state physics and nanooptics as well as chemical physics and chemistry. Theoretical challenges posed by the many-body nature of all real systems are highlighted as well. (Organized by the Semiconductor Physics Division)

Time: Sunday 16:00–18:30 Location: H2

Tutorial TUT 1.1 Sun 16:00 H2

Optimal Control Theory — •E.K.U. Gross — Max Planck Institute of Microstructure Physics, Halle (Saale), Germany

An overview of quantum optimal control theory will be given. Usually in quantum mechanics we prescribe an external field, say a laser or a magnetic field, and then solve the time-dependent Schroedinger equation to calculate from the wave function the observables of interest. Optimal control deals with an inverse problem: One first defines a goal that the laser pulse should achieve, the so-called "control target", and then one calculates, with certain algorithms, an optimally shaped laser field that achieves the prescribed goal. Examples of control targets are (i) to switch the chirality of the current in a quantum ring [1], (ii) to keep electrons localized in a given region of space [2], (iii) to minimize or maximize ionization of a molecule with the total fluence of the laser kept fixed [3], or (iv) to drag a wave packet along a given path through a nanostructure. We shall describe in detail how a given goal can be formulated in terms of a target functional which is to be maximized by the optimized pulse. Together with the underlying equation of motion, i.e. the time-dependent Schroedinger equation or the time-dependent Kohn-Sham equation [4], this maximization leads to a set of variational equations whose numerical solution yields the desired optimal pulses. [1] E. Rasanen, A. Castro, J. Werschnik, A. Rubio, E.K.U. Gross, PRL 98, 157404 (2007). [2] E. Rasanen, A. Castro, J. Werschnik, A. Rubio, E.K.U. Gross, PRB 77, 085324 (2008). [3] A. Castro, E. Rasanen, A. Rubio, E.K.U. Gross, EPL 87, 53001 (2009). [4] A. Castro, J. Werschnik, E.K.U. Gross, PRL 109, 153603 (2012).

Tutorial TUT 1.2 Sun 16:35 H2

Coherent control in ultrafast nano-optics — •Tobias Brixner[1], Martin Aeschlimann[2], and Walter Pfeiffer[3] — [1]Institut für Physikalische und Theoretische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg — [2]Fachbereich Physik and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern — [3]Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25, 33615 Bielefeld

Coherent control in general exploits the phase properties of light fields to manipulate coherent processes. While these concepts have initially been developed for molecular systems, it has recently become possible also to control nano-optical phenomena, i.e., the properties of electromagnetic fields below the diffraction limit of light. In this talk it will be shown how shaped femtosecond laser pulses can be used to achieve spatial and spatiotemporal control, and fundamental mechanisms will be illustrated [1]. Apart from closed-loop implementations using iterative learning algorithms, analytic schemes have been developed and realized experimentally. Applications of ultrafast nano-control also make possible novel nonlinear spectroscopy techniques.

[1] W. Pfeiffer, M. Aeschlimann, and T. Brixner, "Coherent control of nano-optical excitations," in "Optical Antennas," M. Agio and A. Alù, eds. (Cambridge University Press, 2013), Chapter 9.

Coffee break

Tutorial TUT 1.3 Sun 17:20 H2

Coherent control of ultrafast electron dynamics — •Matthias Wollenhaupt — Universität Kassel

Exploiting the coherence properties of laser light along with quantum mechanical interferences of matter waves in order to steer a quantum system into a pre-defined target channel is at the heart of coherent control [1]. The increasing availability of laser sources operating on the time scale of molecular dynamics, i.e. the femtosecond regime, and the increasing capabilities of shaping light in terms of amplitude, phase and polarization (down to zeptosecond precision [2]) brought the temporal aspect of this field to the fore. In this tutorial on coherent control we will shortly review some of the physical principles of coherent control, present some pertinent examples and perspectives of current experimental efforts in controlling electronic excitations with tailored light fields such as the creation of designer electron wave packets [3,4] and charge oscillation driven chemistry [5,6]. [1] M. Wollenhaupt and T. Baumert, Faraday Discuss 153, 9 (2011). [2] J. Köhler et al., Opt Express 19, 11638 (2011). [3] M. Wollenhaupt et al., Appl Phys B 95, 245 (2009). [4] M. Wollenhaupt, M. Krug, and T. Baumert, Phys Journ 11, 37 (2012). [5] M. Wollenhaupt et al., Chem Phys Lett 419, 184 (2006). [6] T. Bayer, M. Wollenhaupt, and T. Baumert, J Phys B 41, 074007-13 (2008).

Tutorial TUT 1.4 Sun 17:55 H2

Ultrafast coherent control of electrical currents in semiconductors and nanostructures — •Markus Betz — Experimentelle Physik 2, TU Dortmund

Current flow through semiconductor devices is usually achieved by applying potential differences to contacts. Over the last 15 years, however, also purely optical approaches to induce currents on the femtosecond timescale have been developed. Ultrabroadband light pulses - synthesized from a fundamental and its second harmonic - have proven particularly useful for such coherent control techniques. Current injection thereby relies on a quantum interference of one- and two-photon absorption pathways. The vectorial direction of the lateral current is dictated by the phase structure of the light field and its polarization. In my talk I will review the concept of coherent control of electrical currents in semiconductors. Starting from current injection in the prototypical direct semiconductor GaAs, we have extended the technique to the indirect bandgap materials silicon and germanium. Currents are also induced in single semiconductor nanostructures. In particular, we analyze optically induced currents in electrically contacted GaAs nanowires as well as hybrid structures functionalized with optical antennas. More recent experiments show up spectroscopic applications which conveniently combine the time resolution of ultrafast optics with amplitude- and phase-resolution of interferometric techniques.

TUT 2: Tutorial: Integration and Modelling of Nanoelectronic Components (DS)

The development of novel nanoelectronic components, e.g. semiconductor nanowires, single organic molecules or magnetic nanoparticles, aims at the creation of electronic circuits at the smallest possible length scale. A first prerequisite for the construction of such electronic components is the formation of a reliable, electrical contact to the electrically active parts and their integration into larger networks. This can be achieved either by self organization or by novel lithography methods. Reliable circuits can only be built if effects arising from transport through individual nanostructures as well as collective effects caused by the integration of the nanostructures into larger networks are well understood and controlled. This tutorial will provide an overview on the experimental realization of the contacts, modeling of the systems, and possible schemes for the development of larger circuits. The introductory talks in this tutorial will be presented by members and collaborators of the International Helmholtz Research School NanoNet, which deals with the development of nanoelectronic circuits.(Organizer: Artur Erbe, Helmholtz-Zentrum Dresden-Rossendorf)

Time: Sunday 16:00–18:15 Location: H3

Tutorial TUT 2.1 Sun 16:00 H3

Current transport through nanoscale electronic components — •Artur Erbe — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

The semiconductor industry has been scaling down electronics in the course of the past decades. It is clear that at the current speed of miniaturization fundamental limits will restrict the further development of nanoelectronics. Therefore, alternative ways for building electronics need to be developed. Possible candidates for active nanoelectronic building blocks are single organic molecules or metallic nanoparticles. The first step in building electronic circuits from these single components is the definition of a reliable contact to external connections. In this talk an overview on contacting schemes will be given and their advantages and problems will be discussed. Typical results, which have been found on single molecules and metallic nanoparticles using these techniques, will be presented. These facts clearly show that nanoelectronic components for future electronic are already being developed and that the next step in these developments will be the interconnecting of these single building blocks in order to produce integrated circuits.

Discussion (5 min)

Tutorial TUT 2.2 Sun 16:35 H3

Theory of electronic transport in single-molecule junctions — •Juan Carlos Cuevas — Departamento de Fisica Teorica de la Materia Condensada, Universidad Autonoma de Madrid, E-28049 Madrid (Spain)

The recent advancements in nanofabrication techniques have allowed to contact individual molecules between metallic electrodes and to investigate their transport properties. This has posed a formidable challenge for the theory, namely to elucidate the physical mechanisms that dominate the electronic conduction at the nanoscale. In this talk I will briefly review some of the theoretical techniques and tools that are currently being used to describe the transport properties of single-molecule junctions, and I will discuss the novel transport phenomena that occur in these systems.

Discussion (5 min)

Tutorial TUT 2.3 Sun 17:10 H3

DNA-programmed assembly of dendrimers and conjugated polymers — •Kurt Gothelf — Aarhus University, Aarhus, Denmark

The idea behind our research is to use DNA as a programmable tool for directing the self-assembly of molecules and materials. The unique specificity of DNA interactions, our ability to code specific DNA sequences and to chemically functionalize DNA, makes it the ideal material for controlling self-assembly of components attached to DNA sequences. We have developed some new approaches in this area such as the use of DNA for self-assembly of organic molecules[1] and position dendrimers. We have used DNA origami to assemble organic molecules, study chemical reactions with single molecule resolution [4]. We have also formed 3D DNA origami structures [5] and dynamic DNA structures [6]. In the presentation I will focus on our recent progress on self-assembly of macromolecular DNA conjugates such as dendrimers and conjugated polymers into DNA origami.

References [1] Ravnsbaek; J. B et al. Angew. Chem. Int. Ed. 2011, 50, 10851-10854. [3] Liu, H. et al. J. Am. Chem. Soc. 2010, 132, 18054-18056. [4] Voigt, N. V. et al. Nature Nanotech. 2010, 5, 200-205. [5] Andersen, E. S. et al. Nature 2009, 459, 73-76. [6] Zhang, Z. et al. Angew. Chem. Int. Ed. 2011, 50, 3983-3987.

Discussion (5 min)

Tutorial TUT 2.4 Sun 17:45 H3

Silicon Nanowires: A Versatile Technology Platform for Nanoelectronic Research — •Thomas Mikolajick[1,2], Andre Heinzig[2], Jens Trommer[1], Dominik Martin[1], Matthias Grube[1], Andreas Krause[1], and Walter Weber[1] — [1]NaMLab GmbH, Nötnitzer Strasse 64, 01187 Dresden — [2]Chair for Nanoelectronic Materials, TU Dresden, Nötnitzer Strasse 64, 01187 Dresden

Silicon nanowire based metal insulator silicon (MIS) devices offer the best gate control and therefore will enable the ultimate scaling of CMOS devices. Moreover, the specific features of a very precise controlled structure and the quasi 1-dimensional geometry (transport) make silicon nanowires an ideal platform for new device concepts like junctionless devices or tunnel field effect transistors. Recently, the reconfigurable field effect transistor (RFET) [1] using the unique properties of silicon nanowires [2] enables the electrical configuration of n- or p-type behavior. In this talk the technology as well as the device properties of the RFET will be explained. It will be shown that the same basic structure can successfully be applied to realize chemical and biochemical sensors. Finally, additional examples of the application of the base technology in anodes for Li-ion batteries will be given. [1] A. Heinzig, et al. Nano Lett. 12, 119 (2012) [2] D. Martin et al. Phys. Rev. Lett. 107, 216807 (2011)

TUT 3: GPU Computing (SKM)

Massively parallel processors are replacing standard few-core CPU architectures for high performance computing. Graphics Processing Units (GPUs) feature hundreds of computing cores and require to adopt a parallel programming paradigm from the beginning. This tutorial focuses on how to put GPUs to use for physics and gives an overview over the architecture, programming environments, and basic algorithms.

Time: Sunday 16:00–18:15 Location: H4

Tutorial TUT 3.1 Sun 16:00 H4

High-performance computational physics on graphics processing units — •Tobias Kramer — Universität Regensburg, Germany

Single core computers are not gaining significant speed anymore and the future compute techniques require to program massively parallel processors. Graphics processing units (GPUs) consist of hundreds of processors and have the potential to speed-up computational physics codes tremendously.

To take advantage of GPUs requires to adopt the parallel programming paradigm from the beginning. The GPU tutorial gives first an overview over the GPU architecture, programming environments, basic algorithms. The second part focuses on applications to physical models, including coherent transport, interaction effects, and excitonic energy transfer in light-harvesting complexes.

Source code for some examples is available at http://quantumdynamics.wordpress.com

15 min. break

Tutorial TUT 3.2 Sun 17:15 H4

Simulating spin models on GPU — •Martin Weigel — Applied Mathematics Research Centre, Coventry University, Coventry, United Kingdom

Over the last couple of years it has been realized that the vast computational power of graphics processing units (GPUs) could be harvested for purposes other than the video game industry. This power, which at least nominally exceeds that of current CPUs by large factors, results from the relative simplicity of the GPU architectures as compared to CPUs, combined with a large number of parallel processing units on a single chip. To benefit from this setup for general computing purposes, the problems at hand need to be prepared in a way to profit from the inherent parallelism and hierarchical structure of memory accesses.

In this tutorial, I will discuss the performance potential for simulating spin models, such as the Ising or Heisenberg models as well as the Edwards-Anderson spin glass, on GPU as compared to conventional simulations on CPU. Different algorithms, including Metropolis and cluster updates, as well as computional tricks such as multi-spin coding are taken into account.

TUT 4: Tutorial: Spindynamics and Spintransport (MA)

Time: Sunday 16:00–18:00 Location: H10

Tutorial TUT 4.1 Sun 16:00 H10

Spindynamics and Spintransport — •Jürgen Lindner — Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, P.O. Box 510119, D-01314 Dresden

The first part of this tutorial focusses on the dynamic response of spin systems to time-dependent driving fields. The experimental method discussed in this context is magnetic resonance. It gives insight into key parameters like magnetic anisotropy, the g-factor, magnetic relaxation, spinwave excitations and magnetic coupling. The experimental setups used to detect magnetic resonance are moreover suitable to be included into many environments like ultrahigh vacuum or to be employed for investigations of nowadays magnetic nanostructures. Examples are given how magnetic resonance is used to study ultrathin films, interlayer coupling, ensembles of magnetic nanoparticles and also single nanostructures.

Tutorial TUT 4.2 Sun 17:00 H10

Spindynamics and Spintransport — •Alina Deac — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

The second part of the tutorial will discuss how spin-polarized currents can be used to excite magnetization dynamics and what applications can be envisioned. The spin-transfer torque arises from a transfer of angular momentum between the spin-polarized current and the magnetization and is sufficiently large to induce either reversal or steady-state precession. Magnetization switching via the spin-transfer torque effect relies on a constant current density, and thus the total current and the power consumption scale down with the lateral size of the device, thereby fulfilling the requirements for Green-Information-Communication Technology components. Spin-transfer driven precession generates output signals with GHz frequencies, which can be tuned by changing the applied current. Based on this effect, efficient frequency-tuneable microwave sources and resonators, nanometer scale transmitters and receivers, signal mixers and signal amplifiers can be designed. These devices could be used for mobile phone applications, on-chip communication, smart cards or even for microwave-assisted recording for hard-disk write heads.

TUT 5: Tutorial: Topological Insulators and Majorana-Fermion Physics (TT)

Topological insulators form a new class of quantum matter, with a bulk gap and exotic conducting surface states. When coupled to superconductors, so-called Majorana bound states are expected to exist under certain conditions. In this Tutorial, an introduction into the basic theoretical ideas is given, and the relevant experimental signatures and results are discussed.

Time: Sunday 16:00–18:25 Location: H20

Tutorial TUT 5.1 Sun 16:00 H20

Topological Insulators and Superconductors — •Andreas Schnyder — Max Planck Institut für Festkörperforschung, D-70569 Stuttgart, Germany

The recent discovery of new topological electronic phases in insulating materials with strong spin-orbit coupling has lead to a renewed interest in topological states of matter. These topological materials have a full insulating gap in the bulk and support exotic metallic surface states, which are a consequence of bulk topological invariants. Topological insulating states have been observed in HgTe/(Hg,Ce)Te semiconductor quantum wells, in BiSb alloys, in Bi_2Se_3, and in other Bi-based compounds. Topological superconductor are fully gapped superconductors that exhibit zero-energy Majorana surface states. Here we review the theoretical foundations for topological insulators and superconductors, discuss topological band theory, and survey recent experimental findings on three-dimensional topological insulators and superconductors.

5 min. break

Tutorial TUT 5.2 Sun 16:50 H20

Proximity Induced Superconductivity in Topological Insulators — •Hartmut Buhmann — Physikalisches Institut, EP3, University Würzburg, Würzburg, Germany

The discovery of Dirac-like surface states on a topological insulator (TI) and their qualitative relation to Cooper-pairs in superconducters inspired the exploration of interactions between those two states. In 2008 L. Fu and C.L. Kane [1] showed that so-called Majorana bound states are expected to exists under certain conditions in the proximity of those interfaces. Since then many ideas for experimental investigations have been published but unfortunately none of those has been realized so far.

In this presentation I will summarize the important signature for the search for Majorana bound states in connection with topological insulators and I will report on recent results on proximity induced superconductivity in TI surface states.

[1] Liang Fu and C. L. Kane, Phys. Rev. Lett. **100**, 096407 (2012)

5 min. break

Tutorial TUT 5.3 Sun 17:40 H20

Majorana Fermions in Hybrid Nanosystems — •Michael Wimmer — Instituut-Lorentz, Universiteit Leiden, The Netherlands

Majorana fermions are particles that are their own anti-particle. To our current knowledge, they do not exist as elementary particles in nature. In the recent years it was however realized that quasi-particle excitations in solid state systems can mimic Majorana fermions. In particular, they appear in topological superconductors.

In the tutorial, I will show the basic properties of these "solid state Majoranas", and discuss how topological superconductors can be engineered in hybrid nanosystems consisting of ordinary superconductors and semiconductors. I will also briefly review the recent experiments that have found strong hints for the evidence of Majorana fermions in such hybrid systems. Finally, I will discuss some of the more exotic properties of Majorana fermions and how they are related to topological quantum computing.