

NanoScience: From Quantum Bits to Life Science

CeNS Winterschool 2005



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Mauterndorf, Austria
21-25 February 2005

NanoScience: From Quantum Bits to Life Science

CeNS Winterschool 2005



Burg Mauterndorf, Austria
21-25 February 2005

Program Committee:

Nanochemistry and Nanomaterials
Photon-nanosystems interaction
Interfaces and soft matter
Biophysics
Mesoscopic and quantum computing

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CeNS Winterschool (Mauterndorf)

21.-25 February 2005

NanoScience: From Quantum Bits to Life Science



Sunday, 20th February 2005

9.00 – 13.00 Internal CeNS Students' Seminar

Monday, 21st February 2005

8.45 – 9.00	Opening
9.00 – 9.50	Christoph Becher, Institut für Experimentalphysik, Universität Innsbruck Quantum computing with single ions
9.50 – 10.40	Jean-Jaques Greffet, CNRS Ecole Centrale Paris Optics & quantum optics of nanostructured surfaces
10.40 – 11.10	Coffee Break
11.10 – 12.00	Michael Mertig, Technische Universität Dresden Biomolecular hybrid structures
12.00 – 17.00	Lunch (not provided) & informal discussions
17.00	Coffee Break
17.15 – 18.15	Yaroslav Blanter, Delft University of Technology Shot noise in nanostructures
18.15	Poster Session 1

Tuesday, 22nd February 2005

- 9.00 – 9.50 Liberato Manna, National Nanotechnology Laboratory of INFN Lecce
Functionalized nanoparticles
- 9.50 – 10.40 Christoph Gauer, advalytix AG München
Manipulating nanoliters - surface acoustic wave fluidics
- 10.40 – 11.10 Coffee Break
- 11.10 – 12.00 Nynke Dekker, Delft University of Technology
Use of Magnetic Tweezers and AFM to study nucleic acids and the motors that work on them
- 12.00 – 17.00 Lunch (not provided) & informal discussions
- 17.00 Coffee Break
- 17.15 – 18.15 Jean-Michel Gérard, CEA Grenoble
Quantum optics experiments with quantum dots
- 18.15 – 19.15 Giacinto Scoles, Princeton University, SI SSA ELETTRA Trieste
In-situ Comparison of Electron Tunneling through Different Self-Assembled Monolayers by Nanografting and Conductive Tip AFM

Wednesday, 23rd February 2005

- 9.00 – 9.50 Richard Warburton, Heriot-Watt University Edinburgh
Tuning the optics of a quantum dot with a voltage
- 9.50 – 10.40 George Malliaras, Cornell University
Organic Electronics
- 10.40 – 11.10 Coffee Break
- 11.10 – 12.00 Friedrich Förster, MPI für Biochemie Martinsried
Electron tomography
- 12.00 – 17.00 Lunch (not provided) & informal discussions
- 17.00 Coffee Break
- 17.15 – 18.15 Karl-Peter Hopfner, Institute of Biochemistry and Gene Center LMU Munich
Molecular Machines in the repair of DNA double-strand breaks
- 18.15 Poster Session 2

Thursday, 24th February 2005

- 9.00 – 9.50 Christoph A. Schalley, Universität Bonn
Molecular Recognition, Templates, and Self-Assembly: The Role of Spatial Arrangement
- 9.50 – 10.40 Aanish Clerk, McGill University
Quantum Noise and Quantum Measurement in Mesoscopic Physics
- 10.40 – 11.10 Coffee Break
- 11.10 – 12.00 Thomas Taubner, MPI für Biochemie Martinsried
Tip-enhanced optical nano-spectroscopy
- 12.00 – 17.00 Lunch (not provided) & informal discussions
- 17.00 Coffee
- 17.15 – 18.15 Colin Nuckolls, Columbia University
Using Self-Assembly to create electronic materials
- 18.15 Paul Koenraad, Eindhoven University of Technology
Atomic Scale Analysis of Magnetic Doping Atoms and Self-Assembled III/V Semiconductor Nanostructures

Friday, 25th February 2005

- 9.00 – 9.50 Stefan Diez, Max-Planck-Institute of Molecular Cell Biology Dresden
Microtubule-based motor systems: From Cellular Function to Bionanotechnology
- 9.50 – 10.40 Bertrand Reulet, Yale University
Measurements of non-Gaussian shot noise
- 10.40 – 11.10 Coffee Break
- 11.10 – 12.00 Udo Hartmann, LMU München
High-frequency shot noise measurement of a quantum point contact: noise assisted tunneling in a quantum dot
- 12.00 – 17.00 Lunch (not provided) & informal discussions
- 17.00 Coffee Break
- 17.15 – 18.15 Franz Giessibl, Universität Augsburg
Atomic force microscopy and its progress in spatial resolution
- 19.00 Farewell Party

Lectures Abstracts

Quantum computing with single ions

C. Becher

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Single Ca^+ ions and crystals of Ca^+ ions are confined in a linear Paul trap and are investigated for quantum information processing. We here report on recent experimental advancements towards a quantum computer with such a system.

Laser-cooled trapped ions are ideally suited systems for the investigation and implementation of quantum information processing as one can gain almost complete control over their internal and external degrees of freedom. The combination of a Paul type ion trap with laser cooling leads to unique properties of trapped cold ions, such as control of the motional state down to the zero-point of the trapping potential, a high degree of isolation from the environment and thus a very long time available for manipulations and interactions at the quantum level. The very same properties make single trapped atoms and ions well suited for storing quantum information in long-lived internal states, e.g. by encoding a quantum bit (qubit) of information within the coherent superposition of the $S_{1/2}$ ground state and the metastable $D_{5/2}$ excited state of Ca^+ .

Recently we have achieved the implementation of simple algorithms with up to 3 qubits on an ion-trap quantum computer. We will report on methods to implement single qubit rotations, the realization of a two-qubit universal quantum gate (Cirac-Zoller CNOT-gate) [1], the deterministic generation of two-ion entangled states (Bell states) [2] and three-ion entangled states (GHZ- and W-states) [3], the realization of a quantum register, the full tomographic reconstruction of the density matrix of such entangled states, the realization of deterministic quantum teleportation [4], quantum process tomography of this teleportation protocol and the encoding of quantum information in decoherence-free subspaces with decoherence times on a second-timescale.

The transport of quantum information over large distances via photons requires an interface between atoms and photons. Such an interface is based on the deterministic coupling of a single atom or ion to a high finesse optical cavity [5]. As a step towards realizing an atom-photon interface we investigated the interaction of a single Ca^+ ion and a cavity vacuum field by measuring the modification of the spontaneous emission rate (Purcell effect) from the metastable $D_{5/2}$ level at various positions in the cavity-enhanced vacuum field [6]. The next experimental step will be the deterministic generation of single photons in a well-defined spatial and spectral mode of the radiation field. Here, we plan to combine the advantages of stimulated Raman emission schemes and laser-cooled trapped ions, stationary coupled to the mode of a high finesse optical cavity [7].

- [1] F. Schmidt-Kaler et al., Nature 422, 408 (2003).
- [2] C.F. Roos et al., Phys. Rev. Lett. 92, 220402 (2004).
- [3] C.F. Roos et al., Science 304, 1478 (2004).
- [4] M. Riebe et al, Nature 429, 734 (2004).
- [5] A.B. Mundt et al., Phys. Rev. Lett. 89, 103001 (2002).
- [6] A. Kreuter et al., Phys. Rev. Lett. 92, 203002 (2004).
- [7] C. Maurer et al., New J. Phys. 6, 94 (2004).

Shot noise in nanostructures

Yaroslav M. Blanter

Delft University of Technology

It was realized some 15 years ago that studies of electrical noise can reveal information on transmission properties of nanostructures which is not available from measurements of the resistance. This initiated the development the field of shot noise. After introducing basic notations, I will turn first to noise produced by non-interacting electrons. The Fano factor - the ratio of zero-frequency shot noise and $2e$ times the averaged current - assumes different values between zero and one for different types on nanostructures. Then I will discuss interaction effects. The simplest way to look at them is to consider weak interactions. They do not affect average conductance, but may have a significant effect on shot noise. Afterwards, I will talk about edge states in a quantum Hall bar as an example of a strongly interacting system, where shot noise measurements are used to extract the information on the charge of quasiparticles. In the end, I introduce very briefly frequency dependence of noise.

Quantum Noise and Quantum Measurement in Mesoscopic Physics

Aanish Clerk

Department of Physics, McGill University, 3600 rue University, Montreal, QC Canada

A number of recent experiments in mesoscopic physics have raised anew the question of what constitutes an "ideal" quantum detector, that is a detector which produces a minimal disturbance of the system being probed. I will discuss recent theoretical work addressing this issue, taking a point of view which stresses the physics of mesoscopic noise, and its connection to ideas from information theory. I will also discuss how these ideas apply to the quantum non-demolition measurement of a qubit, and to the study of nanoelectromechanical systems.

Use of Magnetic Tweezers and AFM to study nucleic acids and the motors that work on them

Nynke Dekker

Delft University of Technology

Over the past few years there has been an explosion in the number of experiments using single molecule techniques (micropipettes, tweezers, atomic force microscopy) to study biological physics. These techniques have allowed for a more complete understanding of the physical properties of long nucleic acid polymers. Subsequently, it has become possible to quantitatively study the motor proteins that work on these substrates. I will discuss the polymer physics of DNA and RNA that is relevant for these assays as well as present the recent results from our laboratory.

Microtubule-based motor systems: From Cellular Function to Bionanotechnology

Stefan Diez

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Inside cells, motor proteins perform a variety of complex tasks such as the transport of vesicles and the separation of chromosomes. While the phenomenological outcome of such motor action is extensively described, its underlying biophysical principles have often not been fully understood yet. We use high-resolution single molecule fluorescence microscopy in conjunction with nanotechnological tools to explore the characteristics of various microtubule based motor proteins [1].

Beyond the biological functioning of motor proteins, we are interested in novel applications of these molecular machines as transporters and manipulators for a wide range of nanoobjects in an engineered, cell-free environment. This idea is intriguing because biomolecular motors can work in parallel, their size is in the nanometer range, they work with a high energy efficiency and their application is potentially cheap. In fact, nature has evolved this machinery over millions of years and now provides us with robust nanotools that can fulfill a wide range of complex tasks. Among other examples, we will report on the use of purified kinesin motors in combination with chemically modified microtubules to transport and stretch single λ -phage DNA molecules across a surface [2]. This technique, in contrast to existing ones, enables the parallel yet individual manipulation of many molecules and may offer an efficient mechanism for the generation of multidimensional, DNA-based nanocircuits [3]. In pursuit of gaining external control over such motor-driven nanotransport systems we will discuss the applicability of hydrodynamic and electrical fields.

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[3] S. Diez, J. H. Helenius, J. Howard: Biomolecular motors operating in engineered environments. In: *Nanobiotechnology: Concepts, Applications and Perspectives*. Niemeyer, C. M. & Mirkin, C. A. (Eds.) Wiley-VCH, Weinheim, ISBN 3-527-30658-7, Chapter 13, pp. 185-199, 2004.

Structural Studies by Electron Tomography: From Cells to Molecules

Friedrich Förster

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Electron tomography (ET) is uniquely suited to obtain 3D reconstructions of pleomorphic structures such as cells, organelles or supramolecular assemblies. While the principles of ET have been known for decades, its use has gathered momentum only in recent years, thanks to technological advances and its combination with improved specimen preparation techniques. The frozen-hydrated preparation provides the best possible structural preservation and allows the imaging of molecules, complexes and supramolecular assemblies in their native state and their natural environment. Devoid of staining and chemical fixation artefacts, ET of frozen-hydrated specimens (cryo-ET) provides faithful representation of both surface and internal structure of molecules. In combination with advanced computational methods, such as molecular identification based on pattern recognition techniques, cryo-ET is currently the most promising approach to comprehensively map macromolecular architecture inside cellular tomograms.

One of our major goals is a quantitative evaluation of cryoelectron tomograms. In order to derive an atlas of large macromolecular assemblies in a cell we have developed pattern-recognition algorithms. The fidelity of these identification algorithms is tested on phantom-cells, i.e. liposomes encapsulating macromolecules, and in first experiments we have been able to derive ribosomal maps of small prokaryotic cells. Furthermore, we are developing procedures to derive high-resolution maps of complexes: The resolution of a cryoelectron tomogram is limited by the applicable electron dose. However, this limit can be overcome by averaging subtomograms of identical macromolecules. This enabled us to resolve the internal structures of the envelope protein complexes of the retrovirus Murine Leukemia Virus and the nuclear pore complex of *Dictyostelium discoideum* in situ.

Manipulating Nanoliters: Surface Acoustic Wave Fluidics

C. Gauer

Advantix AG, Brunnthal, Germany

We present a novel approach of a chip-based microfluidic system with unique properties and functionality. Surface acoustic waves manipulate small quantities of liquids on the flat surface of programmable fluidic chips. Fluidic tracks and functional blocks such as valves, dispensers, mixers, and sensing elements are chemically defined using standard lithographic techniques. The combination of such fluidic networks and our unique pumping technology results in fully programmable microfluidic processor chips. The whole system has no moving parts, and is easily fabricated employing standard semiconductor technologies. Due to the planar nature of the chip all functional blocks are readily accessible from the outside, e.g. by pipettes or spotting robots. As the technology also allows for liquid handling in both closed and open channels our programmable fluidic processors are fully compatible to existing laboratory equipment as well as to most chemical processes and biological assays.

First applications of surface acoustic wave liquid handling include the hybridization of DNA or proteomic microarrays, nano-titration, and cell based assays. It is the ultimate goal to use surface acoustic waves as the liquid handling platform for standard diagnostic assays in both clinical chemistry and immunochemistry.

Quantum optics experiments with quantum dots

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In the last ten years, numerous experiments have shown that semiconductor quantum dots can -to a certain extent- be considered as artificial atoms. As such, these emitters have permitted to realize for the first time in a solid-state system numerous quantum optics experiments, which are usually conducted on real atoms. I will discuss more specifically:

- the generation of quantum states of light
- quantum optics experiments in microcavities
- the potential application of these effects in the fields of optoelectronics and quantum information processing

Atomic force microscopy and its progress in spatial resolution

F. J. Giessibl

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Atomic force microscopy (AFM) is a method that now allows to routinely image conductive and insulating surfaces with atomic resolution. While the STM has rapidly found its place in most surface science laboratories as a tool to obtain atomically resolved images of conductive samples, obtaining atomic resolution by AFM took almost a decade because of the special challenges faced by AFM with respect to STM [1]. One of the challenges originates in the physics of measuring the small forces that act between the tip of a force sensing cantilever and the sample. Frequency modulation AFM, where the cantilever's oscillation frequency is used to determine the forces acting between tip and sample is the method of choice for atomic AFM imaging as frequency measurements are among the most precise physical measurements possible. Early measurements used silicon cantilevers with a stiffness of $k \approx 20$ N/m and oscillation amplitudes of $A \approx 10$ nm [2]. From 1999, we used cantilevers made from quartz with $k \approx 1800$ N/m with sub-nm amplitudes in our laboratory. The stiff cantilever / small oscillation amplitude allows imaging at much smaller tip-sample distances which greatly improves spatial resolution [3]. Even greater resolution is possible by directly mapping higher force gradients in a helium-temperature atomic force microscope [4].

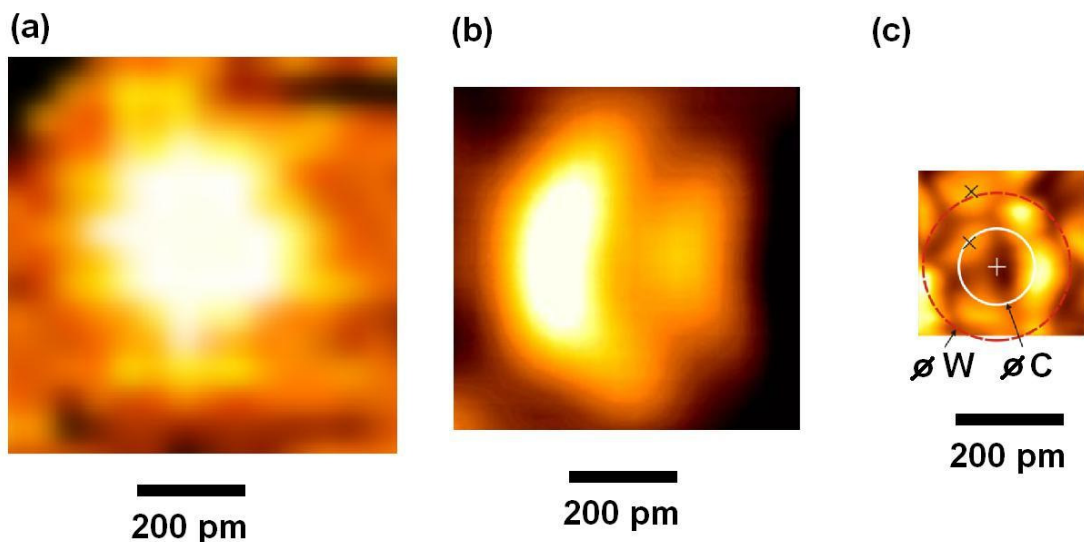


Figure 1. a) AFM image of a single Si atom [2]. b) AFM image of a single Si atom, showing two local maxima attributed to the orbital structure of Si [3]. b) AFM image of a single W atom showing four local charge maxima [4].

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2. F.J. Giessibl, Science 267 (1995) 68.
3. F. J. Giessibl et al., Science 289 (2000) 422.
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5. We kindly acknowledge funding by the Bundesministerium für Bildung und Forschung (contract BMBF 13N6918).

Optics and Quantum-Optics of Nanostructured Surfaces

Jean-Jacques Greffet

Laboratoire EM2C, Ecole Centrale Paris, CNRS

Emission and absorption of light close to the surfaces is strongly modified in the close vicinity of surfaces when surface waves can be excited. We shall study the density of electromagnetic energy and density of states close to an interface. It will be shown that spontaneous emission of light can produce a spatially and temporally coherent electromagnetic field in the near field. We will also show that by taking advantage of the coherence in the near field, it is possible to construct a thermal source of light that generates a beam with a very narrow angular width. Finally, we shall study the forces between two parallel interfaces separated by a vacuum of finite width. It will be shown that there is an attractive force between the two surfaces due to quantum fluctuations of the electromagnetic field. This force can be attributed to the contribution of the surface waves to the electromagnetic density of states.

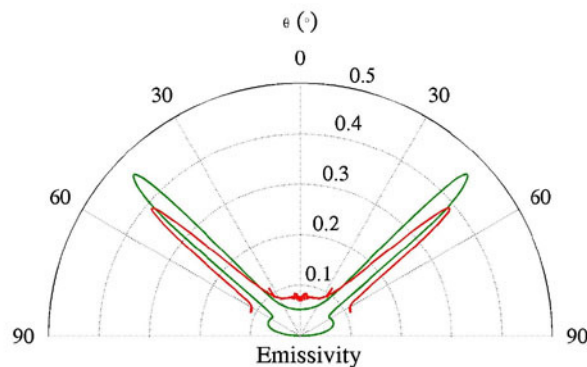


Fig. 1 Angular emission of light by a SiC grating heated at 500°C. It is seen that the surface behaves as an infrared antenna with well-defined emission lobes. From Greffet et al. *Nature* 416 p 61 (2002).

High-frequency shot noise measurement of a quantum point contact: noise-assisted tunneling in a quantum dot

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Udo Hartmann^{2*}, Yuli V. Nazarov¹, and Leo P. Kouwenhoven¹

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We present an experimental realization of a quantum dot (QD) high-frequency noise detector that measures the current shot noise produced by a nearby quantum point contact (QPC) by means of noise-assisted tunneling.

We investigate the dependence of the detector signal on the voltage across the QPC and on the QPC transmissions, this being consistent with previous low-frequency measurements [1,2]. We also observe and explain the saturation and quantum features in the detector signal.

We provide a theoretical model based on the description of photon-assisted tunneling (PAT). In contrast to PAT, we do not describe the environment of the QD as a continuous wave source (e.g. a microwave) of irradiation. Instead, we apply a temperature-dependent $P(E)$ theory to calculate tunneling rates through the QD.

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Molecular Machines in the repair of DNA double-strand breaks

Karl-Peter Hopfner

Institute of Biochemistry and Gene Center , University of Munich

DNA is constantly damaged and repair of DNA is fundamental to genome maintenance, cell survival and prevention of cancer development. DNA double-strand breaks are the most severe form of DNA damage and can lead to loss of chromosome arms, chromosome fusions and other large scale rearrangements in our genome. The Mre11/Rad50/Nbs1 complex is the primary sensor of DNA double-strand breaks and can form large molecular bridges that capture and link DNA breaks in a process that involves ATP-hydrolysis. Related SMC protein complexes form ring structures around chromosomes or condense chromosomes using ATP-hydrolysis. We use X-ray crystallography to investigate the structure and mechanism of these molecular machines in genome maintenance processes. Our results suggest how ATP-driven conformational changes provide the force to alter DNA topology in order to facilitate DNA double-strand break repair and other genome maintenance processes.

Atomic Scale Analysis of Magnetic Doping Atoms and Self-Assembled III/V Semiconductor Nanostructures

P.M. Koenraad

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In the last decade we have witnessed a highly successful integration of electronics and photonics in III/V semiconductor materials. For instance highly efficient and miniature III/V semiconductor lasers operating from the far infrared up to the ultraviolet have become available for just a few euros. Recent successes with spin-manipulation in magnetic III/V semiconductor material point to a merger of electronics, photonics and magnetics in semiconductor devices in the coming decade. Especially, the application of self-assembly and self-organisation to create nanostructures such as quantum dots, rings, rods etc. allows for the development of exciting semiconductor structures, see Fig. 1.

An atomic scale analysis of semiconductor nanostructures is however essential in order to unravel the growth processes forming them and to understand their optical, electronic and magnetic behaviour. With cross-sectional scanning tunnelling microscopy (X-STM) a sample is cleaved under ultra high vacuum conditions and the cleaved surface reveals a cross-sectional image of the grown layer structure. As STM is only sensitive to the top layers of the cleaved surface one can resolve for instance alloy fluctuations, interfaces, doping atoms, segregation and other redistribution effects with atomic precision.

In the presentation I will show that growth details can be resolved which are unattainable by any other technique and how the application of our analysis leads to an improved understanding of the formation of various III/V nanostructures and a new interpretation of their optical and electronic properties. In the presentation also our recent analysis of the shape of the wavefunction of single hole bound to a magnetic Mn-impurity will be discussed as well as some of our ideas for future research on magnetic semiconductors.

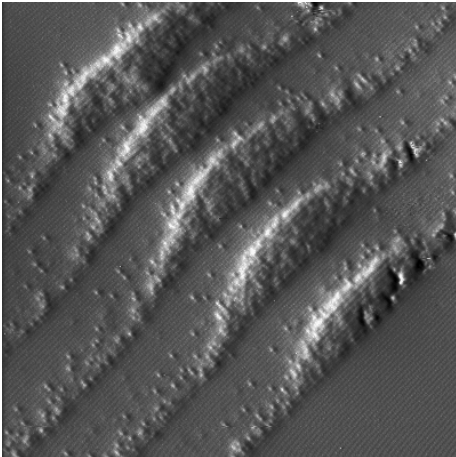


Fig. 1: Cross-sectional STM image of a stack of 5 InAs quantum dots in a GaAs matrix. The growth direction runs from the lower bottom right corner to the upper left corner. The InAs quantum dots appear as lens shaped features. Individual In atoms can be observed in-between the wetting layers and the quantum dots. Image size 55 nm by 55 nm.

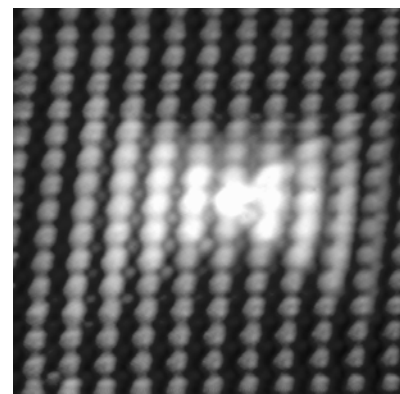


Fig. 2: STM image of neutral Mn impurity in GaAs. The bowtie shaped feature is due to the wavefunction of a hole bound to a Mn impurity located in 3rd sub-surface atomic layer. Image size 5.6 nm by 5 nm.

Organic Electronics

George Malliaras

*Materials Science and Engineering
Cornell University*

During the last fifteen years dramatic advances have been achieved in the performance of organic semiconductor devices. Organic light emitting diodes (OLEDs), for example, were first demonstrated in the late '80s and can now be found in several consumer electronic products. At the same time, organic thin film transistors (OTFTs) are being developed by numerous companies for "disposable" plastic electronics such as smart identification tags. This fast-paced progress can be attributed to unique properties of organic semiconductors such as ease of processing, their compatibility with mechanically flexible substrates and optoelectronic properties that can be tailored via chemical synthesis.

The electronic properties of organic semiconductors and their connection to device performance will be discussed by drawing examples from recent studies of OLEDs and TFTs. In OLEDs, the use of ionic transition metal complexes, such as $[\text{Ru}(\text{bpy})_3]^{+2}(\text{PF}_6^-)_2$ (bpy is 2,2'-bipyridine) as the active layer, has yielded extremely promising results. The mechanism of operation of these devices is determined by a complex interplay between ionic and electronic space charge. Materials issues that need to be addressed for these materials to succeed in display and lighting applications are discussed.

A different set of challenges is encountered in OTFTs, where the mobility of the organic semiconductor has to be as high as possible. Polycrystalline films from small molecules such as pentacene have been shown to exhibit mobilities comparable to those in amorphous silicon. The connection between the growth conditions of these films, their morphology and their electrical properties will be discussed. Finally, applications of OTFTs in biosensors will be presented.

Functionalized nanoparticles

Liberato Manna

National Nanotechnology lab of INFM, Lecce (ITALY)

Colloidal Nanocrystals (NCs) are highly versatile materials because their physico-chemical properties can be finely tuned by controlling their size, shape and composition. NCs are chemically accessible and can be cheaply processed. As a consequence of these appealing properties NCs have been widely developed during the last decade and already applications in diverse technological fields have been demonstrated. This includes applications in light-emitting diodes (LEDs),¹ biological tagging,² sensing,³ photovoltaics⁴ electronics,⁵ and catalysis.⁶ Methods for synthesizing NCs are evolving rapidly. Two important parameters that can be controlled to produce NCs with high degree of complexity are polytypism,⁷ or the existence of two or more crystal structures in different domains of the same crystal, and the manipulation of surface energy at the nanoscale.⁸ Nanocrystals with complex shapes have novel optical, electrical and mechanical properties.

Highly crystalline and monodisperse nanocrystals are synthesized at high temperatures and are coated with surfactants that render them hydrophobic.⁹ Several methods exist for converting such nanocrystals into hydrophilic particles (a prerequisite for biological applications)¹⁰⁻¹³. Most of them rely on the exchange of the surfactant coating with molecules carrying on one end a functional group that is reactive towards the nanocrystal surface and a hydrophilic group on the other end.¹⁴⁻¹⁶ Unfortunately, appropriate ligand molecules have to be chosen for each material. Other strategies have been developed that are based on the addition of a second ligand layer. This layer consists of amphiphilic molecules that can intercalate the first hydrophobic layer with their hydrophobic portion and that ensure water-solubility of the nanocrystal with their hydrophilic groups.

Recently, synthetic methods have been developed which yield nanocrystals "heterostructures" based on inorganic sections of various materials interconnected without the need of organic linkers^{17,18}. Nanocrystal heterostructures represent a convenient approach to the development of nanoscale building blocks,⁷ as they group different functionalities in the same particle. Gold tips on rods or on nanocrystals with other shapes, for instance, can serve as preferential anchoring points for connecting nanocrystals to biomolecules and as such to link them to substrates, to organize them into superstructures, or for their easier orientation under external biases.

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Biomolecular hybrid structures

Michael Mertig

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The bottom-up formation of highly oriented cluster arrays by chemical metal deposition onto a regular 2D protein template is studied. The crystalline bacterial surface layer (S layer) of *Sporosarcina ureae* exhibiting a p4 symmetry with a lattice spacing of 13.2 nm is used as the protein template. Transmission electron microscopy reveals the formation of well separated metal clusters with an average diameter of 2.0 nm. The lateral cluster arrangement is defined by the underlying protein crystal. We observe 7 cluster sites per unit cell corresponding to a density of $4 \cdot 10^{12} \text{ cm}^{-2}$. They are preferentially located in the nano-sized pores of the crystalline S layer.

We report photoemission and NEXAFS measurements of the occupied and unoccupied valence electronic states of the S layer of *Bacillus sphaericus*. The 2D protein crystal shows a semiconductor-like behaviour with a gap value of 3.0 eV and the Fermi energy close to the bottom of the lowest unoccupied molecular orbital. We anticipate that these results will open up new possibilities for the electric addressability of biotemplated low-dimensional hybrid structures.

We report studies on the conditions under which individual carbon nanotubes can be efficiently dispersed into aqueous suspension by means of both single-stranded DNA and amphiphatic proteins. The interaction between the biomolecules and the nanotubes is characterized by AFM, whereas the dispersion efficiency is measured by UV-vis spectroscopy. The efficiency increases with increasing DNA concentration until a saturation value is reached above which unbound DNA is present in the suspension. Interestingly, the carbon nanotubes are not continuously covered with DNA under saturation conditions. We observe only 15% of the tube surface area wrapped by DNA-strands. This value depends only slightly on the pre-treatment of the CNT and the DNA oligomer used. Proteins exhibit a similar behaviour. These results are compared with density functional based calculations of the interaction between CNT and DNA.

Using Self-Assembly to create electronic materials

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This presentation will explore several new classes of molecules, their assembly on metals and metal oxides, and their properties in nanoscale test structures. The goal is to develop a fundamental understanding of how a particular molecular substructure encodes assembly and how in turn the superstructure influences properties at short length scales.

One strategy that is explored here is the use of hydrogen bonding and π -stacking to work synergistically. There are three significant findings from studies on these systems. First, the dipole moments of the subunits provide a stack that has a macroscopic dipole moment. Second, because the association in the stacking direction is stronger than in typical π -stacks, it is possible to create isolated strands of molecules that can be visualized with scanning probe microscopy. Third, it is possible to create the shortest of π -stacks, dimers, on metallic surfaces that are held together through noncovalent forces.

A second area of investigation is in creating new, complex π -systems and determining how they assemble when covalently attached to metal surfaces. One example is a new class of molecules that have a unique, cruciform shape. This rigid, crossed architecture encodes a wide range of assembly patterns depending on the metal/endgroup combination. We are investigating methods to efficiently measure electrical transport through the upright monolayers and chemistry that allows the path of conjugation to be extended.

A third area of exploration is in developing molecular semiconductors that can assemble on the surface of high- k dielectrics. Here we have found new chemistry to afford linear acenes that have their short ends functionalized with endgroups that react with surface oxides. Incorporating this assembly motif into electronic devices allows field effect transistors to be constructed that are one molecule high with approximately a 100 molecules separating the source and drain electrodes.

Measurements of non-Gaussian shot noise

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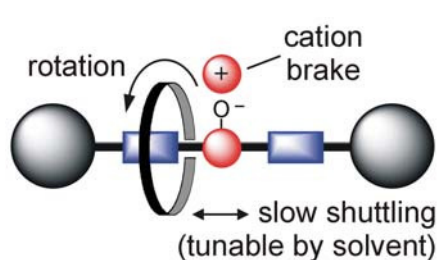
We present the first measurements of the third moment of voltage fluctuations in a conductor. This quantity characterizes the asymmetry of the fluctuations. The shot noise becomes asymmetric, and thus non-Gaussian, as soon as the time reversal symmetry is broken by a dc current. The measurement was performed on non-superconducting tunnel junctions as a function of voltage bias, for temperatures between 50mK and room temperature, and bandwidths up to 1GHz. The data demonstrate the significant effect of the electromagnetic environment of the sample. Part of the effect of the environment comes from external voltage modulating the sample's noise. We show how this phenomenon directly probes the inelastic times in a diffusive wire and present the first experimental evidences.

Molecular Recognition, Templates, and Self-Assembly: The Role of Spatial Arrangement

Christoph A. Schalley

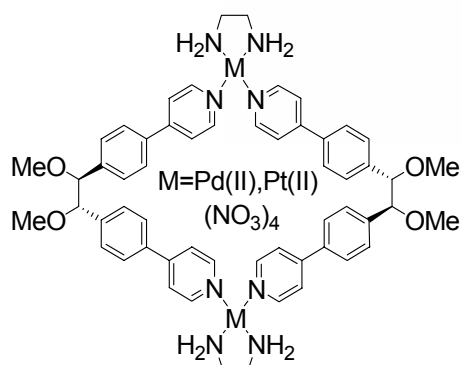
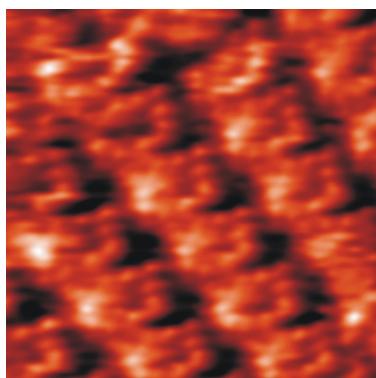
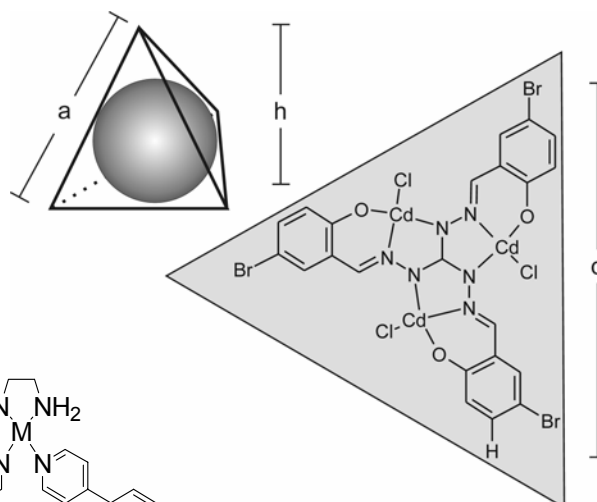
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Two approaches to the generation of complex and functional systems are the utilization of template effects and the programmed self-assembly of simple building blocks into a defined supramolecule under thermodynamic control. The talk discusses the basic features of these strategies and examples:



(i) An acid/base-controlled molecular shuttle based on an amide rotaxane can be prepared by an anion-mediated template effect. The rate of wheel movement along the rotaxane axle can be switched between a fast- and a slow-motion state.

(ii) A metallo-supramolecular tetrahedron self-assembles around a templating cation. Mass spectrometry provides evidence for encapsulation of guest molecules.



(iii) Self-assembling squares can be deposited on chloride-covered Cu(100) surfaces and

examined by scanning tunneling microscopy. The surface acts as a template generating order in that the squares lie flat on the surface with lateral order. Chiral self-assembled metallo-supramolecular macrocycles express their chirality in the formation of domains, for which no mirror domains exist.

In-situ Comparison of Electron Tunneling through Different Self-Assembled Monolayers by Nanografting and Conductive Tip AFM

By

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Understanding charge transport across nanometer scale metal-molecule-metal junctions is not only important for the realization of molecular-based electronics, but can also be useful for understanding electron tunneling in general. By adding a bias to a couple of nano-electrodes when an organic material fills the space between them and by measuring the current tunneling through the gap, the “conductivity” of the junction can be obtained. Self-Assembled Monolayers (SAMs) are organic media in which the configuration of the molecules is stabilized by intermolecular van der Waals forces. Scanning Probe Microscopy (SPM) has been a popular method of measuring the conductivities of SAMs, because of its high resolution imaging and manipulation ability. The most widely tested system so far is that of SAMs of thiols on Au (111), in which the gold surface and the conductive probe of the SPM act as the two electrodes. However, the results reported by different groups are not consistent with one another, because of many uncertainty factors, such as the nature of the electrode materials, the nature of the contact (chemical or Van der Waals), the contact area, the degree of order present in the SAM, etc. etc.

Nanografting is an Atomic Force Microscopy (AFM) based method for nanolithography, in which the AFM tip is used to shear away the thiols on a flat surface by applying a large force load while scanning over a region of the gold substrate in the presence of molecules different than those of the initial SAM that could be the solute in a solution or an adsorbate on the AFM tip. A new patch of SAM composed of the new molecules is then formed on the exposed gold sites surrounded by the previous SAM. In our experiments, after nanografting is performed, a different and CLEAN metal-coated tip is brought to bear at low force loads on the same region while a bias is applied between the tip and the substrate. An amplifier senses the resulting current passing through the sample and two correlated (current and topography) images are simultaneously obtained. By doing so, the uncertainties mentioned above are minimized as much as possible. We have recently obtained results using the following pairs of molecules:

$\text{CF}_3(\text{CH}_2)_{15}\text{SH}/\text{CH}_3(\text{CH}_2)_9\text{SH}$, $\text{CF}_3(\text{CH}_2)_{15}\text{SH}/\text{PhCH}_2\text{CH}_2\text{SH}$ and $\text{HS-Ph-Ph-SH}/\text{CH}_3(\text{CH}_2)_9\text{SH}$, where the first molecule in each pair is grafted into a matrix made with the second one. Experiments have been carried out to clarify how the applied bias voltage and the force load affect the resulting tunneling current. The results, where applicable, are analyzed also with the help of calculations carried out using Density Functional Theory.

* G. Scoles is also affiliated with the International School for Advanced Studies and the Elettra Synchrotron Laboratory in Trieste (Italy).

Tip-enhanced optical nano-spectroscopy

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Spectroscopic methods with high spatial resolution are essential for understanding the physical and chemical properties of nanoscale materials including biological proteins, quantum structures and nanocomposite materials. The diffraction limited resolution of classical microscopy of about $\lambda/2$ can be overcome by scanning near-field optical microscopy (SNOM). Unfortunately, in aperture-SNOM the achievable resolution is practically stuck to a value of about $\lambda/10$, limited by the poor transmission of the aperture probe.

This talk covers the fundamentals and recent advances of a growing microscopic technique which relies on the enhanced electrical field near a sharp, laser-irradiated metal tip. The tip acts as a confined light source which can be used for various optical interactions such as fluorescence, elastic light scattering [1] or inelastic (Raman) scattering [2]. Imaging with a spatial resolution of less than 20 nm is possible with all these interactions. The factor that limits resolution is no longer the wavelength or aperture size, but rather the tip's radius of curvature. Therefore the spectral range usable for imaging is not limited to the visible region. The advantage of infrared, terahertz or even microwave illumination is that specific excitations can be exploited to yield specific contrast, e.g. the molecular vibration offering a spectral fingerprint to identify chemical composition [3].

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- [2] A. Hartschuh, M.B. Beversluis, A. Bouhelier and L. Novotny, *Phil. Trans. R. Soc. Lond A*(2004) 362, 807-819
- [3] T. Taubner, R. Hillenbrand and F. Keilmann, *Appl. Phys. Lett.* 85, 5064-5066 (2004)

Tuning the optics of a quantum dot with a voltage

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Self-assembled quantum dots represent a new opportunity in photonics. The quantum dots are nano-sized with an excellent emission efficiency and reasonably large electric dipole matrix element. Furthermore, the quantum dots can be functionalised by embedding them in a suitably designed semiconductor heterostructure and by post-growth processing. This opens the way for applications of quantum dots in quantum optics experiments and in single photon emitters.

We present here experiments which demonstrate that a single quantum dot at low temperature is a highly coherent quantum object, with an excited state about 1 eV above the vacuum state. The excited state involves creation of an exciton, an electron-hole pair, in the quantum dot. The equivalent Q-factor of the resonance is very large, about 10^6 . This result will be put into context by comparing it to the best optical coherence demonstrated in semiconductor heterostructures with two-dimensional confinement.

We show how the optics of an individual quantum dot can be manipulated with a small voltage. The voltage is applied to the gate electrode of a field-effect structure containing a layer of quantum dots. The voltage gives us control over the exciton charge with extremely high fidelity. Furthermore, we find that we can control not only the exciton charge but also the exciton spin flip rate with the voltage.

Poster Abstracts

Electric transport through carbon nanotubes chemically assembled to 4,4' – diaminoazobenzene

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Azobenzene is a wellknown chromophore which undergoes a transition between its trans and cis isomers when irradiated by light of a certain wavelength, depending on the chemical derivative and its environment. We tried to explore this process, which can be seen as a switch at the molecular level, by chemically connecting a derivative of azobenzene to carbon nanotubes, used here as nanowires. By reacting 4,4'-diaminoazobenzene with chemically functionalized single wall nanotubes, we fabricated structures of interconnected nanotubes, obtaining junctions of two wires and loop structures. We present results on the electric transport of these structures at room temperature, in a three terminal geometry, where the source and drain contacts are defined by electron-beam lithography and the Si/SiO₂ substrate is used as back gate. Some structures exhibiting p-FET and rectifying behaviour, respectively, will be discussed. Preliminary results of optical induced electric response in a loop structure are also presented.

Sensitive Fluorescence Microscopy highlights Nanoparticle Transport in Living Cells

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In our combined wide-field fluorescence microscopy setup we use highly sensitive single particle tracking and optical sectioning by structured illumination as two methods for the investigation of nanoparticle transport processes in living cells. The transport characteristics of fluorescently tagged polyethylenamine (PEI)-DNA nanoparticles, which are used as gene shuttles in therapeutical approaches against some forms of cancer, are derived by a single particle tracking technique. For the assignment of different transport mechanisms to subcellular structures the latter are visualized in three dimensions by an optical sectioning method using structured wide-field illumination. The interaction of PEI-DNA nanoparticles with eGFP-tagged actin fibers and microtubules of human hepatoma cells is presented.

Photoinduced doping of composite films of C₆₀ molecules and CdSe nanocrystals

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We investigate the photocurrent in C₆₀ / CdSe composite films. Crystals of C₆₀ molecules grow during drop casting of a C₆₀ / CdSe nanoparticle solution on top of interdigitating fingerlike electrodes. The CdSe nanoparticles are distributed around the C₆₀ crystals. We find that the photocurrent in these composite structures is increased by three orders of magnitude compared to the photocurrent in bare CdSe and C₆₀ reference films. We explain the high photocurrent by an optically doping of the C₆₀ crystals: Electrons that are photoexcited in the CdSe nanoparticles transfer to the C₆₀, increasing the conductivity in the C₆₀ crystals, while the holes remain in the CdSe nanoparticles. Spectrally resolved photocurrent measurements show that the maxima in the photocurrent spectra correspond to the maxima of the optical absorption spectra of the CdSe nanoparticles in solution. In particular, the photocurrent maximum red shifts with increasing CdSe nanoparticle size. A weak photocurrent for excitation energies below the CdSe absorption edge is explained by an absorption of photons by the C₆₀ molecules and a subsequent transfer of the holes to the adjacent CdSe nanoparticles, leaving an excess of electrons in the C₆₀ crystals.

Probing of the proteasome-protein interaction with forcespectroscopy

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Atomic force microscopy (AFM) is an established method to investigate biological samples in their physiological environment. In our group we are investigating the 20S proteasome from *Thermoplasma acidophilum*. Besides imaging we will focus on force-measuring. The proteasome is a barrel-shaped enzyme of 15 nm height and 11 nm width with a small opening at both ends. Through these two entrances unfolded proteins can access the inner part of the proteasome with the catalytic centers in order to be degraded there. Our goal is to characterize the translocation mechanism, as the forces involved are currently unknown. First step is to immobilize the proteasomes in an upright position which is achieved in our case directly on mica. Imaging the samples ensures the right orientation and the density of the surface covering. Second step will be the investigation of the forces involved in the translocation mechanism. Therefore suitable proteins which are known to be degraded by the proteasome will be bound to the AFM-tip. The forces exerted on the proteins by the proteasomes are transmitted to the tip. While retracting the lever with the tip from the surface the deflection of the lever changes due to the forces. Similarly, when the lever is kept stationary it will be bent towards the sample when the protein is sucked into the proteasome. Such force-distance-curves are offering a promising route to a better understanding of the translocation mechanism.

DNA templated nanostructures

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Rolling circle amplification (RCA) is an elegant biochemical method by which long single-stranded DNA molecules with a repeating sequence motif can be readily synthesized. In RCA, small circular single stranded oligonucleotides serve as templates for the polymerization of the complementary strand. A DNA polymerase with an efficient strand displacement activity can processively copy the circular template without stopping. This results in a long DNA strand with periodic sequence. We here demonstrate that this method – using DNA recognition and biotin-streptavidin binding – provides a simple procedure for DNA-directed nanoscale organization of matter. In particular, a 74 nucleotide (nt) long circular DNA molecule is amplified into a sequence-periodic single strand with a length of several micrometers. Hybridization of this long periodic DNA template to the biotinylated complement of the sequence motif results in a long DNA duplex with a periodic arrangement of biotin binding sites. On this duplex, streptavidin coated particles can be organized into one dimensional arrays. The resulting DNA constructs are characterized by atomic force microscopy, scanning electron microscopy, gel electrophoresis and fluorescence microscopy.

Mapping charge carriers with terahertz radiation

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The recent development of an apertureless terahertz (THz) scanning near-field optical microscope (THz-SNOM) allows for submicron spatial resolutions and suggests a broad variety of novel applications in semiconductor technology [1,2]. The advantage of this approach is that the picosecond pulse duration of the incident THz radiation facilitates time-resolved studies of charge carrier dynamics in a contactless geometry. This is particularly promising for the characterization of quantum electronic building blocks whose time evolution can be significantly influenced by electronic leads.

In this contribution we will demonstrate that apertureless THz-microscopy can be used to detect electron distributions on a microscopic scale. The basic mechanism is that a metallic probe allows a mapping of the THz permittivity of the surface, which depends on the electron density in the region under the probing tip. By applying a potential between the needle and the semiconductor the electron density can be locally controlled. We show first evidence that THz-SNOM is capable of detecting electron populations in n-doped GaAs structures that consist only of about 5000 electrons [3]. It appears reasonable to anticipate that further improvements of the technique may soon allow for the detection of single electrons.

[1] H.-T. Chen et al. Appl. Phys. Lett. 83, 3009 (2003)

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Minituarised chemical sensor elements based on SAW-Chips with nanoporous thin films

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The analysis of gases or gas mixtures at very low concentrations (ppm, ppb-range) plays an important role in the fields of environmental monitoring and process monitoring. A continuing challenge in chemical sensor design is the need to achieve high chemical selectivity coupled with high sensitivity. Miniaturised sensor elements can be realised by using piezoelectric devices such as QCM-chips (Quartz Crystal Microbalance) or SAW devices (Surface Acoustic Wave). In this study we employ zeolites with pore openings from 0.4-1.2 nm and periodic mesoporous materials as basis for chemically selective films on the piezoelectric devices. Several gases (n-butane, 1-butene, iso-butane and iso-butene) at identical partial pressures exhibit different affinities to a film of zeolite silicalite-1. A typical measurement is presented in Fig. 1. Based on the raw data obtained from the measurements, isotherms of different gases were calculated in good agreement with literature data. In Fig. 2 the sorption isotherms of n-butane on silicalite-1 (crystal size ~100 nm) and MCM (wormlike structure) are shown. We demonstrate that the various porous adsorbents exhibit strong differences in the sorption behavior of gases and vapors on the sensor devices.

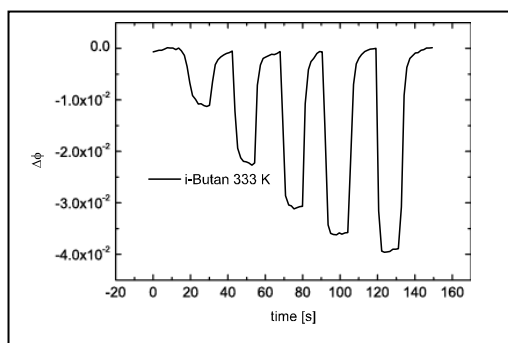


Figure 1: phase shift of SAW due to adsorption of i-butane

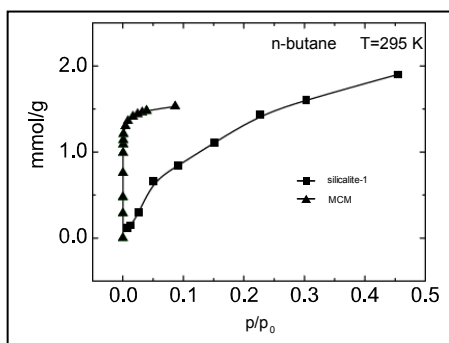


Figure 2: adsorption isotherms of n-butane in thin films of silicalite and mesoporous material

Bi- and tripartite entanglement in a flux-qubit triangle

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We are investigating a system of three superconducting flux qubits, inductively coupled by a surrounding loop or via shared lines.

We derive the possible coupling strength between the qubits and determine the energy level structure. We show, that for a proper and physical choice of parameters, the system shows strong three-qubit entanglement, quantified by the 3-tangle of the system [1].

Systems consisting of three qubits provide the possibility of examining quantum nonlocality using GHZ-states in a potentially more convenient way than the two-qubit Bell inequality. Based on our results, we discuss the feasibility of such a GHZ-experiment using flux qubits.

[1] V. Coffmann, J. Kundu, and W. K. Wothers, *Phys. Rev. A* 61, 052306 (2000).

Exciton recycling in graded gap nanocrystal structures

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We present a cascaded energy transfer (CET) structure made of CdTe nanocrystals motivated by natural antenna complexes and by semiconductor heterostructure lasers. Funnel like band gap profiles are realized by applying layer-by-layer assembly to CdTe nanocrystals of distinct sizes. For high-energetic excitation, the CET structure comprising only one layer of red-emitting nanocrystals emits 4 times more red light than a reference sample of equal absorbance consisting of only red emitting nanocrystals. Hence the final excitation density in the single emitting layer of large nanocrystals is increased by a factor of 28. Time resolved measurements show that the photoluminescence from the central layer is fed from long lived states. The super-efficient exciton funneling can be explained by a fast direct energy transfer along the structure and a recycling of surface trapped excitons that are usually lost for photoluminescence [1].

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Controlled motion of long-living excitons in tunable potential landscapes

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Systems of cold long-living excitons in coupled quantum wells (QW) [1] are expected to exhibit remarkable phenomena, e.g. Bose-Einstein-Condensation. However, the experimental realization of such systems requires a detailed understanding of tuning the temporal and spatial dynamics of excitons. Here we report on recent observations of controlled motion and confinement of long-living excitons in artificial in-plane potential landscapes.

Long-living spatially indirect excitons are created optically in two GaAs QW layers which are separated by a thin AlGaAs tunnel barrier (coupled QWs). Employing the quantum confined Stark effect (QCSE) this results in a dramatic increase in excitonic life time by two orders of magnitude, exceeding 100 ns by far.

To study their transport properties long-living excitons in coupled QWs represent a promising system. Within the plane of the QWs we induce controlled and tunable potential landscapes for excitons via the QCSE using arrangements of metallic gates and SiO₂-structures. By means of temporally, spectrally and spatially resolved photoluminescence experiments we study excitonic drift, diffusion and decay at low temperatures (~4 K). We report on the observation of excitonic drift covering macroscopic distances of more than 100 μm induced via a current-carrying resistive gate. By introducing additional superficial SiO₂ dots to the samples we demonstrated strong ring-shaped confinement of long-living excitons at the dots' border regions. We attribute this to the fact that SiO₂-covered sample areas exhibit flat-band conditions after illumination [3].

The experimental results yield direct insights in exciton dynamics in controlled potential landscapes.

[1] see e.g. Butov et al., Nature 417, 47 (2002)

[2] S. Zimmermann et al., Phys. Rev. B 56, 13414 (1997)

[3] J. Krauß et al., Appl. Phys. Lett. 85, 5830 (2004)

Three Dimensional (3D) Design of Nanostructures

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Recently, numerous studies have been devoted to the fabrication of nanostructures. To achieve well-defined nanostructures, already many patterning techniques have been applied, which is commonly referred to as lithography. However, with the growing demands of the fabrication of microelectric devices, more complex 3D architectures are desired imminently, which requires control of both lateral and vertical dimensions of components. One promising approach is to combine electro-oxidative lithography with surface self-assembly techniques.

Surface terminated $-CH_3$ groups of a *n*-octadecyltrichlorosilane (OTS) self-assembled monolayers (SAMs) were electrochemically oxidized to $-COOH$ functions by means of a negatively biased Scanning Force Microscopy (SFM) tip. By subsequent self-assembly of a short, commercially available silane, as provided by aminopropyltrimethoxysilane (APTMS), the top $-COOH$ groups were transferred into aminoterminated surface patterns. The 3D architecture principle can be achieved by the alternating assembly of negatively charged silica nanoparticles (NPs) via electrostatic interaction and additional layers of APTMS, which provide a new template for the repetitive assembly of silica NPs. In this respect, one of the critical roles is that incomplete NP layers will cause serious defect centers. First results are presented to demonstrate this fabrication approach.

Quantum phase transitions in a 2-qubit system

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For describing local as well as common decoherence effects we investigate a setup of two coupled spins influenced by two local bosonic baths as well as a common one. Here we are interested to go beyond the usual weak coupling regime, as we want to focus on the transition from quantum mechanical behaviour to classical localization of the spins, as well as the emergence and disappearance of entanglement. We start with a quite generic two-spin generalization of the spin-boson model, i.e. where the environmental influences, the spin interactions and the spin Hamiltonian do not commute with each other. In order to eliminate the environmental Hamiltonian terms we unitarily transfer the spin-boson Hamiltonian onto the anisotropic Kondo model, using a technique given in Ref.[1]. Therefrom we derive scaling equations in first order perturbation theory. Considering the corresponding fixed point Hamiltonian we receive first qualitative insights in the different dissipative phase regimes. To get more reliable results we present higher order scaling equations by applying operator product expansions on the generated products of the renormalized spin couplings.

[1]: T.A. Costi and G. Zaránd, Phys. Rev. B 59, 12398 (1999).

Multi-level Kondo effect in single-wall carbon nanotubes (SWNT)

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Recently Herrero et al. investigated the Kondo effect [1] in SWNTs. In absence of a magnetic field an (approximate) orbital as well as a spin degeneracy is present in those SWNT. Herrero et al. were able to identify two consequences of this degeneracy, namely the so-called SU(4) Kondo effect [2] and a purely orbital Kondo effect [3]. A finite magnetic field was found to remove both spin and orbital degeneracy, reflected by multiple splittings of the Kondo resonance. Moreover, a particular magnetic field might even result in a degeneracy between adjacent orbital levels, giving rise to a purely orbital Kondo effect [3]. In some samples, the Kondo resonance is split even in the complete absence of a magnetic field, suggesting that the orbital states are weakly coupled, lifting their degeneracy. Motivated by these experiments, we study a two-level Anderson model by means of Wilson's numerical renormalization group method. We investigate both magnetic field and energy dependence of the spectral function and propose a mechanism that leads to the various types of splittings of the Kondo resonance.

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A microfluidic system for picoliter rheology

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For the rheological and chemical analysis of liquids at a volume scale of several picolitres, measurement tools on the micrometer scale are needed. Nowadays micrometer structures for fluidic systems are mainly manufactured in polymers like SU-8 or PDMS. As with decreasing sizes the role of the capillary forces within the resistive forces becomes more important, by controlling the surface free energy of the system the flow behavior can be adjusted. To achieve this, different methods for surface functionalization shall be tested, among others, mainly plasma activation and wet chemical treatment with ethanolamine. The result of the functionalization is monitored by contact angle goniometry.

Also the mixing of liquids needs new techniques, as on the micrometer length scale the flow characteristic is almost always laminar. Currently different geometries for the mixing systems are under investigation, including, simple diffusion mixers and comb structures as well as turbulators and wiggly lines to enforce turbulences in the liquids.

The integration of these mixing devices and analysing units in one package will allow near time analysis of the obtained mixtures.

Dynamic Reorganization in Molecular Monolayers Observed with Scanning Tunneling Microscopy

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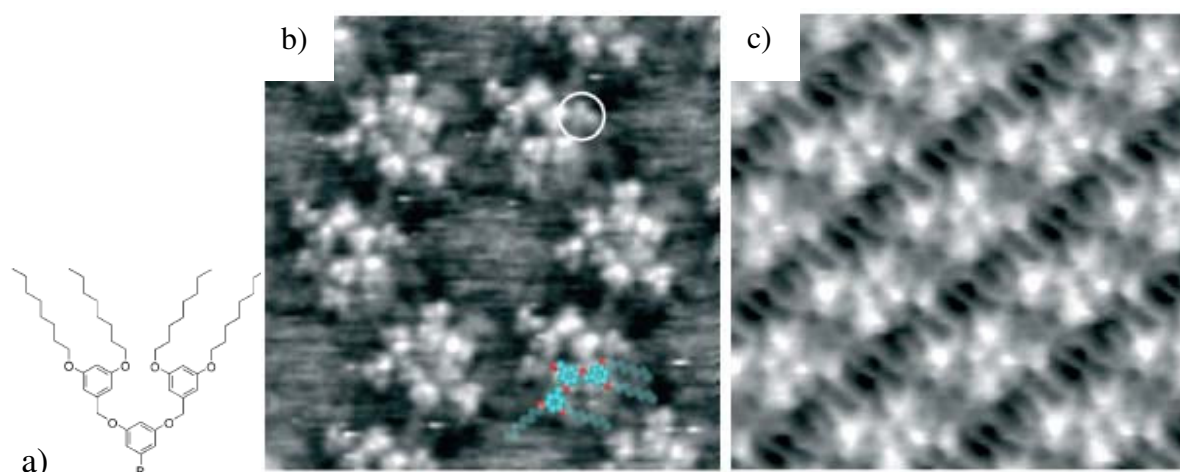
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Self-organization, using molecular recognition interactions between molecules or between molecules and substrates, is an attractive candidate for the construction of nanoscaled devices. If the interactions are sufficiently well understood and the molecular components sufficiently well designed, then the self-organized structure can be spontaneously formed. A detailed STM study of spontaneously formed monolayers of alkyl-decorated Fréchet-type dendrons with benzaldehyde ($R=CH_2OH$) and benzyl alcohol ($R=CHO$) attached is presented [1]. The three aromatic groups together with the alkyl chains appear to be a powerful organization motif on graphite. Highly resolved scanning tunnelling microscopy images are observed at room temperature in air allowing the analysis of the conformation of the adsorbed molecules. To maximise the two-dimensional crystallisation energy, the alkyl chains form interdigitated patterns with the alkyl chains of the neighbouring molecules. The interdigitation of alkyl chains is also observed in single crystal diffraction studies of the solid-state structure of the dendron-benzyl alcohol [1,2].

These achiral molecules form chiral domains upon adsorption on graphite. The long-chain alkyl-decorated dendron wedges initially form a pattern based on trimeric units, organized into hexagonal host structures with a pseudo-unit cell of seven molecules, one of which remains highly mobile. The observed metastable pattern rearranges to a stable one: dimeric rows, as a result of changing the supramolecular arrangement.

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a.) structural formula of Fréchet-type dendron, b.) 10 nm x 10 nm averaged STM image of the trimeric structure, which rearranges to c.) 10 nm x 10 nm averaged STM image of the dimeric rows.

Towards the Planned Bottom-up Fabrication of Nanodimensional Device Structures by Electro-oxidative Nanolithography on Self-Assembly Monolayers

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The combination of self-assembly methods and a versatile patterning technique is required to develop a comprehensive strategy towards the planned bottom-up fabrication of devices and functional nanostructures and many research efforts have been recently devoted into the development of this research area. We demonstrate an approach that utilizes the site-selective chemical activation of a self-assembled monolayer of n-octadecyltrichlorosilane (OTS) molecules on silicon substrates to generate surface templates. By the electrochemical conversion of surface terminal $-\text{CH}_3$ into $-\text{COOH}$ groups, by means of a conductive Scanning Force Microscopy tip, various possibilities for the subsequent derivatization of these templates are feasible. A combination of the self-assembly of additional molecular layers to design chemical properties of the surface templates, the assembly of predefined nanoparticles or nanotubes, that provide interesting physical properties, or even the in-situ generation of nanoobjects directly on the surface template opens numerous possibilities to hierarchically assemble complex nanodimensional architectures. This poster considers different modification schemes as examples for the versatility of the electro-oxidative nanolithography approach and exemplifies the versatile possibilities of the electro-oxidative nanolithography on self-assembly OTS supports in terms of nanofabrication.

Polymeric iridium(III) complexes for applications in light-emitting devices

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The focus of the presented research lies on the synthesis and characterization of novel charged iridium(III) compounds with potential applications in light-emitting electrochemical cells. The design involves iridium(III)-based materials with polymer side-chains leading to linear light-emitting polymer arrangements that show favorable film forming abilities.

To study the electro-optical properties of such light-emitting polymers in films, spin coating and inkjet printing were used as depositing techniques. Optical and electrical screening approaches are introduced. Optical properties are characterized based on steady state UV-vis and fluorescence plate reader technologies. Furthermore, the morphological properties are investigated using optical interferometry and atomic force microscopy (AFM). Some initial local current density studies by AFM have also been performed to characterize the current injection and transport properties of the novel materials. The device setup consists of indium tin oxide glass substrates, a light-emitting polymer layer, and a titanium nitride counter electrode.

Crystallinity Mapping of SiC-surfaces by Infrared Near-field Microscopy

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We exploit phonon-enhanced near-field interaction[1] in an infrared scattering-type scanning near-field optical microscope (s-SNOM) for mapping the structural properties of SiC crystals at nanoscale resolution.

Imaging is done by a s-SNOM in which the probing tip of an AFM is illuminated by infrared light ($\lambda \sim 9-11 \text{ mm}$). Along with the topography the backscattered light is recorded, thereby measuring the complex-valued optical near-field signal originating from the tip-sample near-field interaction. The scattered light exhibits a phonon-polariton resonance close to the LO-frequency in a polar material. The magnitude and spectral position of this resonance is extremely sensitive to the sample's local dielectric function ϵ . Thus this resonance acts as an optical fingerprint of the materials properties.

Experimental evidence to this is given by differentiating 4H - and 6H - SiC polytypes which differ only for 30% in the lattice constant along one principal axis of the unit cell. The sensitivity of this method is represented by mapping linear defects of a SiC crystal. Disordered atomic layers of the crystal result in stacking faults which can be detected in our s-SNOM. Consequently showing influences to the detected signal from crystalline imperfections with nanometre dimensions.

Altogether, spatial monitoring of the local phonon-polariton resonance in s-SNOM could be a useful tool to investigate and characterise SiC crystals.

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Controlling the tunnel splitting in a one-electron double quantum dot

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We present quasistatic transport measurements on a strongly tunnel coupled one-electron double quantum dot (DQD), defined electrostatically in the two-dimensional electron gas of a GaAs/AlGaAs heterostructure. A quantum point contact nearby serves as capacitive charge detector, providing information on the number of trapped electrons. The low energy spectrum of the strongly coupled DQD, if charged with only one electron, is characterized by its quantum mechanical tunnel splitting. We demonstrate how to unambiguously determine this tunnel splitting via transport spectroscopy at finite source-drain voltage. The splitting can be tuned in a range between 30 meV and 300 meV by varying either the voltage on a control gate or the magnetic field. A tentative model based on the WKB-method is in good qualitative agreement with our data.

A.K. Hüttel, S. Ludwig, K. Eberl, and J.P. Kotthaus, cond-mat/0501012.

Total synthesis of modified nucleosides found in tRNA

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More than 80 different natural nucleoside modifications are currently known. Most of them can be found in tRNA. Beside simple modifications like inosine, dihydrouridine or 1-methyladenosine, more complex modifications like archaeosine, queuosine and wybutosine exist. It is assumed that they interact with the ribosome in the translational process, but their exact function is not fully understood.

The goals of our project are the total syntheses of these hypermodified nucleosides (and derivatives) and their incorporation into tRNA strands via automated solid phase synthesis. Functional studies of these nucleosides in tRNA, the translational process as well as their possible contribution to other biochemical processes will be investigated.

2D Molecular Networks on Graphite - Observing Mediated Bimolecular Networks and the Stability of Grain-Boundaries in Monomolecular Systems

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Self-assembled monolayers (SAMs) are an important grounding for future applications of long range ordered molecular structures in nanotechnology. Hence it is of general interest to understand the parameters determining the growth and stability of these systems. Bimolecular monolayers were grown by spontaneous self-assembly from solution at the liquid-solid interface and subsequently investigated by Scanning Tunneling Microscopy (STM). Stable adsorption of one kind of molecule - TPT (1,3,5-tris(4-pyridyl)-2,4,6-triazin) – could never be observed. However in the presence of another species, acting as a kind of “molecular glue”, TPT molecules were stabilized on the surface and could be imaged by STM. As mediators both TMA (trimesic acid) and TPA (terephthalic acid), molecules equipped with carboxylic groups, were suitable. Common features of the various co-crystals are N···H–O H-bonds, rendering mixed molecular aggregates sufficiently large for stable adsorption of monolayers in equilibrium with the liquid phase above. Further investigations deal with the stability of the nanostructure of H-bound molecular monolayers likewise at the liquid-solid interface. Grain-boundaries of two different systems were observed by Video-STM for up to 20 min. Significant differences between the two systems under investigation were found: two-dimensionally H-bound TMA monolayers were remarkably stable. Mainly fluctuations in the vicinity of grain boundaries were revealed, therefore the grain size and shape was mainly preserved. The reason is that each TMA edge molecule is bound by at least four H-bonds (two per carboxylic group), giving raise to the high stability. On the other hand grain boundaries of the one-dimensionally hydrogen-bound TPA structure, which is comprised of linear molecular chains, were metastable at room temperature. Irreversible changes, like one domain growing at the expense of a smaller one – an example of Ostwald ripening, are observed within a time scale of several minutes. The different dynamics of TMA and TPA can be qualitatively explained by molecular mechanics simulations, providing an estimate for the binding energy of edge molecules, i.e. the line energy. These calculations reveal a remarkably smaller binding energy for one TPA facet, acting as the starting point for structural changes.

Diffusion of single fluorescent dyes in nanometersized channels and cage structures

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We investigate the diffusion of individual molecules incorporated into mesoporous hosts. Using wide-field imaging and single particle tracking we collect trajectories of single fluorescent dye molecules (TDI) with high temporal (70 frames/s) and spatial (< 20 nm) resolution. In the present study thin films of spincoated mesoporous silica are used as hosts. Two different pore architectures were obtained by liquid crystal templating: a hexagonal (pore diameter 6 nm) and a cubic phase (9 nm). Our method provides a direct microscopic view of the diffusion process of single molecules, revealing not only differences in the mean diffusivity, but structural heterogeneities on a nanometer scale. Two populations of mobile molecules could be distinguished in the hexagonal samples. In the cubic phase a broad distribution of diffusion coefficients was observed. Strong deviations from Brownian motion occurred: in some cases the shape of the trajectories reflects pore structure and topology of the host system. Simulations of the diffusional behavior based on the structural data of the host-guest systems are done for comparison.

Mesoporous functionalised silica colloids

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Although there are several synthesis routes to mesoporous, functionalised silica reported in the literature,^[1] little is known about how to obtain such materials in the form of nanoscale colloids.^[2] The latter are of interest for a number of applications, for example in the design of chemical sensors in order to obtain homogeneous films by spin-coating.

In this study we have prepared colloidal solutions of nanometer-sized mesoporous silica particles with diameters ranging from about 40 to 80 nm. These materials were obtained by a one-pot co-condensation synthesis route with comparably high yields. Tetraethylorthosilicate (TEOS) and triethoxysilanes (RTES) with different organic groups (phenyl, vinyl, mercaptopropyl, etc.) were used as silica precursors in an aqueous basic solution of triethanolamine using cetyltrimethylammoniumchloride (CTAC) as structure-directing agent.^[3] Apart from increasing the hydrophobicity and thereby improving the stability towards moisture^[4] the functionalisation of the surface is expected to bring about varying selectivities towards the adsorption of different gases. Most of the materials obtained according to the above approach show large surface areas (> 1000 m²/g) and significant remaining pore volumes.

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Gate induced spin-selective optical absorption on single self-assembled quantum dots

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Interband optical absorption on self-assembled semiconductor quantum dots allows for coherent, high-resolution laser spectroscopy measurements [1]. For single quantum dots, we investigated the spin occupation of the Zeeman-split levels of singly charged excitons in high magnetic fields (0-9 T) and at low temperatures (1.5 K). The experiment shows that at high magnetic fields the higher energy Zeeman-branch dominates the absorption spectra. In contrast the absorption line of the lower Zeeman-branch is prohibited due to spin blockade [2].

We find that the spin-blockade is not complete and there remains a leakage of 10% even at high magnetic fields. The spin selective optical absorption could be switched off by changing the applied gate voltage in order to empty the dot of its resident electron. Also rising the temperature lowers the spin selection of the experiment.

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DNA-Transfer in *Bacillus subtilis*

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Bacteria employ a variety of molecular motors near the cell envelope to move and communicate with their environment. We are particularly interested in the molecular machines that transport DNA through the bacterial envelope during transformation. Bacteria can acquire genetic diversity by horizontal gene transfer. Many bacteria are naturally competent for uptake of naked DNA from the environment in a process called transformation. We used optical tweezers to demonstrate that the DNA transport machinery in *Bacillus subtilis* is a force generating motor, that processively transports macromolecular DNA through nanopores. Currently we use a combination of gene- and nanomanipulation to explore the mechanics of the DNA-transport machine.

Driving a DNA nanomachine with a chemical oscillator

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The construction of DNA-based nanodevices is an extremely active field of research which holds great promises for the development of an advanced bio-inspired nanotechnology. DNA-based nanomachines are DNA supramolecular structures which can undergo large conformational changes in the presence of certain trigger molecules such as other DNA strands or small molecules. These conformational changes are accompanied by rotatory, stretching, or, as demonstrated quite recently, even translatory movements. In most cases, however, these molecular machines have to be controlled externally, i.e. a human operator has to add certain compounds to the reaction mixtures to cycle the devices through their various mechanical states. Autonomous behavior of nanodevices has been achieved only in a few cases with the help of enzymes. We here show how a proton-fuelled DNA nanomachine can be autonomously driven by pH variations generated by an oscillatory chemical reaction.

Optical detection of nanomechanical deflections

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Nanoelectromechanical systems (NEMS) nowadays are a rapidly developing field of research. Due to their small sizes and their even smaller actuation ranges their deflections are not easy to investigate. Here, an all-optical method with sub-nanometer resolution is presented that non-destructively detects NEMS deflections and can thus test the functionality of nanomechanical actuators.

The optical investigations were performed on silicon-based cantilevered nanobeams (100 nm x 200 nm x 10 μ m) defined by electron-beam lithography. These free-standing cantilevers were either located 400 nm above a silicon substrate or above a hole-aperture that was etched through the substrate right beneath the cantilevers. An electrostatic actuation of the nanostructures was achieved by applying a voltage drop between two opposing cantilevers.

Images of the NEMS were taken by scanning confocal optical microscopy. Applying a periodic voltage drop to the cantilevers and demodulating the reflected light intensity at the actuation frequency, displacements of less than 0.5 nm were resolved.

Zeolite Films with Bimodal Porosity

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Porous materials such as zeolites and periodic mesoporous materials are promising candidates for the generation of nanostructured hybrid systems. Evaporation induced self-assembly *via* spin coating was employed for the formation of microporous/mesoporous composite films from preformed pure-silica MFI/ethanol and silica/CTABr/ethanol solutions. The thickness of MFI/mesoporous films is in the range of 100-400 nm depending on the different ratios between solutions containing microporous nanoparticles and the preformed silica/surfactant assemblies forming the final coating suspensions. The mechanism of formation was investigated by *in situ* dynamic light scattering (DLS), X-ray diffraction (XRD) using synchrotron radiation, high-resolution transmission electron microscopy (HRTEM), NMR and IR/Raman spectroscopy. The structural evolution and crystal orientation of the polycrystalline films were investigated with grazing incidence diffraction at different penetration depths using synchrotron radiation.

The method described here is suitable for the fabrication of composite films with controlled bimodal porosity for applications requiring gentle processing conditions and accessible pore systems.

Switchable photochromic dyes in mesoporous silicates

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Photochromic materials are a well-known class of compounds that change their colour upon irradiation with light.^[1] We develop synthetic strategies for the encapsulation of photochromic dyes in the pores of mesoporous silicates. One means of controlling the behaviour of the photochromic dye is the modification of the host structure, as the mechanism of photochromism is very sensitive to the local environment.

When the dye molecules are embedded in an inorganic porous host such as periodic mesoporous silica, the molecules retain enough flexibility inside the pores to express photochromism even when the host-guest material is embedded in a rigid environment. The aim of our current work is to encapsulate photochromic dyes in both micrometer- and nanometer-sized mesoporous silicates; the resulting nanostructured host-guest systems are expected to offer potential for a variety of applications such as optical waveguides and shutters, light modulators, or optical storage media.^[2]

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Applications of Pulsed Interleaved Excitation

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Pulsed interleaved excitation (PIE) is used in multi-color experiments, whereby the excitation source of a detected photon is known. In our approach, we use a two channel confocal setup, pulsed lasers as excitation sources and a single photon counting card for data storage. The excitation pulses are delayed with respect to each other such that the fluorescence photons from one excitation source arrive before the other excitation pulse and vice versa. Hence, this technique enables one to eliminate crosstalk or to enhance the sensitivity of fluorescence resonance energy transfer (FRET) experiments.

We show that this technique increases the sensitivity of fluorescence cross-correlation spectroscopy (FCCS) by removing the spectral cross talk as well as provides the possibility of accurate FCCS in presence of FRET. Moreover, PIE can be used in wide field spectroscopy or laser scanning microscopy, where multi-color detection with one detector is possible. In addition to the economic benefits, this allows higher precision in distance measurements between different fluorophores because both colors are imaged with the same optics.

This technique also promises new possibilities in single-pair FRET measurements. With sub-nanosecond pulses, not only stoichiometric information are available, but also the fluorescence lifetime from the same measurements. Thus, the FRET-efficiency can be calculated from either the intensities of donor and acceptor dyes or from their lifetimes.

Dynamics of force induced DNA-slippage

Richard Neher

In double-stranded DNA with repetitive sequences, one strand may locally slip with respect to the other, leading to the creation, annihilation, or diffusion of bulge loops. We study the physics of periodic DNA theoretically, focusing on the dynamics under a shear force, which can be probed experimentally with single molecule devices.

Using an explicit model, we find a rich dynamical behavior with clear signatures in experimental observables. In particular, at a lower critical force f_c the system displays reptation-like dynamics with a mean rupture time that scales with the sequence length as $\langle \tau \rangle \sim N^\beta$. In an intermediate regime $f_c < f < \hat{f}$, the distribution of rupture times is well described by drift-diffusion theory, up to an upper critical force \hat{f} , where

a *dynamical* transition to an unraveling mode of strand separation occurs. We predict that periodic DNA sequences display a viscoelastic behavior with time and force scales that can be *programmed* into the sequence.

Organic thin film transistors

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Within this project we study the structural and electrical characteristics of organic thin film transistors (Pentacene, Coronene). The devices are deposited on SiO₂ substrates with gold contacts. At present, we study especially the influence of metal contact passivation by short-chained thiols. Experimental techniques include x-ray diffraction, AFM and transport measurements.

Patch-clamp on-a-chip setup combined with high-frequency electrical and optical access: response of ion currents to the excitation with high-frequency electrical fields

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We present a versatile setup combining a patch-clamp on-a-chip system with an open-end coaxial probe for the application of high-frequency electrical fields in the vicinity of the investigated cells or bilayer membranes, and optical access for fluorescence measurements.

Ion currents through a micropore and across the cell membrane of rat basophil leukaemia (RBL) cells containing potassium channel K_{ir}2.1 are investigated, while high-frequency fields are applied. An increase of current can be observed in specific frequency ranges between 100 MHz and 50 GHz. Fluorescence-based temperature measurements suggest that the increase in conductivity could be due to a local temperature rise in the micropore.

Supramolecular Polymers Based on Terpyridine Metal Complexes

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An important precursor for terpyridine-containing polymers which can easily be connected to various molecules is 4'-chloro-2,2':6',2''-terpyridine. Terpyridine is a well-studied tridentate chelating ligand which forms octahedral complexes with many transition metal ions (in low oxidation states) leading to different properties. Furthermore, the strength and lifetime of the non-covalent interaction can be controlled simply by the choice of the metal ion. Especially the inert metal complexes are of interest for applications due to their stability and their ability to selectively connect different macromolecules together. Hence, block copolymers can be prepared. In the preparation of these macromolecules, the controlled living radical polymerization, including nitroxide mediated polymerization (NMP), atom transfer radical polymerization (ATRP) and radical addition, fragmentation and transfer (RAFT), can be exploited. These techniques ensure low polydispersity index materials, controlled molecular weight/polymer architecture and defined chain ends. The primary goal of this research is the synthesis of new materials with desired properties which find several applications in nanotechnology. In order to combine both, the controlled living radical polymerization and terpyridine-consisting metal complexes, an initiator for nitroxide mediated polymerization bearing a terpyridine unit was developed. That initiator was used for the synthesis of polystyrene. The obtained polystyrene could now act as a macroinitiator resulting in the formation of a block copolymer. The second way, block copolymers can be obtained is by connecting the polystyrene at the terpyridine end-group with another terpyridine-consisting macromolecule to form an asymmetric bis-complex. The building block for this was prepared by end-group modification reaction followed by complexation with RuCl_3 . Two model complexes were obtained using this procedure.

A Microfluidic Concept for X-ray Scattering at the Solid-Liquid-Interface

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The focus of this project is to design a sample environment for the study of supported membranes at liquid interfaces using surface-sensitive x-ray techniques. X-ray reflectivity and grazing-incidence small angle scattering (GISAXS) can provide information on thin films the nanometer-scale (e.g. lipid bilayers), such as electron density distributions and correlations in surface morphology.

We have designed a microfluidic chamber that is optimized for x-ray diffraction studies of supported membranes at the liquid/silicon interface. Silicon or SiO_2 -substrates offer well defined surfaces with very low roughness that are well suited for bio-functionalization. The major problems that arise from studying such buried interfaces with synchrotron x-rays are irradiation damage of the biological sample and a relatively high beam attenuation and background, caused by interactions of the beam with the liquid and chamber material. Experiments of our group at ESRF Grenoble and Hasylab Hamburg have successfully shown that these problems can be minimized by manufacturing the chamber on an as-small-as-possible scale (fluidic channel of some 100 μm thickness) and by using a plastic material with low beam attenuation for x-rays in the energy range from 20 to 25 keV. The reflectivities of single membranes at the water/ SiO_2 -interface were successfully recorded up to a momentum transfer of $q_z = 0.5 \text{ \AA}^{-1}$, which represents a far better momentum resolution than achievable with comparable techniques such as neutron scattering.

Fluorescence spectroscopy of DNA nanodevices

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DNA tweezers consist of three branches of single stranded DNA one of which is labelled with a fluorescence resonance energy transfer (FRET) pair. The three single strands form two double-stranded arms of 18 base pairs or roughly 6.1 nm length connected by a short hinge.

The two duplex arms can be pulled together by the addition of a fourth single stranded DNA. In this case the dyes are in close proximity and FRET is very efficient. For the open configuration of the tweezers the average distance between the dyes was determined to be around 6 nm which corresponds to a mean opening angle between the duplex arms of 60°. However this value represents an average value over many possible configurations.

Our aim is to perform single pair FRET experiments on three different configurations of the tweezers: fully stretched, where the dyes are separated by 40 base pairs, opened and closed. The width of the distribution of FRET efficiencies contains important information about the flexibility of the DNA nanodevice.

Gold Nanoparticles quench fluorescence by phase induced radiative rate suppression

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In hybrid systems of gold nanoparticles (AuNPs) and chromophores, the AuNPs can serve as ultra efficient quenchers of molecular excitation energy, outranging the quenching efficiency of organic acceptor molecules. This effect remains significant even when the emission spectrum of the molecules and the absorption spectrum of the AuNPs have only a weak overlap. We show that in this case the dominant contribution to fluorescence quenching is due to suppression of the radiative rate.

In our study, both radiative and non-radiative decay rates of Cy5 molecules ($\lambda_{em} = 670$ nm) attached to AuNPs ($\lambda_{ex} = 520$ nm) via ssDNA spacers are determined by means of time resolved photoluminescence spectroscopy. The use of two different ssDNA lengths and variation of the nanoparticle coverage with ssDNA allow us to fine-tune the distance in the range between 2.2 and 16.2 nm. A reduced quantum yield is found for all distances.

Remarkably, in the non-resonant situation studied, this effect is almost exclusively governed by the suppression of the radiative rate, which is caused by the phase mismatch between nanoparticle plasmon and molecular dipole.

Quantum Dots in Suspended Nanowires

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We fabricate a freely suspended nanoscale bridge by applying two steps of etching on a GaAs/AlGaAs heterostructure. After defining a few micrometers long bar by Vertical dry etching, a sacrificial layer 120 nm below the surface is selectively removed by isotropic wet etching.

Our heterostructure contains a two dimensional electron gas (2DEG) approximately 40 nm below the surface. The bridge confines the 2DEG to a nanowire having a width comparable to the 2DEG's Fermi wavelength. In addition, the thickness of the bridge of only 120 nm causes a modification of the phonon spectrum with respect to the bulk crystal.

Nearby metal gates can be used to locally deplete the electron system in the nanowire in order to define freely suspended quantum dots. We plan to study the electron-phonon interaction and its impact on the transport properties of such suspended low dimensional electron systems.

Geometric model for the Analysis of plateau heights in AFM-based single molecule force spectroscopy

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Single-molecule force spectroscopy is used to measure the behaviour of polymers attached between AFM-cantilever and sample surface in an appropriate solvent.

While under good solvent conditions peak-like rupture events are observed, under poor solvent conditions force plateaus occur, i.e. while retracting the cantilever from the surface one can measure a constant non-zero force, that drops at a given distance instantaneously.

Our samples were prepared by deposition of a polymer film on the surface, therefore we attribute the resulting forces to polymers being pulled out of the film.

The force-distance curves show a high adhesion peak for short distances, which can be attributed to many polymers rupturing at once, followed by a series of force plateaus at forces of a few hundred pN, that can have lengths of close to the contour length of the molecule.

A statistical analysis of the plateaus allows the assignment of the measured plateau heights to a specific number of molecules bridging cantilever and surface. As these plateau heights are not directly proportional to the number of molecules due to intermolecular interactions we used a simple geometric model to account for the interactions.

The simple model can explain the observed decrease in plateau heights.

In our sample system Carboxymethylcellulose (CMC), the interactions are mainly caused by inter- and intramolecular hydrogen bridges.

Time-resolved coherent mid-infrared spectroscopy

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A new concept of broadband Fourier-transform infrared spectroscopy is demonstrated. By means of difference frequency generation in GaSe, ultrashort pulses from Ti:Sa lasers are converted to the mid-infrared frequency range.

The comb-like spectrum of the mid-infrared radiation can be exploited when two such pulse trains with slightly offset repetition rates are superimposed on a single detector. In this multi-heterodyne detection scheme we obtain full amplitude and phase spectra within

10^{-4} s at a rate of >20 Hz. The measured spectra quantitatively agree with classical FTIR results and presently resolve features down to

2 cm^{-1} .

The coherent dual-beam can in principle be focused diffraction-limited and illuminate scattering-type near-field microscopes. In recent experiments, we exploit its undisturbed long-distance propagation to track the release of ammonia outside the laboratory at a time resolution of 60 ms.

Investigating the Dynamics of TBP-NC2 Complexes on DNA by FRET

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Gene expression is an essential process in life and starts with the transcription of DNA into mRNA. The initiation of DNA transcription is a popular target for gene regulation. The process of transcription is initiated by the binding of the TATA-Box Binding Protein (TBP) to the gene promoter site on the DNA. Inhibition of DNA transcription occurs by the presence of Negative Cofactor 2 (NC2) due to the interaction of NC2 with TBP. Results of biochemical experiments suggest that the TBP-NC2 complex diffuses along the DNA. Inhibition by NC2 can be explained by the dislocation of TBP from the promoter site. To verify this hypothesis, we have performed fluorescence resonance energy transfer (FRET) experiments on single FRET pairs to investigate the mobility of the TBP-NC2 complex along the DNA. TBP was labeled specifically with a donor molecule while the end of a 70 bp dsDNA was labeled with an acceptor. The DNA contains a TATA sequence in the middle. The FRET efficiency was measured without NC2 and the variation in FRET efficiency was measured with time after addition of NC2 to the solution.

Kondo effect in a lateral double quantum dot

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We observe Kondo effect in a strongly tunnel coupled few electron double quantum dot. Kondo current as well as co-tunnel processes are detected in the regime of either $N=1$, 2 or 3 electrons. For $N=2$ the Kondo current decreases monotonically with increasing magnetic field oriented perpendicular to the two-dimensional electron system. In contrast, for $N=1$ we observe a non-monotonic magnetic field dependence of the Kondo current at small fields below 100 mT. We present our data and discuss possible interpretations.

AFM-based single molecule force spectroscopy of surface-grafted polymer monolayers

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Surface-grafted polymer layers created by the so-called “grafting-from” technique on the basis of nitroxide-mediated polymerization (NMP) feature controlled monolayer thickness and polymer dimensions. Therefore, they offer a broad range of applications, whenever specific properties of the interfaces are tuned by proper surface modification. For a better understanding of the structure-property relationships in these polymer layers, which is necessary for the tuning of the materials properties, there is need for characterization at the molecular level.

Here, we present our results of desorption experiments of the interfacial polymer chains as obtained by AFM. The measured force curves reflect number, lengths and desorption forces of the substrate-bound polymer chains from an opposing silica surface. Most importantly, the lengths of the adsorbed polymer chains determined with force spectroscopy are in good agreement with previous molecular weight determination obtained by GPC. Thus, our results promise the implementation of the AFM method as an analytical tool for the analysis of chain length distribution and grafting density in surface-grafted polymer layers.

Sub-microsecond molecular thermometry using thermal spin flips

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Thermal effects such as heat generation and dissipation are increasingly important in micro- and nanoelectronics and provide a substantial barrier to further miniaturisation. Molecular semiconductors such as conjugated polymers are often advocated as building blocks for nanoscale electronic devices, but the intrinsically low mobility of these materials implies that most of the electrical energy passed through the material is converted into heat. Consequently, there is considerable interest in techniques for thermal measurements on organic devices. We recently presented a highly sensitive molecular thermometer based on dual emission from the commonly used organic semiconductor platinum octaethyl porphyrin (PtOEP). This enables contact free optical thermometry of very thin films of conjugated polymers, such as in light-emitting diodes, and provides direct information on non-radiative decay channels in organic semiconductors (Appl. Phys. Lett. 81,2478(2002)).

We have now improved our detection scheme and are able to demonstrate the exceptional time resolution achievable with PtOEP molecular thermometers by measuring the instantaneous temperature of a conducting strip line on the nanosecond time scale. As the molecular thermometer works by thermally activated emission from a long-lived meta-stable state, we are able to achieve fluorescence based thermal imaging without the potentially perturbing influence of the exciting light source. Our method, which relies on gated fluorescence spectroscopy, therefore allows absolutely non-invasive characterisation of a totally thermally isolated system. Besides the technological implications and applications of adiabatic fluorescence thermometry to, for example, organic displays, the observation of externally triggered fluorescence bursts from organic semiconductors is of considerable fundamental interest. An external stimulus, in this case an electrically generated heat pulse, is used to flip the spin of the excited electron through reverse intersystem crossing from the triplet to the singlet state. Although the spins remain unpolarised, the control over spin correlation may provide a basis for molecular spintronic devices.

Inorganic Nanocrystals for Functionalization of Polymer Microcapsules

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We report on the recent developments of multi-functional polymer microcapsules incorporating different classes of inorganic nanocrystals with a final aim on their applications as a drug delivery system. The capsules were produced by the layer-by-layer adsorption of oppositely charged macromolecules on colloidal templates ranging in size from 0.5 to 10 microns. The cores were decomposed leaving behind empty capsules. The outer polymer multilayer shell remained intact providing the capsule stability from one hand and the permeability for inorganic nanocrystals from the other hand. The shells of the capsules were functionalized with highly luminescent CdTe nanocrystals. Using such nanocrystals, both single-color and multi-color labelling with controlled emission intensity ratios was demonstrated. Simultaneous encapsulation of both luminescent semiconductor and magnetic oxide nanoparticles in polymer microcapsules was further achieved. CdTe nanocrystals served as luminescent markers, while magnetic Fe_3O_4 nanoparticles allowed for external manipulation of capsules by magnetic field gradient. Finally, incorporation of metal nanocrystals consisting of gold or dielectric core/gold shells provided a mean for controlled heating and opening of the capsules under the laser beam, which should allow for the stimuli-responsive release of encapsulated substances.

Nanomechanical Tuning of an Optical Near-field Interaction Resonance

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We use a scattering-type near-field optical microscope (s-SNOM) to experimentally demonstrate the controlled shift of a near-field optical polaritonic resonance. Therefore we study both amplitude and phase of light scattered from a metallic s-SNOM's tip probing a flat SiC sample, at mid-infrared frequencies where surface phonon polaritons resonantly enhance the tip-sample near-field interaction [1]. Especially, we concentrate on effects of varying the gap width between tip and the sample. This changes the resonant coupling between the tip and the resonant sample, in analogy to the coupling of two plasmon-resonant particles [2] or a plasmon-resonant particle with a plane surface [3].

In our phonon-resonant system we find that a decreasing distance causes a red-shift of the resonance, accompanied by strong optical phase changes [4]. Both effects can be explained by theory that treats the system as a point dipole (tip) interacting with its image dipole (sample), in electrostatic approximation. For a plasmon-resonant sphere-plane system representing an s-SNOM a redshifting of the resonance with decreasing distance has been predicted by exact theory [3].

The resonance shifts and phase effects are not restricted to phonon polariton excitation in polar dielectrics like SiC, but should rather be observable also for resonances related to plasmons and excitons. Tuning the polaritonic resonance of a nanosystem by adjusting nanometric distances could be applied to control confinement and transport of light in nanoassemblies [4].

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Spin-conserving carrier recombination in conjugated polymers

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According to simple spin statistics the intrinsic quantum efficiency of polymeric light emitting diodes (PLEDs) is limited to 25%, as generally only singlet excitons contribute to the electroluminescence of the device. In contrast to this, several publications suggested that this upper limit could be surpassed if the energy difference between bound singlet and triplet polaron pairs (PPs), which constitute precursors to exciton formation, were negligible. However, little is known experimentally about this energy difference and the crucial exchange energy of PPs.

The use of a novel class of polymeric material makes it possible to observe singlet and triplet excitations simultaneously, as the phosphorescent decay channel of usually invisible triplets is activated [1]. In this way we can efficiently differentiate between PPs of different spin-states by spectroscopic means. Starting from optically generated excitons, PPs are formed and stabilized over timescales relevant to the operation of PLEDs by applying an external electric field. Astonishingly, during this electrostatic storage fast mixing of spin-states, which would be expected for isoenergetic PPs of different spin multiplicity, cannot be observed even at room temperature. This observation shows an exceptionally and unexpected strong exchange interaction between carriers constituting the PP and highlights that intersystem crossing is much weaker in the PP state than in the exciton [2].

The results thus suggest that the efficiency of non-phosphorescent PLEDs will be limited to 25% while the strong long-range exchange interaction in turn may open up new avenues in the field of spintronics.

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Modified metallo-supramolecular Squares and Triangles on the Nanometer Scale

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Recently, self organizing, metallo-supramolecular squares^[1] were characterized in detail by NMR-techniques, mass spectrometric methods^[2] as well as numerous X-ray crystal structure analyses.

Herein we would like to present modified squares with derivatives of literature known 3,3'-disubstituted [4,4']-bipyridines as building blocks. The synthesis and characterization of these ligands and the resulting squares as well as their application in supramolecular chemistry are presented; e.g. STM-examinations^[3] on a chloride-covered copper (100) surface, or their use in the sensing of ethene by quartz micro- balances^[4].

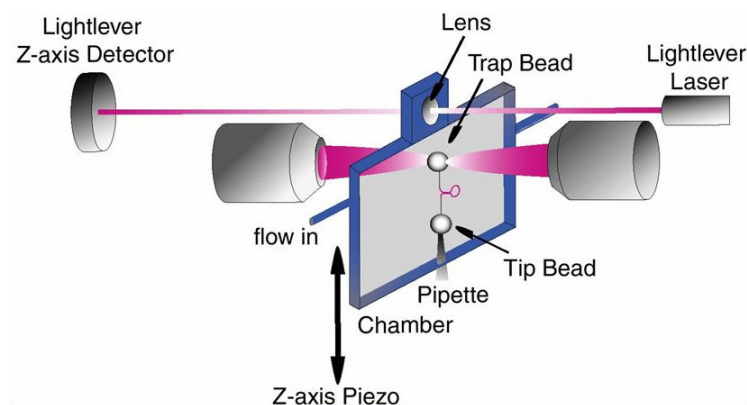
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Single-molecule studies of molecular motors

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We are interested in understanding the molecular mechanisms that underlie the biological activity of proteins. We are studying enzymatic processes such as polymerization reactions, or DNA translocation, in well defined in-vitro assays. We employ single-molecule force spectroscopy to investigate, how force, applied to a molecule externally, influences its enzymatic activity. In order to apply such a force we use micro-fluidics as well as optical- and magnetic tweezers. We furthermore use single dye molecules as a reporters for the dynamics of macro-molecules. We apply different single-molecule fluorescence techniques, such as confocal microscopy, total internal reflection microscopy, fluorescence resonance energy transfer or single particle tracking, to observe the dynamic behaviour of proteins or DNA molecules during the in-vitro processes. With this we can determine how conformational changes are coupled to enzymatic activity. These direct and real-time measurements are an important addition to structural or biochemical studies, since they provide dynamic information and avoid averaging over an ensemble of molecules.



Schematic drawing of single-molecule force spectroscopy experiment in an optical tweezers apparatus. A single-molecule is attached to two beads, one held at the end of a micropipette.

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Investigation and applications of colloidal nanoparticles

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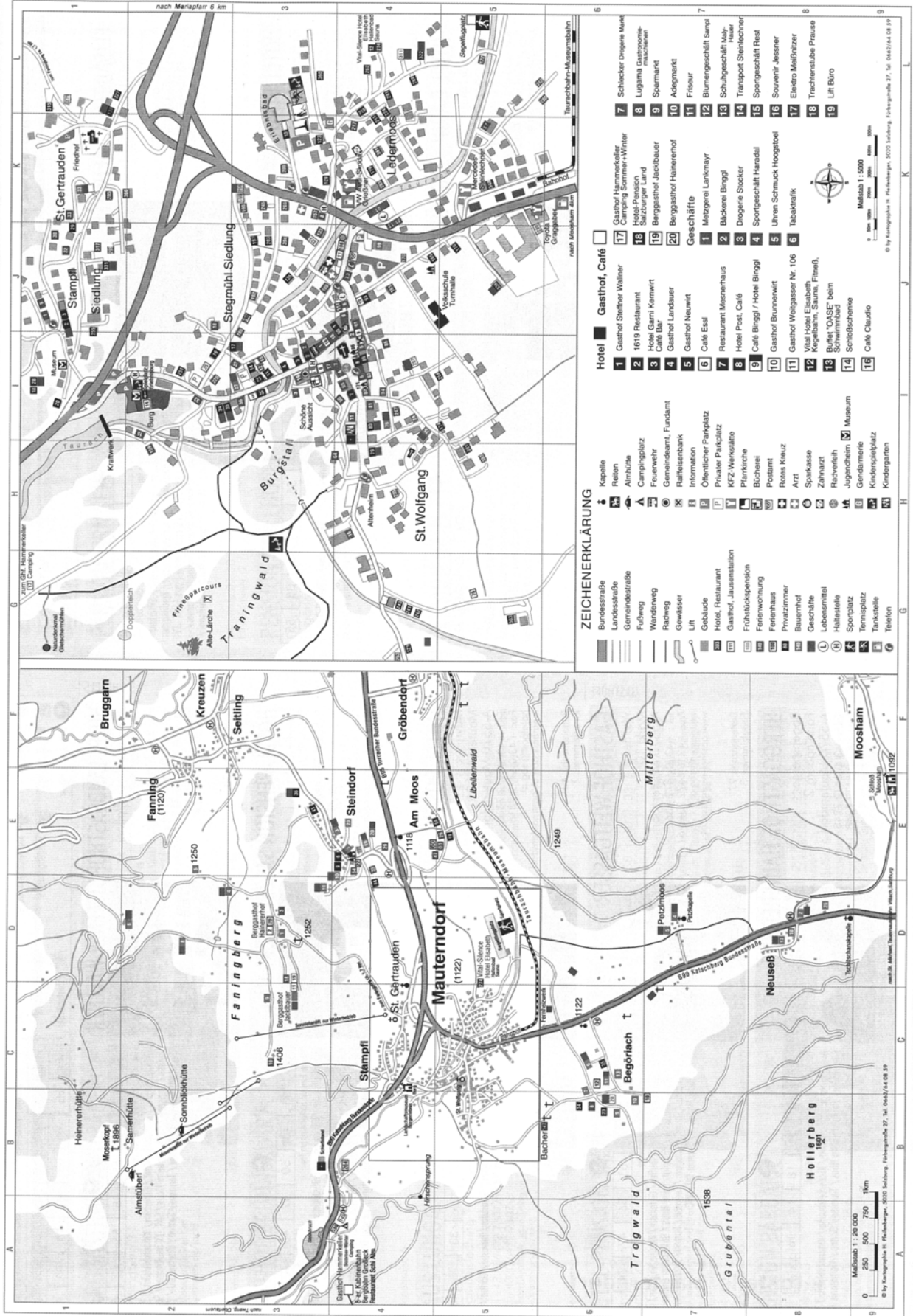
Colloidal quantum dots are semiconductor nanocrystals well dispersed in a solvent. Their optical properties, in particular the wavelength of their fluorescence, are strongly dependent on their size. Moreover with only one excitation wavelength one can excite several different fluorescence colours, which makes them attractive as fluorescent probes in all types of labelling studies. Development in the synthesis of particles is leading towards hybrid materials which combine the tunable properties of two or more materials in one nanocrystal. Examples are magnetic FePt particles connected to fluorescent CdS particles or dumbbells made of CdSe rods and PbSe dots. In our group we are studying synthesis, bioconjugation, cytotoxicity, and possible applications of this kind of nanoparticles. A new group's target will be the biocompatibility of metal, semiconductor and insulating nanocrystals. In particular we are interested in the behaviour of magnetic nanoparticles and to nanocrystals with optical and magnetic properties synthesis. They are interesting materials as they can be directed by a magnetic field.

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Map:



ZEICHENERKLÄRUNG

- | | | | |
|--|------------------|--|------------------------|
| | Bundesstraße | | Kapelle |
| | Landesstraße | | Reiten |
| | Gemeindefußweg | | Almhütte |
| | Wanderweg | | Campingplatz |
| | Radweg | | Feuerwehr |
| | Gewässer | | Gemeindefundament |
| | Lit | | Raiffeisenbank |
| | Gebäude | | Information |
| | Hotel | | Öffentlicher Parkplatz |
| | Restaurant | | Privater Parkplatz |
| | Jausenstation | | KFZ-Werkstätte |
| | Frühstückspenion | | Bucherei |
| | Ferienwohnung | | Postamt |
| | Friedhof | | Rotes Kreuz |
| | Privatzimmer | | Arzt |
| | Bauernhof | | Sporthaus |
| | Geschäfte | | Zahnarzt |
| | Lebensmittel | | Jugendheim |
| | Haltestelle | | Gendamerie |
| | Sportplatz | | Kinderspielplatz |
| | Tennisplatz | | Tankstelle |
| | Telefon | | Kindergarten |

Hotel, Gasthof, Café

- | | | |
|--|----|--------------------------------|
| | 1 | Gasthof Hammerkeller |
| | 2 | 1619 Restaurant |
| | 3 | Hotel Garn Kernwirt |
| | 4 | Gasthof Landauer |
| | 5 | Gasthof Neuwirt |
| | 6 | Café Esel |
| | 7 | Restaurant Metznerhaus |
| | 8 | Hotel Post, Café |
| | 9 | Café Bingli / Hotel Bingli |
| | 10 | Gasthof Brunenwirt |
| | 11 | Gasthof Weigasser Nr. 106 |
| | 12 | Hotel Elisabeth |
| | 13 | Buifert "OASE" beim Schwimmbad |
| | 14 | Schloßscheune |
| | 15 | Café Claudio |

Gasthof, Café

- | | | |
|--|----|--------------------------------|
| | 17 | Gasthof Hammerkeller |
| | 18 | Camping Sommer-Winter |
| | 19 | Hotel-Pension |
| | 20 | Berggasthof Jackbauer |
| | 21 | Berggasthof Heinerhof |
| | 22 | Geschäfte |
| | 23 | Merzgerle Lanemayr |
| | 24 | Bäckerei Bingli |
| | 25 | Drogens Stocker |
| | 26 | Sportgeschäft Haradl |
| | 27 | Uner Schmuck Hoopstrol |
| | 28 | Gasthof Weigasser Nr. 106 |
| | 29 | Hotel Elisabeth |
| | 30 | Buifert "OASE" beim Schwimmbad |
| | 31 | Schloßscheune |
| | 32 | Café Claudio |



Maststab 1:5000
 0 250 500 750 1000
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Mein Fahrplanheft

gültig vom 19.02.2005 bis 27.02.2005

Salzburg Hbf – Mauterndorf im Lungau Gemeindeamt

Ab	Zug	An	Umsteigen	Ab	Zug	An	Dauer	Verkehrstage
11:17	IC 517	12:35	Radstadt	12:35	Fußweg (1 Min.)			täglich
		12:36	Radstadt Bahnhof (Vorplatz)	12:38	Bus 780	13:36	2:19	
13:04	EC 113 ✕	13:51	Bischofshofen	14:13	OEC 669 ✕			täglich
		14:35	Radstadt	14:35	Fußweg (1 Min.)			
		14:36	Radstadt Bahnhof (Vorplatz)	14:38	Bus 780	15:26	2:22	
13:20	☉ 3	14:18	Bischofshofen	14:25	R 3589			täglich
		14:53	Radstadt	14:53	Fußweg (1 Min.)			
		14:54	Radstadt Bahnhof (Vorplatz)	15:38	Bus 780	16:26	3:06	
15:17	IC 611	16:35	Radstadt	16:35	Fußweg (1 Min.)			täglich
		16:36	Radstadt Bahnhof (Vorplatz)	16:45	Bus 780	17:36	2:19	

Legende

✕ = BordRestaurant



Bahn wirkt.

Mein Fahrplanheft

gültig vom 16.02.2005 bis 10.12.2005

Mauterndorf im Lungau Gemeindeamt – Salzburg Hbf

Ab	Zug	An	Umsteigen	Ab	Zug	An	Dauer	Verkehrstage
9:29	Bus 780	10:25 Radstadt Bahnhof (Vorplatz)		10:25 Fußweg (1 Min.)				a
		10:26 Radstadt		11:08 R 3584				
		11:37 Bischofshofen		11:40 R 5021		12:40	3:11	
9:32	Bus 780	10:23 Radstadt Bahnhof (Vorplatz)		10:23 Fußweg (1 Min.)				b
		10:24 Radstadt		11:08 R 3584				
		11:37 Bischofshofen		11:40 R 5021		12:40	3:08	
12:29	Bus 780	13:25 Radstadt Bahnhof (Vorplatz)		14:10 Bus 3201				c
		14:50 Bischofshofen Bahnhof (Vorplatz)		14:50 Fußweg (3 Min.)				
		14:53 Bischofshofen		15:08 SPR 1609		15:55	3:26	
12:32	Bus 780	13:23 Radstadt Bahnhof (Vorplatz)		13:23 Fußweg (1 Min.)				b
		13:24 Radstadt		13:25 OEC 668 ✕				
		13:47 Bischofshofen		14:08 EC 112 ✕		14:55	2:23	
14:32	Bus 780	15:23 Radstadt Bahnhof (Vorplatz)		15:23 Fußweg (1 Min.)				d
		15:24 Radstadt		15:25 IC 514		16:44	2:12	
16:29	Bus 780	17:25 Radstadt Bahnhof (Vorplatz)		18:10 Bus 3201				c
		18:50 Bischofshofen Bahnhof (Vorplatz)		18:50 Fußweg (3 Min.)				
		18:53 Bischofshofen		19:08 SPR 1613		19:55	3:26	
16:32	Bus 780	17:23 Radstadt Bahnhof (Vorplatz)		17:23 Fußweg (1 Min.)				b
		17:24 Radstadt		17:25 IC 518		18:44	2:12	

Index

- a = 16. Feb bis 3. Apr
- b = 4. Apr bis 10. Dez
- c = 16. Feb bis 1. Apr Mo - Fr; nicht 28. Mär
- d = 4. Apr bis 9. Dez Mo - Mi, Fr; nicht 16., 17. Mai, 11. Jul bis 9. Sep, 26. Okt, 1., 2. Nov; auch 7., 14., 21., 28. Apr, 12., 19. Mai, 2., 9., 16., 23., 30. Jun, 7. Jul, 15., 22., 29. Sep, 6., 13., 20., 27. Okt, 3., 10., 17., 24. Nov, 1. Dez

Legende

- ✕ = BordRestaurant

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Fax: 0043-6472-7426-22
Mobile: 0043-664-4305890

Burgschänke
Herr Pfeifer
0043-6472-7294

Taxi Mauterndorf:
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Tel: 0043-64747130 (ev. günstiger)

Watzinger Busreisen
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For your notes:

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