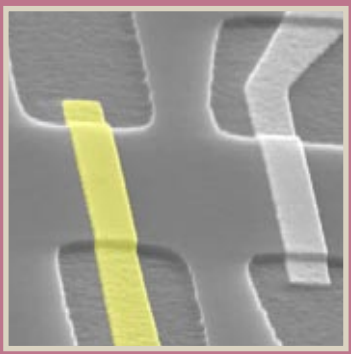
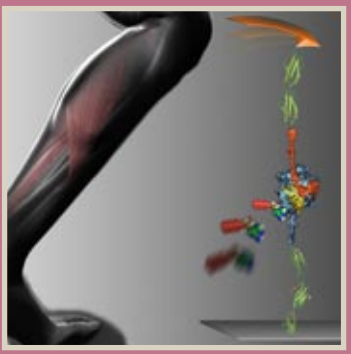
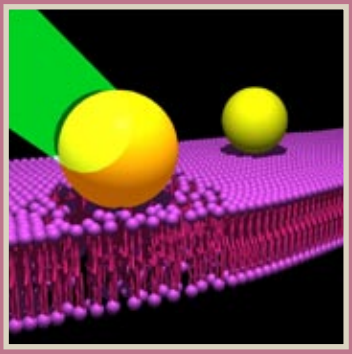
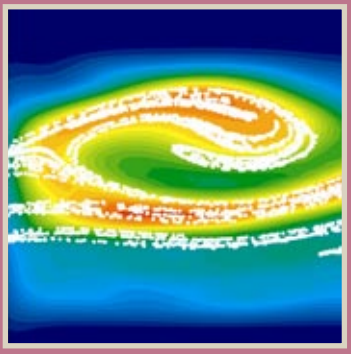
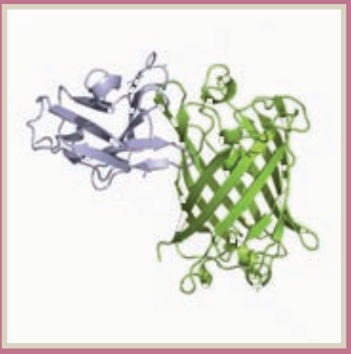
Center for NanoScience

ANNUAL REPORT 2009



CeNS
Center for NanoScience | LMU

CONTENTS

WELCOME

More is different - these words by the physics Nobel Laureate Philip Anderson go a long way in explaining the continuing overwhelming success and growth of CeNS. While we all believe that the material world can be reduced to a handful of fundamental laws, we also recognize the emergence of a myriad of complex phenomena at the nanoscale beyond these fundamental laws that call for explanations, new concepts and new technological applications throughout physics, chemistry, biology and medicine and continue to challenge and excite us every day.

As in past years, in 2009 CeNS has attracted numerous new members, both junior and senior; CeNS members have received multiple scientific awards and business competition prizes as well as outside offers representing both a compliment and a challenge for CeNS. In its second decade of existence, CeNS is spinning off more and more new companies in the world of nanoscience.

The outreach of CeNS continues to grow, for example by joining forces with the Nanosystems Initiative Munich (NIM), one of our local clusters of excellence - but as always, CeNS also reaches out beyond Munich: in 2009, CeNS was invited to show an experiment on the "Science Train", that visited more than 60 cities, to name a more unusual initiative.

Being a new member both of CeNS and its board, I may still have some kind of outside perspective on CeNS. So let me just say that one of my first and most challenging tasks was to help choose papers for our publication awards: I had not really realized before what avalanche of papers is published by CeNS members in the world's leading journals every year, rendering the task essentially impossible.

CeNS is turning 12 this year which makes it quite a youngster - so there is still a lot of room for growth, and we all expect an even more exciting year 2010!

Prof. Ulrich Schollwöck
Member of the Scientific Board of CeNS

NEW MEMBERS

PROF. ULRICH SCHOLLWÖCK

LMU Munich

Originating from Munich, Ulrich Schollwöck studied physics at LMU and at Balliol College Oxford. Ulrich Schollwöck then moved to Paris where he earned his PhD in

1995 at the Service de Physique Theorique of the French Atomic Energy Agency (CEA). From 1995 to 2002, he was Assistant Professor in the group of Prof. Herbert Wagner at LMU Munich and then became a group leader at the MPI for Solid State Research in Stuttgart. Subsequent to a stay at LMU as Associate Professor in theoretical physics (2003-2004), he held a Chair in theoretical physics at RWTH Aachen from 2004 to 2009. Since April 2009, Ulrich Schollwöck holds a Chair in theoretical physics at LMU Munich where his work focuses on the simulation of strongly correlated quantum systems in solid state physics and atomic and molecular quantum optics.

PROF. ALEXANDER HÖGELE

LMU Munich

Alexander Högele studied physics at the University of Heidelberg and at LMU Munich where he graduated in 2002. He then continued his research in spectroscopy of semiconducting quantum dots as a PhD student in the group of Prof. Khaled Karrai. In 2005, Alexander Högele completed his PhD with a thesis on "Laser spectroscopy of single charge-tunable quantum dots" which was distinguished with the "Promotionsförderpreis der Münchener Universitätsgesellschaft". He then joined the group of Prof. Atac Imamoglu at ETHZ as postdoctoral research fellow developing cryogenic spectroscopy techniques for semiconducting carbon nanotubes and advanced methods of laser spectroscopy for controlled manipulation of quantum dot electron and nuclear spins. Alexander Högele returned to LMU in December 2008 as Juniorprofessor of experimental physics (nanoscience) to establish a research program with the emphasis on quantum control and quantum coherence in photoactive solid-state nanosystems.

PROF. WOLFGANG SCHMAHL

LMU Munich

Wolfgang W. Schmahl studied crystallography and materials science. He spent an extended post-doc period at the University of Cambridge, and at the Technical University of Darmstadt. After lectureships at Tübingen University and Ruhr-University Bochum he became Chair of Geomaterials Science at LMU in 2004. His main areas of research are structures of materials from the molecular scale to the microscale and surface reactivity of solids. In his group electron diffraction, x-ray and neutron diffraction, AFM, and polarization microscopy are the main techniques.

DR. ENRICO DA COMO

LMU Munich

Enrico Da Como studied chemical physics at the Universities of Modena and Bologna. He obtained his PhD in the group of Michele Muccini at the Italian National Research Council in Bologna. During this period he worked on the optical properties of self-assembled organic semiconductors on silicon. After a fellowship in the same group working on organic lighting, he moved to the group of Prof. Jochen Feldmann at LMU Munich. There he worked on single molecule spectroscopy of conjugated polymers and quantum tetrapods. In 2008 he became group leader for the research dealing with the optical properties of organic and hybrid nanosystems. In 2008 he has been visiting scientist at the Physics Department of University of Utah.

PROF. TIM LIEDL

LMU Munich

Tim Liedl received his diploma in physics in 2004 in the group of Wolfgang J. Parak at LMU Munich where he worked on the development of hydrophilic coatings for fluorescent semiconductor nanoparticles. In 2007 he obtained his PhD in the group of Friedrich C. Simmel studying DNA-based nanodevices. From spring 2007 until summer 2009 he visited William M. Shih's laboratory at Harvard Medical School where he used the DNA-origami method to construct self-assembling 2D and 3D structures. Since 2009, Tim Liedl is professor for experimental physics at LMU Munich. His current research is multi-disciplinary and exploratory positioned at the interface between nanoscience, synthetic biology and cell-biology. It is suited to address questions arising from the complexity of living organisms.

DR. THORBEN CORDES

LMU Munich

Thorben Cordes studied chemistry at the TU Braunschweig and the University College Cork (Ireland) from 2000-2005. He obtained his PhD in the group of Wolfgang Zinth at LMU Munich. During this period he focused on time-resolved spectroscopy and non-linear optics to study the photochemistry of ultrafast photoswitches and their biophysical applications. The PhD was followed by a short postdoctoral fellowship in early 2008 at the same institute, where he worked on complex photoreactions and isomerization reactions. Subsequently, he moved to the group of Prof. Philip Tinnefeld at the Chair for Applied Physics at LMU Munich. His current research involves time-resolved and single-molecule spectroscopy to study a variety of photophysical and photochemical processes.

PROF. DIRK TRAUNER

LMU Munich

Coming back from the University of California, Berkeley, in summer 2008, Dirk Trauner took on a professorship for chemical biology and genetics at LMU Munich. He first studied biology and then biochemistry at Freie Universität Berlin, Johann Wolfgang Goethe-Universität Frankfurt and the University of Vienna, and earned his PhD in organic chemistry from the University of Vienna in 1997. Dirk Trauner then went on to the Sloan-Kettering Cancer Center in New York, where he worked as postdoctoral fellow with Professor Samuel J. Danishefsky. From 2000 to 2008, he was assistant professor and later associate professor at the Department of Chemistry of the University of California, Berkeley. His current research in Munich is focused on the production of biologically active natural substances by biomimetic synthesis.

DR. ANDRÁS DEÁK

LMU Munich

András Deák obtained his PhD in chemistry in 2007 from the Budapest University of Technology and Economics, in Hun-

gary. Since 2007, he holds a permanent position at the Research Institute of Technical Physics and Materials Science of the Hungarian Academy of Sciences. His main fields of interest are colloid chemistry, interfacial phenomena, nanoparticles, optical properties of nanoparticles and their application. In 2009 he was granted an "Excellent Research Fellowship" from LMU and joined the group of Professor Jochen Feldmann at the end of 2009. His current activity is primarily focused on metallodielectric core-shell nanoparticles for solar cell application.

PROF. BETTINA LOTSCH

LMU Munich

Between 1997 and 2002 Bettina Lotsch studied chemistry at the LMU Munich and the University of Oxford and received her PhD from LMU Munich in 2006. In 2007/2008 she joined the group of Professor Geoffrey Ozin at the University of Toronto as a Feodor-Lynen postdoctoral research fellow. There she explored the integration of chemically functional materials with photonic crystals for the design of label-free chemooptical sensors. In 2009, Bettina Lotsch accepted a W2 tenure track position at LMU Munich. Her future research will focus on the synthesis of functional porous framework materials as well as the utilization of colloidal chemistry approaches to design nanostructures thereof, including stimuli-responsive photonic crystals.

PD DR. MANFRED OGRIS

LMU Munich

Manfred Ogris studied biotechnology at the University for Applied Life Sciences (BOKU) in Vienna and finished his PhD in 1999. After being a postdoctoral research fellow and Marie Curie Fellow in the lab of Len Seymour at the CRC Institute for Cancer Studies (Birmingham, UK), he joined the Department of Pharmacy at LMU Munich in 2001 were he is an independent group leader at the Chair of Pharmaceutical Biotechnology led by Prof. Ernst Wagner. His research focus is tumor targeted delivery of therapeutic nucleic acids. This includes the development of synthetic nucleic acid carriers enabling receptor mediated internalization of such carriers into target cells after systemic administration. With the help of bioluminescence *in vivo* imaging biodistribution and functionality of such carriers are studied in tumor models in rodents. Additionally, heat inducible gene carriers are developed for targeting them to tumors treated by locoregional hyperthermia.

DR. THOMAS FRANKE

University of Augsburg

Thomas Franke studied physics at the University in Göttingen and accomplished his diploma thesis at the Max Planck Institute of Biophysical Chemistry. He did his doctoral research at the Max Planck Institute of Colloids and Interfaces and received his PhD in 2004. He then went to the University of Ulm as a postdoctoral fellow and joined the Dynamics of Complex Fluids group at the Max Planck Institute for Dynamics and Self-Organization in Göttingen. Since 2005 he is a research group leader at the chair of experimental physics at the University in Augsburg. In 2008, he spent a sabbatical at the School of Engineering and Applied Sciences, Harvard University, Cambridge, MA. His research interests include biological physics and microfluidics, cell mechanics, and complex fluids.

PD DR. CHRISTIAN PLANK

TU Munich

Christian Plank graduated in biochemistry from the University of Vienna in Austria in 1994. He carried out his PhD work at the Research Institute for Molecular Pathology in Vienna in the group of Prof. Ernst Wagner. From there he moved on to the University of California in San Francisco where he was a postdoctoral fellow in the group of Prof. Francis C. Szoka at the School of Pharmacy. Since 1997 Christian Plank is head of a research group at the Institute of Experimental Oncology which focuses on nucleic acid and gene therapies as well as on molecular medicine and molecular imaging. Christian Plank has developed a method of magnetically guided nucleic acid delivery which is known as Magnetofection. In 2003, he co-founded OZ Biosciences, a company that develops and markets reagents and technologies for the delivery of active substances to living cells.

DR. ULRICH ROTHBAUER

LMU Munich

Ulrich Rothbauer studied biology at LMU in Munich. After finishing his Diploma thesis in the lab of Prof. Svante Pääbo working on tRNA processing in human mitochondria he started his dissertation at the laboratory of Prof. Walter Neupert at the Medical Faculty at LMU. In his thesis he focused on the molecular basis of a mitochondrial disease - the Mohr-Tranebjearg Syndrom. In 2004 he returned to the Department of Biology as a PostDoc in the laboratory of Prof. Heinrich Leonhardt working on the functional analysis of DNA Methyltransferase 1. In 2005 he started to work on camelid antibodies, nanobodies and chromobodies. In 2007 he became an independent group leader to explore and develop new applications and technologies based on the Chromobody-Technology. Since 2008 he is CEO of the company ChromoTek which he also cofounded.

PD DR. ROSSITZA PENTCHEVA

LMU Munich

Rossitza Pentcheva studied physics at the University of Sofia and Cologne. During her diploma thesis at Research Center Jülich and her PhD thesis at the Fritz-Haber Institute at the Max-Planck Society in Berlin she specialized in density functional theory calculations to model the growth and properties of ultrathin transition metal films. Having received a DFG research grant she moved to LMU Munich, Section Crystallography in 2002, investigating the surface properties of complex oxides as potential spintronics materials. After returning from a research stay at the University of California at Davis in 2005, she built up a group in computational materials science at the Section Crystallography (Chair of Prof. Schmahl) and completed her habilitation in materials science in 2008. Her research focuses on mechanisms that control the stabilization of novel electronic and magnetic phases at oxide surfaces and interfaces.

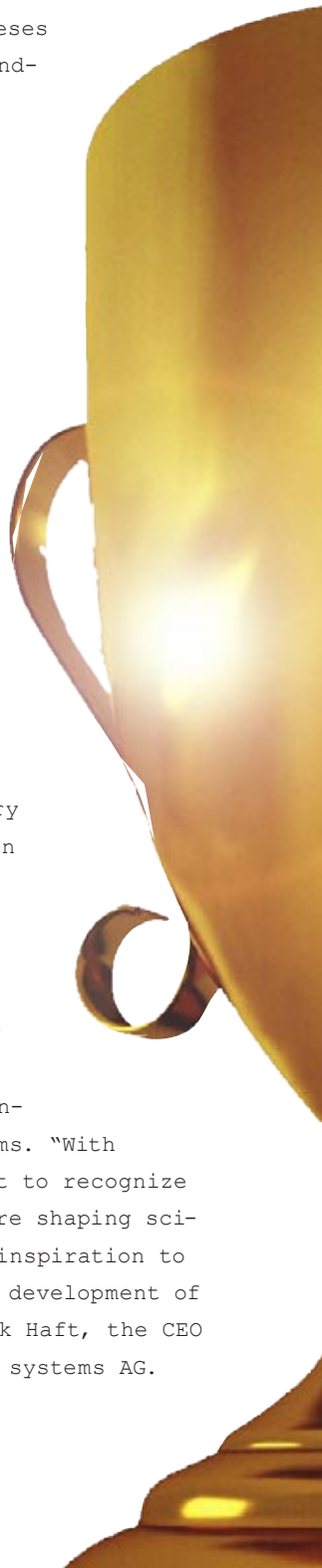
AWARDS 2009

Publication Award 2009

Each year, CeNS awards prizes for excellent publications of CeNS members which have been published during the past 12 months. With this award, successful cooperation projects within CeNS as well as outstanding research of individual research groups of CeNS are distinguished. From the numerous submitted articles which appeared in high-impact journals between October 2008 and October 2009, the CeNS board composed of Prof. Bein, Prof. Gaub and Prof. Schollwöck had a hard time to select the 19 winning publications. Amongst these were successful CeNS-internal collaboration projects such as those between the groups of Joachim Rädler and Erwin Frey, Hermann Gaub and Ulrich Gerland, Thomas Bein and Christoph Bräuchle, Philip Tinnefeld and Friedrich Simmel, Patrick Cramer and Jens Michaelis, Jochen Feldmann and Joachim Rädler, Christoph Bräuchle and Christian Plank. The winning articles from individual research groups had been published in renowned journals such as Nature, Science, PNAS, Nature Nanotechnology and Physical Review Letters. The announcement of the winners took place at the IDK-NBT/CeNS Come-Together-Event in mid-November.

attocube-Wittenstein Award 2009

In 2009, the CeNS spin-off company attocube systems AG and its partner WITTENSTEIN AG honored outstanding scientists with the newly established attocube-WITTENSTEIN award. The happy winners were announced at the CeNS summer party on July 10th subsequent to the annual event "CeNS meets Industry". With this prize, PhD theses and Diploma theses showing outstanding scientific accomplishments and innovative ideas with significant impact on potential industrial applications were recognized. Dr. Qian Huihong and Dr. Elias Puchner were the successful winners in the category "PhD thesis", sharing the prize money of 5'000 EUR. Their supervising laboratories, i.e. the groups of Prof. Achim Hartschuh and Prof. Hermann Gaub, received 5'000 EUR each for their contribution to the successful theses. In the category "Diploma thesis", Sebastian Stapfner from the lab of Dr. Eva Weig was honored and took home a cheque of 2'500 EUR. The winners were chosen by a jury composed of three professors of CeNS and a representative from attocube systems. "With this award we not only want to recognize outstanding students who are shaping science, but we hope that they are an inspiration to other students to contribute to the development of science in a decisive way." says Dirk Haft, the CEO and one of the founders of attocube systems AG.



>>> **Prof. Christoph Bräuchle** was honored by being elected a member to the **Academia Europaea**. >>> **Prof. Patrick Cramer** received the **Ernst-Jung-Award for Medicine 2009**. >>> The Universidad de Sevilla bestowed the degree of **Doctor honoris causa** to **Prof. Peter Hänggi**. Moreover, he was appointed **Outstanding Referee of the American Physical Society (APS)** and was selected for ISIHighlyCited.com for his exceptional citation count in the field of Physics. >>> **Prof. Khaled Karrai** was named an **honorary professor** by the LMU Munich and also received the **Rudolf-Diesel-Fellowship** of the TUM. >>> **Dr. Martin Kroner** won the **PhD Award** of the "Münchner Universitätsgesellschaft" of the LMU Munich. >>> **Prof. Jörg P. Kotthaus** was honored by being elected a member to the German Academy of Sciences **"Leopoldina"**. >>> **Prof. Jens Michaelis** is the recipient of a **Starting Investigator Grant** of the European Research Council (ERC) for his research on "ATP dependent nucleosome remodelling – Single molecule studies and super-resolution microscopy." >>> The LMU Munich presented the **Therese-von-Bayern-Preis** to **PD Dr. Rossitza Pentcheva**. >>> **Prof. Ulrich Schollwöck** joined the **Wissenschaftskolleg zu Berlin** (Institute for Advanced Study) as a fellow. >>> **Prof. Ulrich S. Schubert** was rewarded with the **Pieter Jan Lemstra Invention Award 2009**. >>> **Prof. Philip Tinnefeld** won the **Akademiepreis für Chemie** of the Akademie der Wissenschaften zu Göttingen. >>> The CeNS spin-off **ChromoTek** came in first in the category Marathon at the **Munich Business Plan Contest** (MBPW). >>> Another CeNS spin-off, the company **ibidi**, received the **Fast 50 Award** of Deloitte. >>> **NanoTemper Technologies** were rewarded with the **CyberOne-Award** and furthermore came in second in the category Sprinter at the Munich Business Plan Contest. >>> **NanoStove** as well as **ChromoTek** are winners of the **Science4Life Venture Cup** (Concept stage). >>> **Nanion Technologies** are the recipients of the **Deutscher Gründerpreis 2009**. >>> The **attocube-WITTENSTEIN awards 2009** went to **Dr. Elias Puchner**, **Dr. Qian Huihong** and **Sebastian Stapfner**. >>>

MEMBERS' NEWS

Thomas Franosch accepted a call to the University of Erlangen-Nürnberg as professor (W2) for theoretical physics.

Kay Gottschalk accepted a call to the University of Greifswald in the framework of the initiative HIKE (Humoral Immunoreactions in Cardiovascular Disease).

Wolfgang Heckl accepted a call from the TU Munich to the "Oskar-von-Miller"-chair for science communication at the School of Education.

Florian Marquardt declined a call from the University of Bochum (W2 professorship) and accepted a call from the University of Erlangen-Nürnberg as full professor (W3).

Accepting a call as professor of experimental physics (W2, tenure track), **Tim Liedl** returned to LMU Munich where he did his PhD (2007) and Diploma (2004) thesis.

CELLS IN FOCUS

The CeNS spin-off company ibidi GmbH was founded in 2001 by Dr. Valentin Kahl, Dr. Roman Zantl, Dr. Ulf Rädler and Prof. Joachim Rädler. The company develops, produces and commercializes cell biochips (µ-slides) and accessories for cell based assays. Since its foundation, ibidi has become renowned worldwide for its innovative products for cell analytics. In 2009, the company was awarded the FastTrack50 Award conferred by the audit and consulting firm Deloitte for belonging to the ten fastest growing high-tech companies in Germany. Since 2009, co-founder Dr. Valentin Kahl is also elected member of the advisory board of the Germany Physical Society (DPG).

Dr. Kahl, how was the company ibidi founded and what was your personal motivation to become an entrepreneur?
In 1999 we participated in the MBPW (Munich Business Plan Competition) with the idea of plastic based biochips. During our PhD work, we figured out that several types of plastics with a very good optical quality were available. My personal motivation was the idea to transfer academic knowledge in a successful company and to be a leading part of this company. Ibidi was founded as a corporation in 2001.

Which role did CeNS play in the foundation of ibidi?
We have always been in good contact with the other spin-off companies of CeNS. This small network has been very helpful. We also have interesting scientific cooperations with academic groups at CeNS and cooperative projects funded by the BMBF.

How did you acquire the entrepreneurial knowledge necessary to found and run a company?
During my studies in Physics, I visited lectures in economics. Moreover, I attended lectures given by the Munich Network regarding entrepreneurship. While writing the first business plan, we cooperated with the ODEON Center for Entrepreneurship, which is now called the LMU Entrepreneurship Center. However, the most effective way to learn how to run a business is by just doing it.

What were the milestones in the evolution of your company?
We had some important technology motivated milestones, but the most impressive breakthrough was the awareness that you have to be market and costumer driven. Even an interesting technology is worthless if you don't have a unique application and a very good market access.

How did you find investors?
Our first investors were Business Angels who were connected to the Munich entrepreneurial environment.

Who are your main customers and which countries do you export your products to?
Every person who is interested in the behavior of living cells is a potential customer of ibidi products. Right now, we have over 1.000 customers worldwide. Our largest customer generated less than 5% of our whole sales. We export in over 30 countries in cooperation with distribution partners.

How many employees does ibidi have at present and how many of these have a university education in natural or life sciences?
We have 21 employees of which 9 have a university education in life sciences (including Biophysics).

Dr. Roman Zantl (left) and Dr. Valentin Kahl (right).

What was the most difficult period for your company and how did you manage to overcome it?
The most difficult situation for all start ups is running out of money. It is always very important to have a realistic cash flow plan and a relationship with your investors which is based on mutual trust.

Do you like your job? Does it meet the expectations you had when you decided to found the company?
I enjoy my profession. I didn't have so many expectations at the beginning; I just thought that it would be a very interesting chance to become a start-up entrepreneur. I had no idea how much work it is to build up a company. Right now I am very happy that we are still the same team and that we are working together very effectively and result-orientated.

What are your major goals for the future?
To be successful. To me, success is the best motivator.

Which errors does a young entrepreneur typically make and how can they be prevented?
Underestimating the impact of sales is the typical and most dangerous error. A company lives from its customers, not from the technology, the investors or from government funding. To prevent this, you have to talk with your potential customers and you have to understand their needs.

Which qualities does a researcher need to possess in order to become a successful entrepreneur and what would be your advice to those who plan to start a business?
I think it is important to have the ability to listen. It is important to understand the expectations of your customers, co-founders, your employees, your investors, and last but not least of your suppliers. An entrepreneur should also have the ability of self motivation and constancy. It is also important to know what not to do.

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MEMBERS' NEWS

Bettina Lotsch accepted a call as professor (W2, tenure track) from the department of chemistry at LMU Munich where she finished her PhD thesis in 2006.

Andrey Rogach was appointed full professor at the department of physics and materials science at the City University of Hong Kong.

Matthias Schneider declined a grant of the European Research Council and accepted a call from Boston University as assistant professor in the department of mechanical engineering.

Fernando Stefani accepted a joint call from the University of Buenos Aires (UBA) and the National Research Council of Argentina (CONICET) as assistant professor at the physics department of UBA.

Philip Tinnefeld received a call as full professor (W3) of biophysical chemistry at the Technical University of Braunschweig.

EVENTS & ACTIVITIES

JOINT WINTER SCHOOL TOGETHER WITH NIM

Breaking with an old tradition, the biannual winter school of CeNS was this time located in the midst of the beautiful mountain scenery of St. Christoph

am Arlberg (Austria). Teaming up with the Nanosystems Initiative Munich (NIM), an impressive number of internationally renowned speakers followed the invitation to present their latest research results. Thus, the broad audience composed of junior and senior scientists of CeNS and NIM took advantage of a large variety of talks about cutting-edge nanoscience insights from all

around the world. The spare time after the talks was filled with animated discussions between speakers and participants of all academic levels exchanging new ideas and scientific expertise.

SUMMARIZING WORKSHOP OF THE SFB 486 – NANOMAN

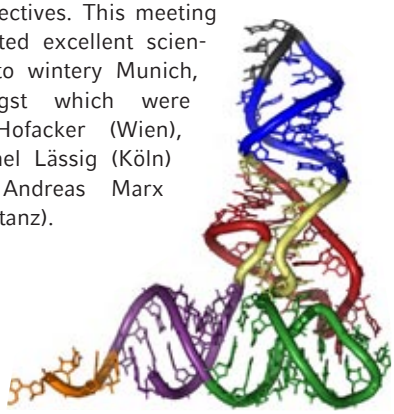
After ten successful and stimulating years, the SFB 486 (collaborative reseach centre) summed up its research activities with a workshop held at the Venice International University on San Servolo from September 16th to 19th. Under the theme "NANOMAN - 10 Years in a Nutshell", spokesman Prof. Hermann Gaub brought together all principal investigators of the different sub-projects which had joined their efforts during this past decade to advance research dealing with the manipulation of matter at the nanoscale.

In their inspiring talks, the project leaders presented an overview of the research they performed as a member of the SFB 486. To complete the insights into each sub-project, one or two PhD students presented current research highlights during two lively poster sessions in the evening of the first and second workshop day. The summarizing conference was furthermore enriched by the stimulating talks given by the reviewers who traveled to Venice to celebrate this closing event of the SFB 486.

In his closing remarks at the end of the workshop, Prof. Hermann Gaub thanked the German Research Foundation (DFG) and the reviewers for their support and announced the creation of a new collaborative research centre which had recently been granted. Under the guidance of Prof. Matthias Rief, this new SFB will investigate "Forces in Biomolecular Systems".

FOCUS WORKSHOPS

Together with Prof. Fritz Simmel (TU Munich), LMU-based Prof. Dieter Braun organized a one-day workshop at the Center for Advanced Studies (CAS) of LMU Munich. The aim of this meeting was to illuminate novel approaches of synthetic evolution to develop artificial structures and functions from different perspectives. This meeting attracted excellent scientists to wintery Munich, amongst which were Ivo Hofacker (Wien), Michael Lässig (Köln) and Andreas Marx (Konstanz).



Following the invitation of Prof. Hermann Gaub and Humboldt Visiting Fellow Prof. Dean Astumian (University of Maine), speakers from all over Europe and local scientists held a workshop on single molecule thermodynamics. The discussed topics included thermodynamically consistent model for Kinesin (Imre Derenyi, Budapest), making molecular motors out of DNA (Andrew Turberfield, Oxford), quantum fluctuation theorems (Michele Campisi, Augsburg) and single molecule thermodynamics (Miguel Rubi, Barcelona).

COLLOQUIUM

During the semester, the CeNS team organizes a weekly colloquium where speakers from various research areas are invited to give a talk on a topic related to nanosciences. Preceded by discussions with coffee and cookies, the colloquium takes place every Friday from 3:30 to 4:30 p.m. either on the LMU main campus or at the Chemistry Department in Großhadern.
www.cens.de/calendar/cens-colloquium

CeNS MEETS INDUSTRY

Once a year, CeNS invites representatives from industry to present their company and employment possibilities to the CeNS community. At the meeting in 2009, the following speakers gave interesting overviews and provided helpful insights into their professional surrounding: Dr. Andrea Brüggemann (Nanion Technologies GmbH), Dr. Alois Friedberger (EADS Innovation Works), Dr. Berthold Reusch (3M ESPE AG), Dr. Michael Riepl (Olympus Life Science Research Europe GmbH) and Dr. Bettina Schrick (TechnoStart GmbH). The event was followed by the traditional summer party where about 140 CeNS members took the opportunity for discussions with the speakers and with the other CeNS members and alumni. The event was animated by the band "UnCeNSiert" with a repertoire ranging from Jazz - Dixieland to Klezmer.

TRANSFER TO INDUSTRY

Together with its young spin-off company Nanotemper Technologies GmbH, CeNS was present at several trade fairs during the year 2009. Supported by CeNS, the founders of Nanotemper, Dr. Stefan Duhr and Dr. Philipp Baaske, set up their booth at the Biotechnica in Hannover which is Europe's top annual meeting-place for the biotech and life sciences industry. They furthermore presented their new prototype at the Forum Life Science in Garching and at the BioM-Technica in Martinsried. "For us, it was a great possibility to present our latest product and to establish new contacts in basic research and industry", says Dr. Stefan Duhr, CEO of Nanotemper Technologies and former PhD student at CeNS.

NETWORKING LUNCH

To enhance discussions and the exchange of ideas and knowledge between the junior scientists of the different groups at CeNS, networking lunches are organized once a month during the semester. Jointly with the colleagues from NIM, the CeNS team offers home-made meals to PhD and Diploma students who are interested in scientific discussions in an informal setting. The lunch is followed by the IDK-NBT lecture series and the CeNS colloquium.

ENTREPRENEURSHIP WORKSHOPS

In collaboration with the Entrepreneurship Center of the LMU, CeNS again offered its PhD students a three-day introduction into entrepreneurship covering many relevant topics such as how to recognize business potential, how to write a business plan and how to get early financing for start-ups. The seminar which took place in Freising from November 9th to 11th combined theory and practical exercises. In addition, successful entrepreneurs and specialists shared their knowledge and experience with the participants.
www.entrepreneurship-center.uni-muenchen.de

How do you found a nanotech company? Supported by CeNS, Theresa Hecht, former PhD student and PostDoc in the group of Prof. Jan von Delft, participated in the third Nano-Entrepreneurship-Academy (NEnA III) held in Darmstadt where she got insights into this complex topic. The nation-wide initiative is organized by the German Ministry for Education and Research with the aim to promote the entrepreneurial autonomy of female young scientists in the field of nanotechnologies. During this intense and diversified six-day workshop, the participants not only followed a crash course on entrepreneurship skills, but also had to develop their own business ideas in a structured way. The lectures included topics like patent protection, market analysis and funding schemes and were complemented by an interactive business plan game. Furthermore, team building, idea creation and presentation skills were trained in the framework of an improvisation theatre workshop. The implementation of the acquired knowledge was practiced in final presentations of the group projects to the other participants and to a jury composed of entrepreneurs.
www.nano-4-women.de

SCIENCE EXPRESS

Between April and November 2009 CeNS was on board of the exposition train "Science Express" which traveled across Germany, stopping at the main railway stations of more than 60 cities. Invited to contribute an exhibit to the train carriage named "Nano and Bio Sciences Converge", CeNS exposed a macroscopic model of an Atomic Force Microscope (AFM) which demonstrates the working principle of this important technique. The science exhibition train was initiated by the German Ministry for Education and Research and organized by the Max-Planck-Society to give the general public insights into the world of tomorrow and to provide an outlook into topics and developments that are only emerging.
www.expedition-zukunft.org

LECTURE SERIES NANOBIOTECH

Once a month, a lecture on nanobiotechnology held by researchers of CeNS precedes the colloquium from 2:00 to 3:00 p.m. This series of lectures is part of the educational program of the International Doctorate Program NanoBioTechnology. The lectures of the series are recorded and are available online for members of CeNS.
www.cens.de/calendar/lecture-series

THE INTERNATIONAL DOCTORATE PROGRAM NANOBIOTECHNOLOGY

The International Doctorate Program NanoBioTechnology is an international doctoral excellence program in the field of nanobiotechnology, funded by the Elite Network of Bavaria (ENB). It offers outstanding graduate students the opportunity to earn their doctoral degree in a stimulating scientific and academic environment providing interdisciplinary research conditions and excellent education. The program involves faculty members from Biophysics, Physical Chemistry, Biochemistry, Biology and Medicine and is administrated by the Center for NanoScience (CeNS) at the Ludwig-Maximilians-University in Munich (Bavaria). The International Doctorate Program NanoBioTechnology (Internationales Doktorandenkolleg: IDK-NBT) came into existence in 2004 and is now in its second funding period lasting until 2010. Since its beginning, the number of PhD students supported by the program has grown from 19 in 2004 to 42 in 2009.

THE PROGRAM

The IDK-NBT offers its members a comprehensive educational program and financial support for travel expenses and literature. Approximately two thirds of the scholarship holders also receive their salary from the IDK. Furthermore, new students coming from abroad are offered their first German course in Munich to guarantee a quick integration into their research groups and social surroundings.

The PhD students can choose from a variety of multidisciplinary scientific seminars, summer and winter schools and colloquia covering all aspects of their research. Furthermore, the IDK-NBT offers a special lecture series on nanobiotechnology where CeNS scientists give introductions to their respective research fields. To allow revision of the topics covered in the talks, the lecture series is recorded on video and made available online for the students for further studies and preparation of their dissertation examination.

Apart from the scientific program, all members of the IDK-NBT can participate in various professional skills courses offered by the ENB. There, the PhD students receive training in important fields like “leadership skills: how to guide oneself and others”, “effective presentation and communication” or “intercultural competence for speech and negotiation”. Upon special request of the members, the IDK office organizes complementary seminars on topics not covered by the ENB program. As such, seminars on project management, patents or self-management have been offered during the last years. In the latter workshop, the participants learned to define their goals in life, how to cope with daily stress and to manage their time.

NEW PROGRAM MANAGER

Since January 2009, Marilena Pinto has been working at CeNS as the program manager of the International Doctorate Program NanoBioTechnology. Having German-Indian origins and a Masters’ Degree in English linguistics, Ms. Pinto has started working for the mulitinational group of PhD students with enthusiasm and fresh energy. In her function, she is the main contact point for the young researchers and is in charge of all administrative matters of the doctorate program.

SUPERVISION & SUPPORT

To ensure a qualified scientific supervision all members of the doctoral program have a second thesis advisor which takes care of the PhD students jointly with the main thesis advisor. The co-advisor evaluates the annual progress reports all members have to hand in at the end of each funding year and discusses with the student possible problems or improvements based on this report. Complementary to the intensive supervision of the scientific advisors, the CeNS network offers additional support via its numerous meetings where the PhD students can discuss their research with scientists of the broad multidisciplinary community of CeNS as well as with the renowned speakers invited from all around the world. Furthermore, the IDK-NBT office team helps its members in administrative matters and supports the realization of ideas concerning new event formats or necessary improvements to the program.

NETWORKING & COLLABORATIONS

To foster the scientific and personal exchange of the members of the IDK-NBT, internal workshops are offered where the PhD students present their research work to their peers. Different formats are proposed as e.g. an internal summer school at lake Chiemsee or one-day workshops in Munich. Furthermore, members of the different elite programs of the ENB meet and exchange ideas

at the regular soft skills seminars organized by the Elite Nework which take place in Beilngries. At the monthly CeNS/IDK/NIM lunch, IDK-NBT students meet with their colleagues from CeNS and NIM at a home-made lunch taking place on Fridays before the lecture series on nanobiotechnology.

As a direct result of these meetings, joint scientific projects have emerged which lead to publications in peer-reviewed journals. As such, theorist Jan-Tim Kuhr (LMU) teamed up with experimentalist Madeleine Leisner (LMU) for a work on the "Kinetics of Genetic Switching into the State of Bacterial Competence". And Australian Tom Sobey (TUM) joined efforts with Christian Steinhauer (LMU) for their experimental work on "DNA Origami as Nanoscopic Ruler for Superresolution Microscopy".

INTERNATIONALITY

Approximately 30% of the members of the IDK-NBT come from foreign countries such as Australia, Brazil, Canada, China, India, Iran, Poland and the Ukraine. Since 2008, the IDK-NBT has introduced an online application portal where candidates submit all necessary information and documents via a special website. The establishment of this tool has been offered by the LMU GraduateCenter with which the IDK-NBT has close collaborations. Thanks to the increase in international advertising of the scholarships via internet, e-mails and flyer mailings to relevant research institutions and Master programs worldwide, the number of submitted applications increased from less than 100 before 2008 to almost 300 in 2009.

Following the international call for application, candidates from 41 different countries worldwide completed their web-based application. Via the online tool, only complete application documents can be submitted by the candidates, thus providing a comprehensive picture of each student and reducing the administrative efforts for the office team considerably. After evaluation of the documents of all applicants, the most promising candidates are further reviewed via telephone interviews by the corresponding project leaders. Those applicants who pass this test by convincing their potential project leaders are invited to Munich for a one-day selection workshop where they present their Masters' work to the members of the selection committee. The candidates' visit in Munich is further complemented by a social gathering and a guided tour across Munich's city center taking place the evening before the official selection day.

TAKING RESPONSIBILITIES

The success of the IDK-NBT depends on the involvement of the students in the organization of the program. This important issue is realized by annual "get-together" events where students are able to discuss openly with the program manager and the scientific manager of CeNS about their needs, ideas and suggestions concerning their doctorate program. Furthermore, two student representatives gather the thoughts and wishes of all IDK members and discuss these with the spokesman of the program, Prof. Joachim Rädler, and the IDK office. On the occasion of the welcome event in November 2009, two new student representatives were elected by the members of the IDK. In their election speech, the new representatives Julia Blechinger (physical chemistry) and Philipp Severin (biophysics) highlighted their wish to "give something back to the IDK" after having benefited from the program for more than one year.

WHAT STUDENTS SAY

Lidiya Osinkina from Ukraine.

"Being accepted as an IDK doctorate at the IDK-NBT is a great honour for me. It enabled me to do my PhD exactly in the field I like to work in. CeNS provides all kinds of support for members and gives very good chances for professional and personal growth by arranging lectures on the latest scientific achievements and creating a network between young researchers. Last but not least, Munich is one of the best cities in the world and above all my favorite city . I felt here at home from the very first day. Dreams come true, thanks CeNS and the IDK-NBT!"

Kulpreet Virdi from India.

"I've found IDK to be a wonderful platform for interaction between young graduates pursuing research in a common field. The constant exposure to the wide variety of workshops and seminars organised by CeNS and NIM keeps one's mind abuzz about the latest happenings in the field. [...] Munich, despite being the epicentre of high tech industry in Germany, still carries its charm as an old city with a large student population."

Elisângela Linares from Brazil.

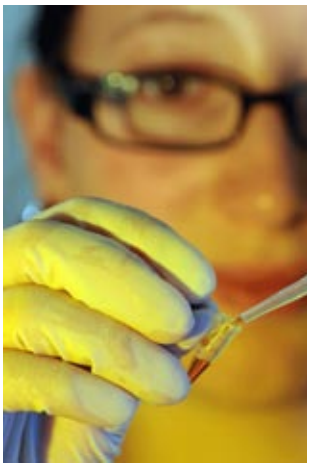
"Before starting my PhD, I spent two months in Munich participating in the NIM summer school. It was an excellent way to get an overview of Munich and I could notice the stimulating scientific environment and also the high quality level of the interdisciplinary works developed at the universities and research centers."

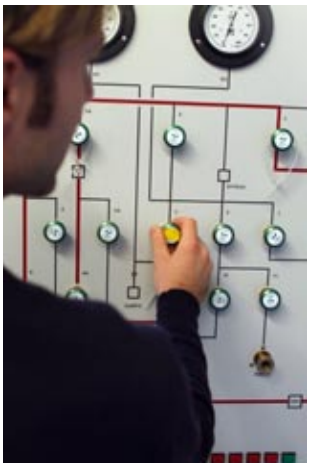
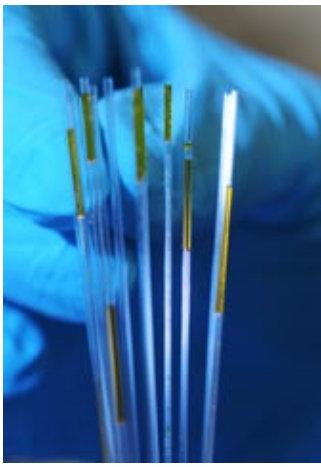
ALUMNI CAREERS

Although the program has been running for only 5 years, the IDK-NBT can already look with pride onto the careers of its alumni: While some obtained attractive PostDoc positions at internationally renowned research institutes worldwide such as Harvard University, Rockefeller University or the University of California, others now apply their knowledge and skills to industry such as Linde, Carl Zeiss or Novartis. A few alumni have even secured professorship positions, such as Tim Liedl who is now himself faculty member of the IDK-NBT and offers a PhD position in the next application round for the upcoming generation of junior researchers.

www.cens.de/doctorate-program.html

SELECTED RESEARCH PROJECTS

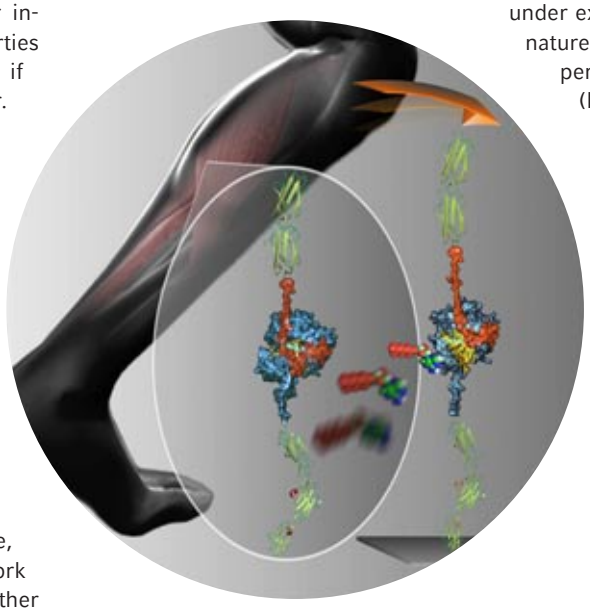



PROBING AND SWITCHING MOLECULES BY FORCE, CHEMISTRY AND VOLTAGE

Dr. Ralf David, Dr. Ann Fornof, Prof. Hermann E. Gaub, Prof. Ulrich Gerland and Prof. Thomas Carell (LMU Munich)

The response of living systems to forces requires molecules and molecular interactions with adequate properties to counteract both in a passive and also, if needed, in an active, dynamic manner. However, at the level of individual molecules these forces are so minute that the development of sophisticated experiments to measure and control them is required. These techniques, particularly the AFM-based single-molecule force spectroscopy, matured into commercial instruments. The scope has widened considerably and more and more studies shed light onto the different aspects of biomolecular mechanics. Enzymes changing their conformation while interacting with a substrate can be influenced by external forces (Gumpp *et al.*) and some, as the titinkinase, are particularly designed to begin to work under external load (Puchner *et al.*). Other molecules change their mechanical properties under external stimuli of chemical or electrical nature as shown by force spectroscopy experiments of DNA molecules on surfaces (Erdmann *et al.*). ➤



The molecular-force sensor titin kinase (TK) is embedded in the M-band structure of the sarcomere at an ideal position to sense force imbalances. H. E. Gaub and E. M. Puchner demonstrate in their communication a new AFM-based single-molecule pump-and-probe protocol to mechanically prepare different conformations of TK and to read out their function. The results show that the binding pocket for the co-substrate ATP is shielded by two sequential barriers in the force-induced activation pathway.

M. Erdmann, R. David, A. Fornof, H. E. Gaub: Electrically controlled DNA adhesion; Nature Nanotechnology 5, 154 (2010) Epub 2009

E. M. Puchner, H. E. Gaub: Force and function: probing proteins with AFM-based force spectroscopy; Curr Opin Struct Biol. 19, 605 (2009)

H. Gumpp, E. M. Puchner, J. L. Zimmermann, U. Gerland, H. E. Gaub, K. Blank: Triggering enzymatic activity with force; Nano Lett. 9, 3290 (2009)

David, Fornof, Gaub: *http://www.biophysik.physik.uni-muenchen.de/*

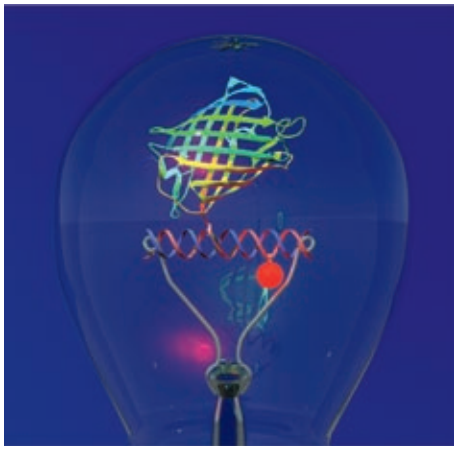
Carell: *http://www.cup.uni-muenchen.de/oc/carell/*

Gerland: *http://www.physik.uni-muenchen.de/~gerland*

SINGLE-MOLECULE INVESTIGATIONS OF A PHOTOSWITCHABLE NANODEVICE

Prof. Christoph Bräuchle and Prof. Don C. Lamb (LMU Munich)

Due to the specificity of Watson–Crick base pairing, DNA is an excellent molecule for the fabrication of nanostructures. It has been shown that DNA can be used as a scaffold for positioning proteins and synthetic molecules with nanometer accuracy. As the next step in adding complexity and functionality to these nanodevices, optical addressability is incorporated. The fluorescent protein Dronpa, which can be optically switched between a fluorescent state and a dark state, is mounted on a DNA scaffold in the proximity of a synthetic fluorophore. Hence, the system can be optically switched between the dark state and an optically active state that undergoes Förster resonance energy transfer. As nanodevices operate as individual units, the functionality of the device is analyzed using single-molecule microscopy. The physical characteristics of nanodevices make them well suited as probes for investigating cellular processes or as shuttles for gene therapy. Hence, the functionality of the nanodevice is verified in the context of cellular measurements. ➤



As a next step in the complexity of nanodevices, a protein-DNA-fluorophore complex was constructed that could be addressed optically. Energy transfer between the photoswitchable fluorescent protein Dronpa and the acceptor fluorophore Atto647 could be switched on and off using different wavelengths of light.

G. Heiss, V. Lapiene, F. Kukolka, C. M. Niemeyer, C. Bräuchle, D. C. Lamb: Single-Molecule Investigations of a Photoswitchable Nanodevice; Small 5, 1169 (2009)

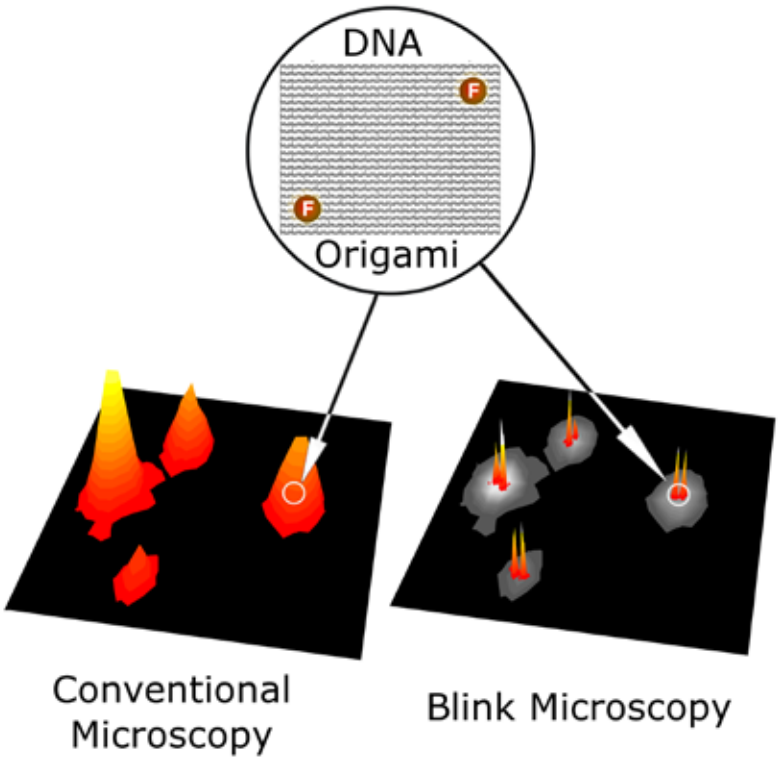
Bräuchle: *http://www.cup.uni-muenchen.de/pc/braeuchle/index.html*

Lamb: *http://www.cup.uni-muenchen.de/pc/lamb/index.html*

DNA ORIGAMI AS NANOSCOPIC RULER

Prof. Friedrich C. Simmel (TU Munich)
Prof. Philip Tinnefeld (LMU Munich)

Optical microscopy is one of the key analysis tools in modern life science. However, the resolution of this technique has always been limited by diffraction, that is, a structure which is smaller than about 300 nm cannot be resolved. To overcome this fundamental restriction, a couple of super-resolution methods were developed in recent years which provide a resolution better than the diffraction barrier. For comparison and evaluation of several super-resolution approaches as well as calibration of each super resolution microscope, a nanoscopic ruler is needed. The basis for such a ruler was found with the so called DNA origami structures, where a long strand of DNA is folded into any desired shape. With a diameter of typically 100 nm and a fully addressable breadboard-like structure, DNA origami can be used to arrange nanoscale objects with nanometer precision. Scientists from the Tinnefeld (LMU) and the Simmel (TUM) group used the origami technique to develop a nanoscopic ruler and applied it to an assortment of super resolution techniques including blink microscopy. Single fluorophores were clearly resolved at a distance of 90 nm showing that fluorescent structures made of DNA origami are the perfect samples to test the resolving power of a microscope and furthermore a formidable tool for fluorescence microscopy in general. ➤



Top: Schematic representation of a DNA origami with two fluorophores attached at a distance of 90 nm. Bottom: Images of fluorescently labelled DNA origami taken with conventional diffraction limited fluorescence microscopy and super-resolution blink microscopy.

C. Steinhauer, R. Jungmann, T. L. Sobey, F. C. Simmel, P. Tinnefeld: DNA Origami as Nanoscopic Ruler for Superresolution Microscopy;
Angew. Chem. Int. Ed. 48, 8870-8873 (2009)

Tinnefeld: *http://www.biophysik.physik.uni-muenchen.de/lsgaubstaff/philiptinnefeld*

Simmel: *http://www.e14.ph.tum.de/*

ENERGETIC DISORDER LIMITS ENERGY TRANSFER IN SEMICONDUCTOR NANOCRYSTAL-DNA-DYE CONJUGATES

Prof. Andrey Rogach (LMU Munich, now at City University of Hong Kong)
Prof. John Lupton (University of Utah)
Prof. Jochen Feldmann (LMU Munich)

Förster (or fluorescence) resonant energy transfer (FRET) is a powerful spectroscopic technique to study conformational and distance changes in hybrid (bio)-nanosystems. Being conjugated with biomolecules and organic dyes, semiconductor nanocrystals (NCs) have been increasingly used as donors in FRET related studies. Conjugates of semiconductor NCs with organic dyes are further considered as promising artificial light-harvesting complexes, which harvest and direct light energy to a molecular acceptor. The influence of spectral linewidths of individual donor-acceptor couples on energy transfer efficiency in semiconductor nanocrystal – DNA – organic dye conjugates has been demonstrated. Temperature dependent single molecule and ensemble spectroscopy data are analyzed using the Förster theory within the macroscopic and microscopic approaches. The results obtained evidence on the importance of the spectral overlap between emission of a single donor and absorption of a single acceptor in its close vicinity, which determines the microscopic resonance and transfer efficiency between individual neighbours. This realization poses important implications on the applicability of ensemble spectral overlap for the analysis of distance dependencies of nanoscopic objects. It is the spectral overlap between emission of a single donor and absorption of a single acceptor in its close vicinity which determines the microscopic resonance and transfer efficiency between individual neighbours. The macroscopic spectral overlap derived from inhomogeneously broadened ensemble spectra leads to a substantial overestimate of the transfer efficiency and cannot reproduce the observed marked temperature dependence of FRET. ➤

K. Becker, A. L. Rogach, J. Feldmann, D. V. Talapin, J. M. Lupton: Energetic Disorder Limits Energy Transfer in Semiconductor Nanocrystal-DNA-Dye Conjugates;
Appl. Phys. Lett. 95, 143101 (2009)

Rogach: *www.ap.cityu.edu.hk/personal-website/webpage Rogach with photo.htm*

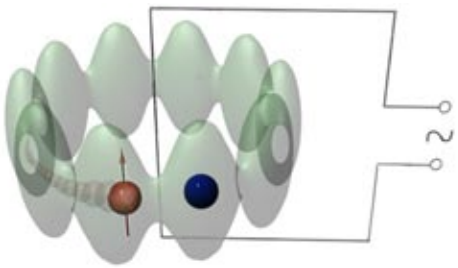
Lupton: *http://www.physics.utah.edu/~lupton/*

Feldmann: *www.phog.physik.uni-muenchen.de*

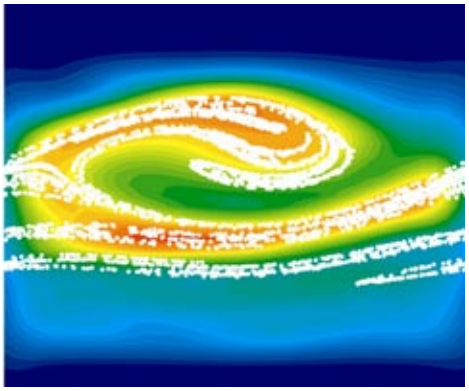
STARTING UP A QUANTUM ENGINE

Prof. Peter Hänggi (University of Augsburg)

How to put a purely quantum engine into action? This challenge can now be achieved via suitably manipulating cold atoms. Our group at the University of Augsburg unravelled this task by presenting a first realization of this objective. Astonishingly, although our devised quantum engine utilizes solely those ideal, non-classical principles of quantum dynamics, its response nevertheless acquires many features of a conventional, classical electric motor. The stylized quantum motor consists of two interacting cold quantum particles, one the "rotor" and another one acting as the "starter", that are trapped in a ring-shaped optical potential (see upper figure). The "rotor"-atom is set into directed controllable rotational motion by exerting a time-periodic magnetic field. The quest for harvesting unidirectional rotor motion rests upon the key element of using a non-biased drive that dynamically breaks the forward-backward symmetry. Exploring the intriguing operational range of the motor near resonances paves the way for such a quantum engine to perform reliable work against an external load. ➤



Crank it! If it could be built, this quantum-mechanical contraption consisting of two atoms in a ring of light would be the smallest electrical motor.



Classical versus quantum Brownian motor transport occurring in a periodic potential which is rocked by a harmonic mixing signal. The classical dynamics transport moves in phase space along definite transporting trajectories. The quantum dynamics transport instead is based on a wave function spreading in phase space. The plot depicts a transporting chaotic quantum attractor within its "Husimi"-representation which nevertheless keeps track of the classical chaotic attractor, as marked by the superimposed white markings.

A. Ponomarev, S. Denisov, and P. Hänggi: ac-driven atomic quantum motor; Phys. Rev. Lett. 102, 230601 (2009)

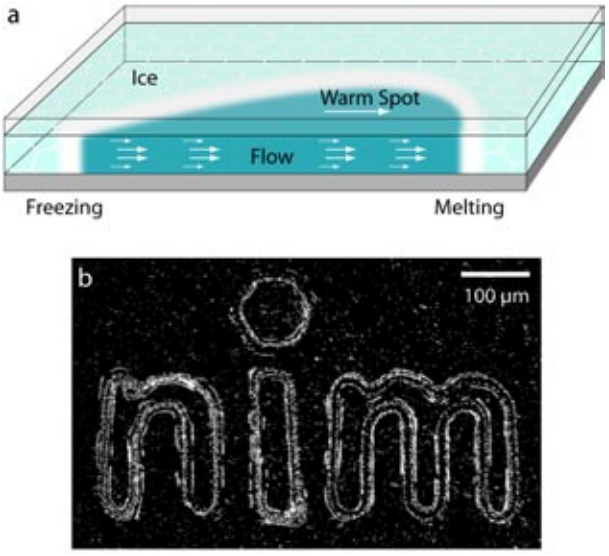
Hänggi: *www.physik.uni-augsburg.de/theo1/hanggi*

LIGHT DRIVEN MICROFLUIDICS IN ICE

Prof. Dieter Braun (LMU Munich)

The chemistry lab of the future fits on a finger. In such a "Lab-on-a-Chip" tiny amounts of biological material can be analyzed. A challenge is still the directed movement of fluids on the micrometer scale. Franz Weinert, Max Wühr and Prof. Dieter Braun have developed a novel method for this. The driving force is a laser beam, which temporarily melts water and drives it through channels of ice. This non-contact method opens novel ways to control biological fluids on the microscale from far away, not requiring any structured microchannels.

The physics behind is the volume change between ice and water. As the water melts in the front of the moved warm spot, water contracts and moves the molten droplet along the laser. Since the ice sheet is on the micron scale, the laser can be repeated up to 1000 times per second and allows to move water with velocities of up to 60mm/s. The advantage is that diffusion is limited by the ice and thus we can transport biological molecules along arbitrary paths with high velocity at optical resolution. ➤



Light driven Microfluidics in Ice. Water pockets are driven in ice sheets with velocities of 60 mm/s with optical resolution. It allows a random access of fluidics without diffusive loss. The water is driven by the volume changes in the phase transition water-ice.

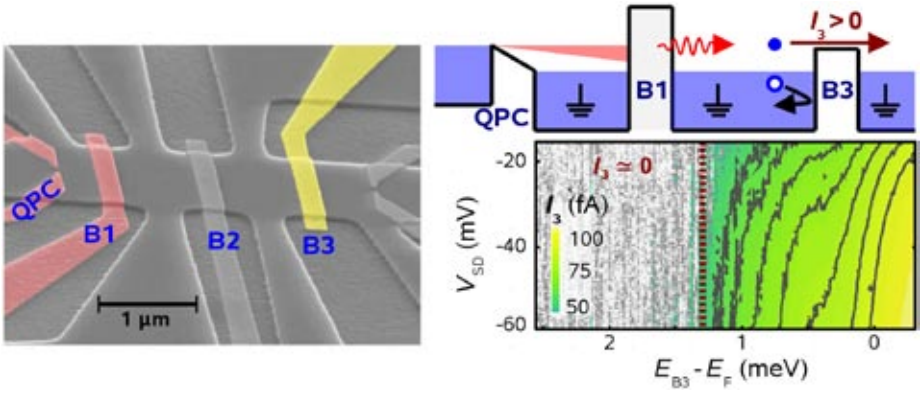
F. M. Weinert, M. Wühr, D. Braun: Light driven microflow in ice; Applied Physics Letters 94, 113901 (2009)

Braun: *http://www.biosystems.physik.lmu.de/*

PHONON-MEDIATED NON-EQUILIBRIUM INTERACTION BETWEEN MESOSCOPIC DEVICES

Priv.-Doz. Dr. Stefan Ludwig and Prof. Jörg P. Kotthaus (LMU Munich)

Quantum interactions in nanoscale circuits become increasingly important with shrinking device dimensions. In mesoscopic circuits interactions can be transmitted by Coulomb interaction, by plasmons or by phonons. Here, we investigate the contribution of acoustic phonons to the non-equilibrium interaction between electrically separated circuits at low temperatures (~ 0.1 K). The left figure shows a Hall-bar (elevated), which contains a two-dimensional electron system (2DES). Negative voltages applied to the (colored) metal gates cause local depletion of the 2DES. They are adjusted to define a quantum point contact (QPC) and potential barriers (B1 and B3). B1 is very high and electrically separates the emitter (left of B1) from the detector circuit (right of B1). By biasing the almost pinched-off QPC with the voltage V_{SD} ballistic electrons are injected with a well defined excess energy (eV_{SD}) into the emitter circuit (compare sketch). While B1 is opaque for electrons energy can still be transmitted into the unbiased detector circuit, for example by acoustic phonons. These energy-quanta can then excite electrons from the cold Fermi-sea (sketch). Barrier B3 in the detector circuit is tuned to have a height near the Fermi-energy so that it locally separates excited electrons from the now positively charged remaining Fermi-sea. Because most of the energy is absorbed between barriers B1 and B3 the energy selectivity of barrier B3 results in a detector current I_3. The color scale plot shows the detector current as a function of the voltage V_{SD} applied across the QPC and the height E_{B3} of barrier B3 compared to the Fermi energy E_F. We observe a sudden onset (dashed line) of the detector current at a barrier height of 1.3 meV above the Fermi-energy. Hence the excess energy of electrons in the detector circuit is limited by an upper bound of about 1.3 meV. This value corresponds to the maximum energy of acoustic phonons that can be absorbed by equilibrium electrons and indicates that the energy is indeed transmitted by phonons rather than Coulomb interaction. Our studies illustrate the importance of acoustic phonons for the interaction in mesoscopic circuits. ➤



G. J. Schinner, H. P. Tranitz, W. Wegscheider, J. P. Kotthaus, and S. Ludwig: Phonon-Mediated Nonequilibrium Interaction between Nanoscale Devices; Phys. Rev. Lett. 102, 186801 (2009)

Kotthaus: *http://www.nano.physik.uni-muenchen.de/*

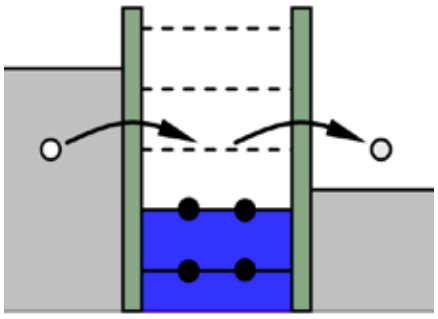
Ludwig: *http://www.nano.physik.uni-muenchen.de/quantumtransport/*

VARIATIONAL MATRIX-PRODUCT-STATE APPROACH TO QUANTUM IMPURITY MODELS

Prof. Jan von Delft and Prof. Ulrich Schollwöck (LMU Munich)

Quantum impurity models represent a generic setting for small quantum systems embedded in a larger non-interacting macroscopic environment. Both, the quantum impurity and the environment are easy to solve on its own, but in their combination highly non-trivial strongly-correlated many-body physics can emerge at low temperatures, the Kondo model being a prototypical physical example. The numerical renormalization group (NRG, Wilson, 1975) represents a hallmark numerical approach to exactly these kinds of models. The spectral distribution of the non-interacting bath is discretized (coarse-grained) with exponentially increased resolution towards small energies, followed by an exact mapping onto an effective semi-infinite tight-binding chain with exponentially decaying couplings and with the impurity coupled to the beginning of the chain only. This quasi-one-dimensional system then is well-suited for numerical treatment in the spirit of NRG: through the argument of energy scale separation the system is solved iteratively starting from a short chain and adding one new site at a time.

The key insight at the basis of this work is that by the iterative nature of NRG, it generates a so-called matrix-product-state (MPS), and as such allows for a direct link to the density matrix renormalization group (DMRG, White, 1992). MPSs are highly efficient compact representations for quasi-one-dimensional quantum-many-body states, with DMRG being essentially a variational prescription on this basis, easily accessible through concepts of quantum information. This paper nicely combined therefore expertise from the NRG (von Delft group), the DMRG (Schollwöck group) and concepts of quantum information (MPQ Garching, I. Cirac), and thus showed that certain limitations of NRG such as limited resolution at finite frequency for spectral data can be clearly improved upon by combining these concepts. ➤



Schematic quantum impurity model.

A. Weichselbaum, F. Verstraete, U. Schollwöck, J. I. Cirac, Jan von Delft: Variational matrix-product-state approach to quantum impurity models; Phys. Rev. B 80, 165117 (2009)

Schollwöck: *www.theorie.physik.uni-muenchen.de/lsschollwoeck/members/professors/schollwoeck/*

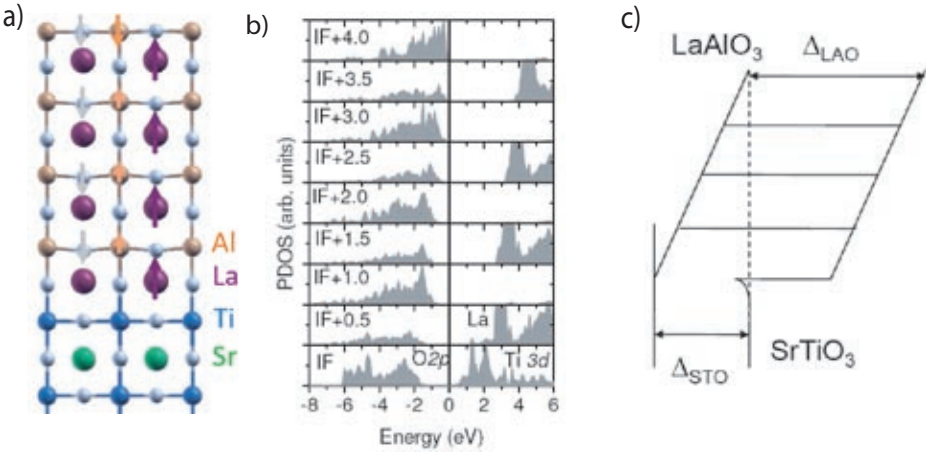
von Delft: *http://homepages.physik.uni-muenchen.de/~vondelft/*

ORIGIN OF METAL-TO-INSULATOR TRANSITION IN ULTRATHIN $LaAlO_3$ FILMS ON A $SrTiO_3$(001)

Priv.-Doz. Dr. Rossitza Pentcheva (LMU Munich)

Polar discontinuities can drive novel electronic behaviour even at the interface of conventional band insulators as $LaAlO_3$ and $SrTiO_3$. Recently, Mannhart and coworkers [S.Thiel et al., Science 313, 1942 (2006)] reported a thickness dependent switching from insulating to conducting behavior in thin $LaAlO_3$ films on a $SrTiO_3$(001)-substrate.

Density functional theory calculations reveal that a strong polar distortion creates the necessary screening and enables several unit cells of $LaAlO_3$ to sustain their ionic charges and remain insulating. However, the band gap of the system, defined by O 2*p* states at the surface and Ti 3*d* states at the interface decreases with each added $LaAlO_3$-layer, before an insulator-to-metal transition and a crossover to an electronic reconstruction takes place at around 5 ML (monolayers) of $LaAlO_3$. Thereby two different, spatially separated types of carriers are created - holes at the surface and electrons at the interface – making this system promising to explore excitonic phenomena. ➤



a) Side view of the relaxed structure of 4 ML $LaAlO_3/SrTiO_3$(001) showing a strong polar distortion of the $LaAlO_3$ film dominated by a 0.2 - 0.3 Å outward relaxation of La3+ (purple atoms) and additional buckling in the subsurface AlO_2 layers; b) layer resolved density of states of 4 ML $LaAlO_3/SrTiO_3$(001) with relaxed positions of the cations. The strong lattice polarization allows the system to remain insulating (here band gap of 0.4 eV) until a crossover to an electronic reconstruction takes place at around 5 MLs of $LaAlO_3/SrTiO_3$(001); c) schematic figure of the band bending in $LaAlO_3/SrTiO_3$(001).

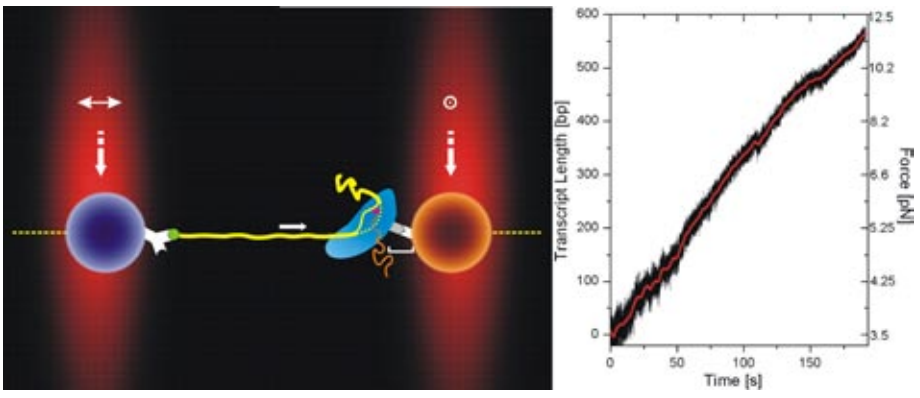
R. Pentcheva and W. E.Pickett: Avoiding the polarization catastrophe in $LaAlO_3$ overlayers on $SrTiO_3$ (001) through a polar distortion; Phys. Rev. Lett. 102, 107602 (2009)

http://www.krist.geo.uni-muenchen.de/ober/pentche.htm

TRANSCRIPTION OF RNA POLYMERASE II – FOLLOWING SINGLE ENZYMES IN REAL-TIME IN AN OPTICAL TWEEZERS ASSAY

Prof. Patrick Cramer and Prof. Jens Michaelis (LMU Munich)

Following the action of a single enzyme in real time is one of the great achievements of novel single-molecule techniques. Using high-resolution optical tweezers to immobilize and mechanically manipulate DNA protein complexes, the Michaelis group has shown that the transcription of the eukaryotic RNA polymerase II complex is an inhomogeneous process. One important result of this collaboration with the Cramer laboratory is that the polymerase can synthesize the new RNA molecule from the DNA template against an external mechanical force (almost) without loss of speed, thus constituting a powerful molecular motor. Moreover, phases of active transcription are interrupted by pauses of the polymerase and sometimes even retrograde movement is observed. Implications for such a backtracking behavior of the enzyme can be found in various aspects of gene expression, where control of expression rates of certain genes is essential. Thus, the successful implementation of a real-time single molecule assay for eukaryotic transcription is only the first step towards the mechanistic understanding of gene expression control in eukaryotes. ➤



Schematic of an optical tweezers assay used for the real time observation of the transcription of DNA into RNA by a eukaryotic RNA polymerase (left). The observed data shows phases of rapid elongation which are interrupted by pauses of the enzyme (right).

J. Michaelis, A. Muschielok, J. Andrecka, W. Kügel, J. Moffitt: DNA based molecular motors; Physics of Life Reviews 6, 250-266 (2009)

Cramer: http://www.lmb.uni-muenchen.de/cramer/

Michaelis: http://www.cup.uni-muenchen.de/pc/michaelis/

SUPERRESOLUTION IMAGING WITH ORDINARY FLUORESCENT DYES

Prof. Philip Tinnefeld (LMU Munich)
Dr. Thorben Cordes (LMU Munich, now at the University of Oxford)

In recent years, it has been realized that breaking the diffraction limit in fluorescence microscopy requires fluorescent dyes that can be switched between a fluorescent and a non-fluorescent state. Photochromic compounds, however, often show complex photophysics and are not very photostable. In this work, researchers from the Tinnefeld group have managed to switch the fluorescence of ordinary fluorescent dyes exploiting a generic dark state exhibited by all fluorophores, that is, a radical anion state. Selecting fluorescent dyes with high electron affinity, single fluorophores could be switched on and off by adapting the environmental conditions: reducing to switch off and oxidizing to switch on. These off-states were then used for superresolution imaging of actin filaments on glass slides and within cells. Therefore, the environment was adapted with a mixture of reductants and oxidants in order to induce blinking. This blinking shelved the largest fraction of dyes into the off-state so that the remaining fraction was spaced sparse enough that diffraction limited single-molecule emission did not overlay in the camera image. The single-molecule spots were then fitted with a Gaussian function to localize the molecule with a precision of ~20 nm. Measuring the positions of all molecules over time then allowed reconstruction of superresolution images with this so-called Blink-Microscopy. ➤

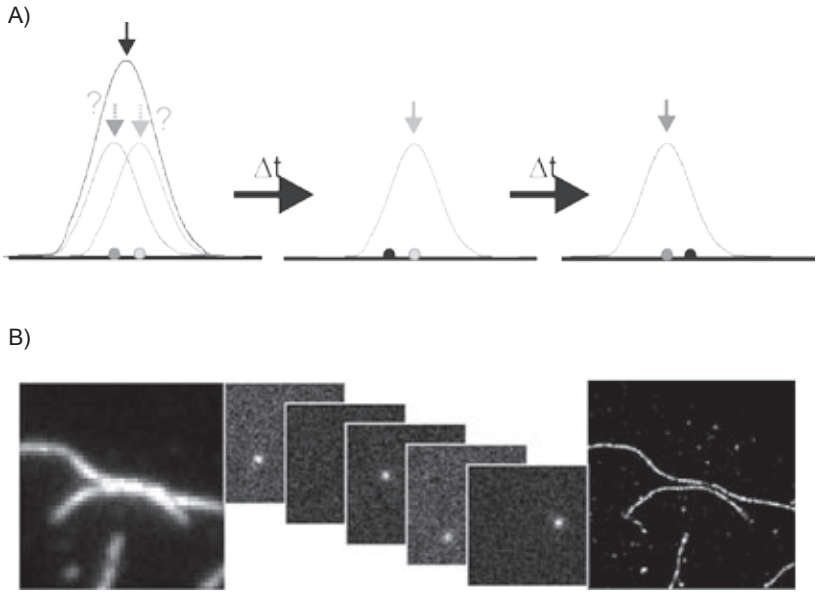


Figure 1. A) Scheme of fluorescence nanoscopy using stochastic switching and localization of single-molecule fluorescence. B) Example of resolution enhancement with Blink Microscopy: Diffraction limited image of actin filaments immobilized on a glass slide (left), some frames from a time series that show single molecule emission (center) and the resulting superresolution image (right).

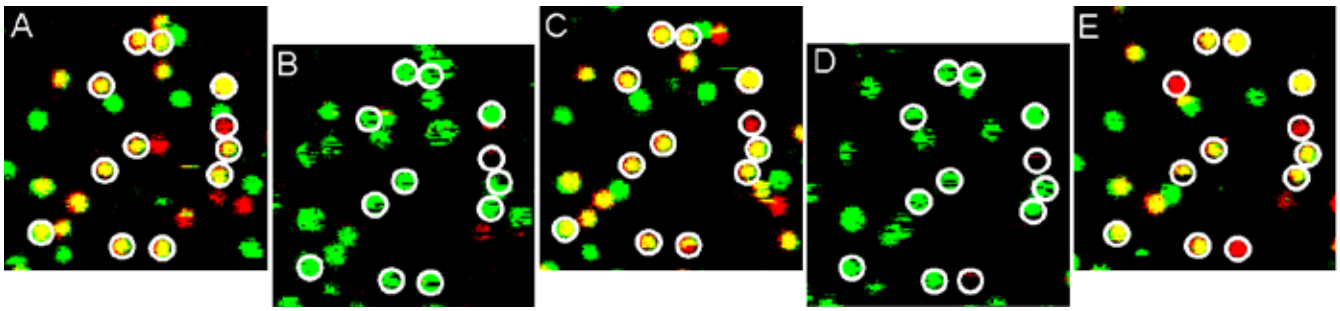


Figure 2. Fluorescence images of single-molecules on a glass slide. Red spots represent the oxazine ATTO655 exhibiting a high electron affinity. The green dye Cy3B was also attached to identify the same areas on the surface when ATTO655 was in the reduced off-state (B,D). Yellow spots represent colocalization of both dyes in the false-color image. The conditions were alternated between ordinary phosphate buffer (A, C, E) and reducing buffer (with ascorbic acid, oxygen removed) (B,D). The red dyes were transiently switched off into a metastabile reduced state.

J. Vogelsang, T. Cordes, C. Steinhauer, C. Forthmann, P. Tinnefeld: Controlling the Fluorescence of Ordinary Oxazine Dyes for Single-Molecule Switching and Superresolution Microscopy; Proc. Natl. Acad. Sci. USA 106, 8107 (2009)

Tinnefeld: *http://www.biophysik.physik.uni-muenchen.de/lsgaubstaff/philiptinnefeld*

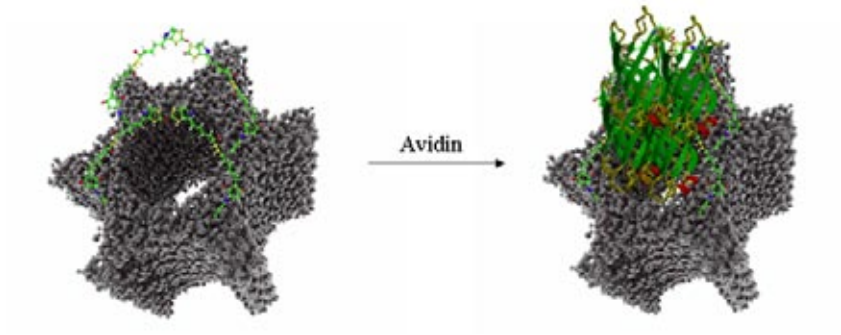
Cordes: *http://www.physics.ox.ac.uk/users/cordes/*

BIOTIN-AVIDIN AS A PROTEASE-RESPONSIVE CAP SYSTEM FOR CONTROLLED GUEST RELEASE FROM COLLOIDAL MESOPOROUS SILICA

Prof. Thomas Bein (LMU Munich)

Nanoporous capsules of silica are exceptionally suitable for encapsulating medicinal drugs, additives in detergents or other active ingredients. These substances can be stored very stably in tiny channels of a few nanometers in diameter. The objective is to release them at the desired place of destination or under certain conditions, for instance, by the addition of chemical substances or by a change in temperature. For this purpose, the capsules must first be closed off tightly. However, the materials primarily used previously for this purpose, such as cadmium sulfide, are either unstable or poisonous in a biological environment. They are therefore not suitable for storing active medicinal ingredients or detergent additives.

Prof. Thomas Bein and his coworkers at the chair of Physical Chemistry II have now found a promising solution for this problem. For closing the capsules, they use a combination of biotin, that is vitamin B_7, and avidin, a natural "adhesive" for biotin molecules. Both materials are safe from a health point of view and, at the same time, make it possible to close off the nanocapsules securely. The active ingredients stored may be released, for example, by the addition of trypsin, which is a mixture of human digestive enzymes. The trypsin decomposes the avidin and, in doing so, opens the capsule, so that the encapsulated active ingredient is released. This work opens the door for developing related systems whose functionality can be adapted to specific applications, such as controlled release of drugs in cells. ➤



The picture shows the closure of a biotin-decorated mesopore with a large avidin molecule.

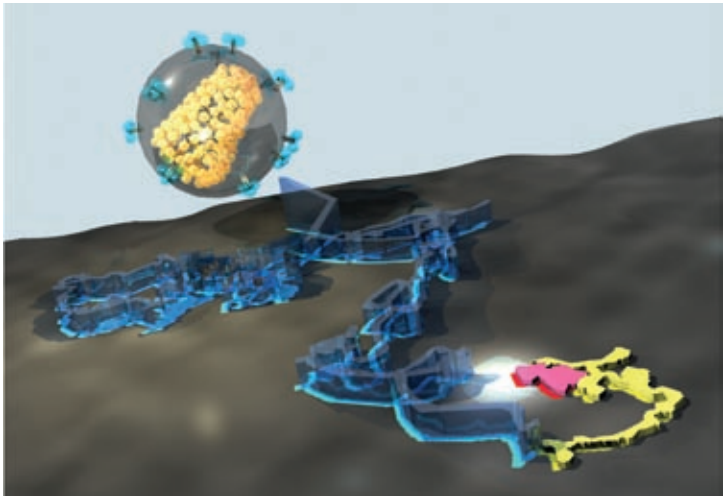
A. Schlossbauer, J. Kecht, T. Bein, Biotin-Avidin as a Protease-Responsive Cap System for Controlled Guest Release from Colloidal Mesoporous Silica, Angewandte Chemie, International Edition 48, 3092 (2009)

Bein: *http://bein.cup.uni-muenchen.de/index.php*

FORMATION OF HIV-1 VIRUSES IN AN INFECTED CELL: DYNAMICS, ASSEMBLY AND RELEASE

Prof. Christoph Bräuchle and Prof. Don C. Lamb (LMU Munich)

Assembly and release of the human immunodeficiency virus (HIV) occur at the plasma membrane of infected cells and are driven by the Gag polyprotein. Using a combination of wide-field and total internal reflection fluorescence microscopy, we have investigated the assembly and release of fluorescently labelled HIV-1 at the plasma membrane of living cells with high time resolution. Gag assembled into discrete clusters corresponding to single virions. Assembly kinetics were rapid, corresponding to 8 – 9 min for 90% completion of assembly for a single virion. Release of extracellular particles was observed at ~ 1,500 ± 700 s after the onset of assembly. This is the first time that the formation kinetics of new viruses (HIV) in an infected cell has been observed. ➤



Using a combination of total internal reflection fluorescence microscopy and wide-field imaging on live cells (grey ground), the assembly of individual fluorescently labelled HIV particles were followed from initiation to release. The trajectory is shown in three-dimensions going from red to yellow to blue depending on the phase of assembly processes. Assembly occurs on the time scale of approximately 30 min.

S. Ivanchenko, W. J. Godinez, M. Lampe, H.-G. Kräusslich, R. Eils, K. Rohr, C. Bräuchle, B. Müller, D. C. Lamb: Dynamics of HIV-1 Assembly and Release; PLoS Pathogens 5(11), e1000652 (2009)

Bräuchle: *http://www.cup.uni-muenchen.de/pc/braeuchle/index.html*

Lamb: *http://www.cup.uni-muenchen.de/pc/lamb/index.html*

DYNAMIC PATTERNS IN A SUPPORTED LIPID BILAYER DRIVEN BY STANDING SURFACE ACOUSTIC WAVES

Prof. Achim Wixforth (University of Augsburg)
Prof. Joachim O. Rädler (LMU Munich)
Prof. Matthias F. Schneider (University of Augsburg, now at Boston University)

In the past decades supported lipid bilayers (SLBs) have been an important tool in order to study the physical properties of biological membranes and cells. So far, controlled manipulation of SLBs is very limited. In this project a new technology has been developed to create lateral patterns in lipid membranes controllable in both space and time which then are used to manipulate membrane-bound macromolecules. Surface acoustic waves (SAWs) generate lateral standing waves on a piezoelectric substrate which create local ''traps'' in the lipid bilayer and lead to a lateral modulation in lipid concentration. It was demonstrated that pattern formation is reversible and does not affect the integrity of the lipid bilayer as shown by extracting the diffusion constant of fluid membranes. As certain lipids are capable of specifically binding other macromolecules (e.g. proteins or DNA), the lipid demixing can directly be used for the creation of controlled dynamical macromolecule patterns. Applying beating waves, membrane-bound proteins and DNA can be patterned and transported in 2D, forming a "molecular band conveyor". As different lipids and their bound proteins interact in different ways with the applied wave – actually there are "high density seekers" preferring antinodes of the wave and "low density seekers" found in the nodes – this method can even be used for separating membrane bound proteins. This chip is capable of manipulating and measuring at the same time since the surface acoustic wave chips are sensitive to mass changes, comparable to quartz crystal microbalances.

As this approach is kept highly modular with flexible protein-membrane anchor systems, it is not limited to membrane-bound macromolecules like receptors, peripheral proteins or ion channels but can easily be extended to viruses, bacteria or entire cells bound to a support. Even spreading entire native biomembranes (like erythrocyte ghosts) followed by separation, accumulation or purification of macromolecules ("2D electrophoresis") can be realized. In particular when combined with other planar lab-on-a-chip technologies, one envisions an entire "Flatland Factory" with single molecule conveyer belts, assembly lines and acoustically driven microfluidics for applications such as blood screening or protein and DNA analysis. ➤

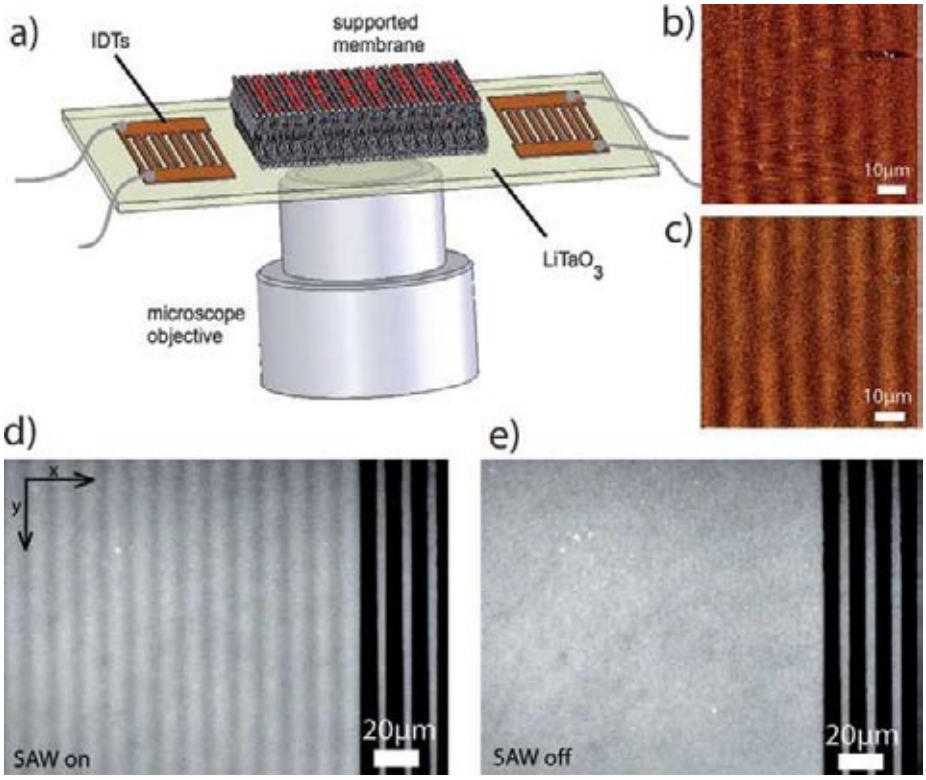


Fig. 1 a) Diagram showing the experimental setup, including the piezoelectric chip and the inverted microscope. The interdigital transducers excite a standing SAW, which induces lateral demixing of the supported lipid membrane. b) Shear waves visualized by AFM under water in lateral deflection mode. The pattern periodicity is half of the wavelength of the SAW (13.3 mm). c) AFM-image of shear SAWs in air. d) Typical micrograph of a fluorescently-labelled demixed membrane after the SAW has been switched on. The membrane pattern correlates with the periodicity of the IDTs (black stripes on the right side). e) When the SAW is switched off, the dye relaxes within seconds into its equilibrium distribution.

M. Hennig, J. Neumann, A. Wixforth, J. O. Rädler and M. F. Schneider: Dynamic patterns in a supported lipid bilayer driven by standing surfaceacoustic waves; Lab Chip 9, 3050 (2009)

Wixforth: *http://www.physik.uni-augsburg.de/exp1/wixforth/wixforth.html*

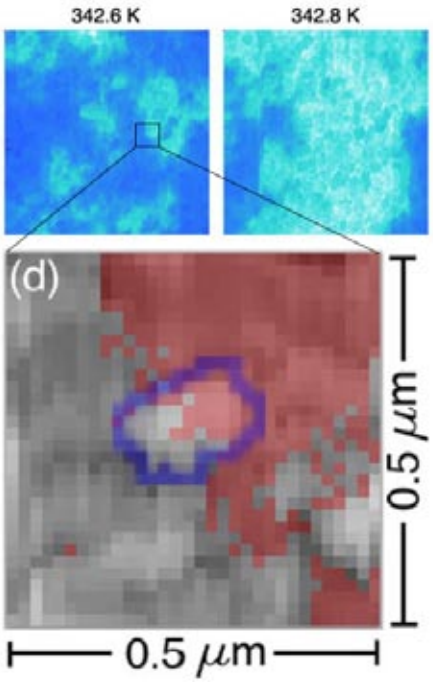
Rädler: *http://softmatter.physik.lmu.de/tiki-index.php*

Schneider: *http://www.bu.edu/me/people/faculty/pz/schneider/*

PHASE COEXISTENCE AT THE NANOSCALE

Dr. Fritz Keilmann (Max-Planck-Institute of Quantum Optics, Garching)

The infrared near-field microscope has revealed that nanometric-sized single crystals may support two differnt electronic phases at the same time. The observation was made with a polycrystalline film of VO_2 slowly heated through the insulator-to-metal phase transition (IMT) near 342 K. Metal regions were identified from the infrared signal, and overlaid (in red) with the topography image. Signal processing in the latter had served to identify the grain boundaries, one of them depicted in the shown image (in magenta). A single crystalline grain is expected to contain few defects. Therefore, phase coexistence in a grain reveals the true first-order nature of the IMT arising from competing electronic phases. Further statistical analysis proves in addition that the IMT begins within 10 nm from grain boundaries and crevices, suggesting that also extrinsic local inhomogeneities in electronic structure and/or strain fields can serve as nucleation sites for the metallic instability. Generally, the combination of infrared signature and topography offers a powerful insight in real-space inhomogeneity at the nanoscale that is expected with many solid-state physics issues. ➤



Infrared nanoscopy of a phase transition in progress: the near-field microscope at 10 μm wavelength recorded high intensity (turquoise color) where the polycrystalline VO_2 had turned metallic, a transition driven by rising temperature. Surprisingly, the borderline between metal and insulator can go right through a 150 nm sized crystal demonstrating intra-grain phase coexistence.

M. M. Qazilbash, M. Brehm, G. O. Andreev, A. Frenzel, P. C. Ho, B. G. Chae, B. J. Kim, S. J. Yun, H. T. Kim, A. V. Balatsky, O. G. Shpyrko, M. B. Maple, F. Keilmann, and D. N. Basov: Infrared spectroscopy and nano-imaging of the insulator-to-metal transition in vanadium dioxide; Phys. Rev. B 79, 075107 (2009)

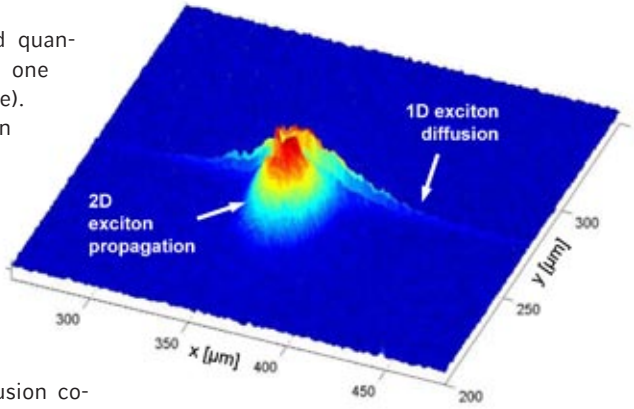
A. Frenzel, M. M. Qazilbash, M. Brehm, B.-G. Chae, B.-J. Kim, H.-T. Kim, A. V. Balatsky, F. Keilmann, and D. N. Basov: Inhomogeneous electronic state near the insulator-to-metal transition in the correlated oxide VO_2; Phys. Rev. B 80, 115115 (2009)

Keilmann: *www.attoworld.de/sharedPages/People/KeilmannFritz/KeilmannFritz.html*

DYNAMICS OF INDIRECT EXCITONS IN LOW-DIMENSIONAL POTENTIAL LANDSCAPES

Prof. Jörg P. Kotthaus (LMU Munich)
Prof. Alexander W. Holleitner (TU Munich)

Photogenerated electron-hole pairs in double quantum well devices can be manipulated both in lifetime and position via a mesoscopic voltage-controlled electrostatic landscape (A. Gärtner *et al.*, APL 89, 052108). The quantum-confined Stark effect allows us to create long-living indirect excitons with a microsecond-lifetime. Recently, we demonstrated a novel electrostatic trap for indirect excitons in coupled GaAs quantum wells embedded in a field-effect device (A. Gärtner *et al.*, PRB 76, 085304). There, the indirect excitons are trapped in the quantum wells just below the perimeter of SiO_2-layers, which are sandwiched between the surface of the GaAs heterostructure and a semitransparent metallic top gate. In a recent study, we investigated the lateral expansion of dipolar excitons in coupled quantum wells in two (2D) and one (1D) dimensions (see Figure). In 2D, the exciton expansion obeys nonlinear temporal dynamics due to the repulsive dipole pressure at a high exciton density. In contrast, the observed 1D expansion behaves linearly in time even at high exciton densities. The corresponding 1D diffusion coefficient exceeds the one in 2D by far and depends linearly on the exciton density. The findings are attributed to screening of quantum well disorder by the dipolar excitons in one dimension. ➤



Spatial distribution of the photoluminescence of indirect excitons in a two-dimensional (2D) and one-dimensional potential landscape in a GaAs-based heterostructure at 6 K.

X. P. Vögele, D. Schuh, W. Wegscheider, J. P. Kotthaus, and A. W. Holleitner: Density Enhanced Diffusion of Dipolar Excitons within a One-Dimensional Channel, Phys. Rev. Lett. 103, 126402 (2009)

Kotthaus: *http://www.nano.physik.uni-muenchen.de/*

Holleitner: *http://www.wsi.tum.de/Research/HolleitnergroupE24/tabid/166/Default.aspx*

DYNAMICS OF STIFF BIOPOLYMERS IN A DISORDERED ENVIRONMENT

Prof. Thomas Franosch (LMU Munich, now at the University of Erlangen)
Prof. Erwin Frey (LMU Munich)

Brownian motion of highly anisotropic particles is considerably more complex than the diffusion of spherical objects, the basic understanding of which is founded on the seminal works by Einstein and Smoluchowski. A shape anisotropy results in diffusion coefficients that depends on the direction of motion in the body frame, thus inducing a coupling of translation to the orientation. Already on the level of a single anisotropic body a solution for the probability distribution for the displacements and reorientation has been lacking so far. Even less is known for strongly interacting suspensions of anisotropic particles of large aspect ratio.

In this project we have investigated the dynamics of slender rods in concentrated solution. Such suspensions constitute a widely used model system with rich dynamics: transport slows down drastically and the anisotropy of the motion becomes arbitrarily large. We have developed a mesoscopic description of the dynamics down to the length scale of the interparticle distance. The theory is based on the exact solution of the Smoluchowski-Perrin equation; it is in quantitative agreement with extensive Brownian dynamics simulations in the dense regime. In particular, it is shown that the tube confinement is characterized by power law decay of the intermediate scattering function with exponent ½. ➤

T. Munk, F. Höfling, E. Frey, T. Franosch: Effective Perrin Theory for the anisotropic diffusion of a strongly hindered rod; EPL 85 (2009) 30003

Franosch: *http://www.theorie1.physik.uni-erlangen.de/people/thfran/*

Frey: *www.theorie.physik.uni-muenchen.de/lsfrey/*

FUNCTIONALIZATION OF SELF-ASSEMBLED MONOLAYERS AND SURFACE TEMPLATES BY SURFACE REACTIONS

Prof. Ulrich S. Schubert (Friedrich-Schiller-Universität Jena & Eindhoven University of Technology)

The functionalization of surfaces can be performed by means of self-assembled monolayers. Readily available precursor molecules can be used to tailor the properties of surfaces or to introduce potential binding sites into the system. Therefore, two major strategies can be applied; the synthesis of suitable functional precursors, or the chemical modification of reactive monolayer systems can be pursued. The latter approach has advantages, as well ordering systems can be chosen that provide a maximum density of functional groups. This approach was investigated in a number of studies by using nucleophilic substitution reactions and click-chemistry approaches to tailor the chemical nature of 11-undecyltrichlorosilane monolayers. A consecutive chain of knowledge was developed that allowed the chemical functionalization of silicon and glass substrates and different functional groups could be implemented. These attached functionalities span the range of fluorescent dye molecules, small molecules, polymers and supramolecular binding motifs. Detailed studies, revealing the influence of steric hindrance as well as co-adsorption of different molecules was tested. The introduction of supramolecular binding units resulted in switchable surfaces that could reversibly be opened and closed by external triggers. Additional investigations of the reaction kinetics and the use of microwave synthesis strategies led to the implementation of surface reactions that can be performed in very short time scales.

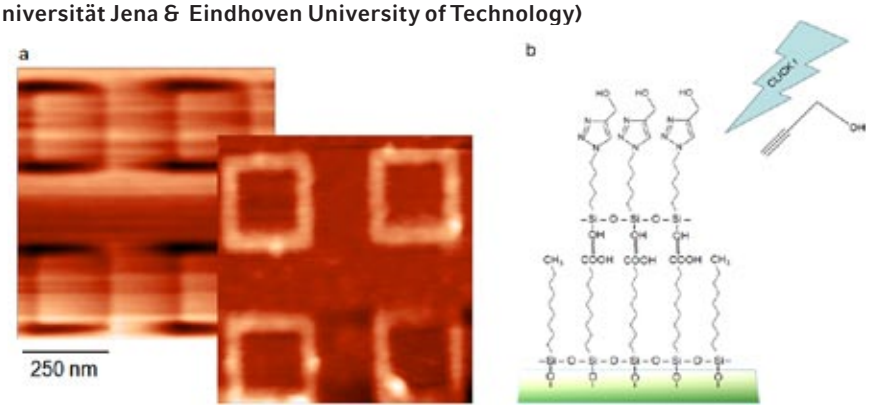


Figure 1: Click-chemistry on nanometer confined surface templates. a) Squares consisting of 50 nm lines have been inscribed into a self-assembled monolayer by means of electrochemical oxidation lithography (background) and structures were modified by click chemistry (front). Propargyl alcohol molecules were self-assembled on the template structures. b) Schematic representation of a cross section of the structure.

Based on these chemical surface reactions the approach could also be used to demonstrate the selective functionalization of surface templates that have been fabricated by means of electrochemical oxidation lithography of a base n-octadecyltrichlorosilane monolayer. The findings of these studies provide a platform to functionalize entire surfaces and nanometer surface templates as well as to introduce a large variety of chemical functions. ➤

C. Haensch, S. Hoeppener, U. S. Schubert: Clicking on the Nanoscale: 1,3-Dipolar Cycloaddition of Terminal Acetylenes on Azide Functionalized, Nanometric Surface Templates with Nanometer Resolution; Nanotechnology 20, 135302 (2009)

Schubert: *http://www.schubert-group.com/*

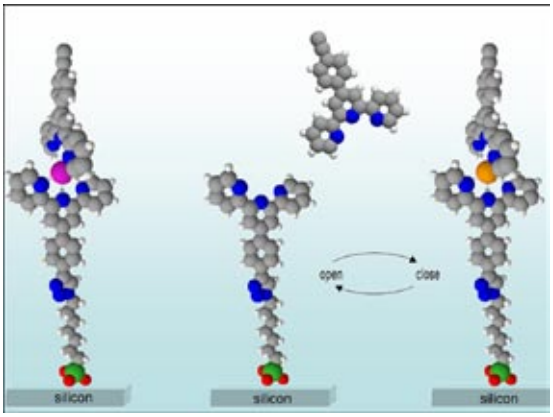


Figure 2: Reversible functionalization of surfaces by means of supramolecular binding motifs.

UNIVERSAL TRANSDUCTION SCHEME FOR NANOMECHANICAL SYSTEMS BASED ON DIELECTRIC FORCES

Dr. Eva Maria Weig and Prof. Jörg P. Kotthaus (LMU Munich)

Dielectric forces have been known to act on polarizable materials subject to electric field gradients for a long time. This phenomenon – well known from the macroscopic world, since it allows e.g. a charged object to bend a thin water jet – is technologically employed to manipulate small particles. Examples range from optical tweezers, where the trapping force is controlled via the intensity of a laser beam, to dielectrophoresis, where electric fields are employed to control the motion of particles suspended in a liquid.

Now, this simple concept of dielectric forces has been adopted for the surprisingly efficient transduction of nanomechanical systems. To this end, the electric gradient field is created electrically by two suitably biased gold electrodes placed nearby the mechanical resonator as indicated in Fig. 1. A key feature of the presented scheme is that the mechanical element is thereby not modified; in particular no metal has to be deposited on top of the resonator.

Applying a DC voltage to the electrodes influences a dipolar moment within the resonator, such that an additional RF voltage modulates the attractive force, thus causing resonant motion of the mechanical oscillator (Fig. 2). The actuation shows to be very effective; e.g. one can achieve forces that are a factor of 10^6 larger than the weight of the element.

Dielectric actuation can be applied to any material and works over a wide range of actuation frequencies. The fact that the resonator moves in a gradient force field allows for simple voltage tuning of its resonance frequency, as seen in Fig. 2c. Even more, the capacitive influence of the moving resonator on the gold electrodes can be used to detect the resonant motion, allowing for all-integrated transduction of nanomechanical systems. ➤

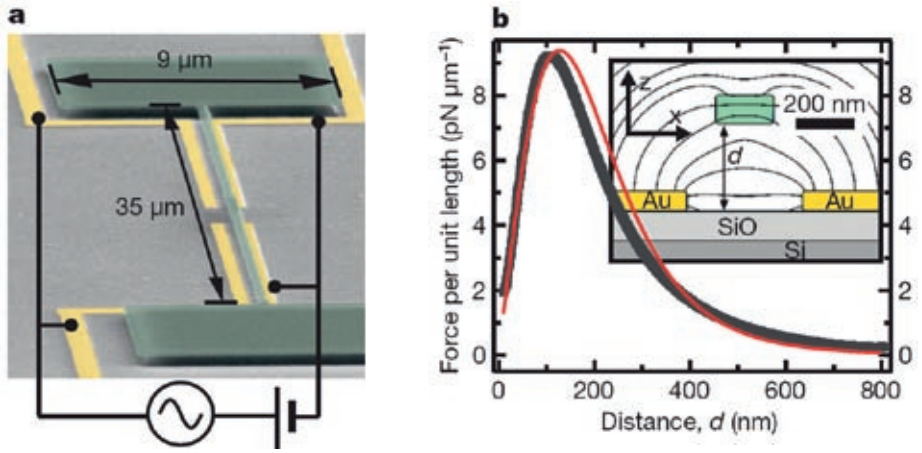


Figure 1: a) Scanning electron micrograph of a representative device. A high-stress silicon nitride film (green) forms the suspended doubly clamped beam and its supports. The four nearby gold electrodes (yellow) are connected to both a DC and an RF voltage source used to polarize and resonantly excite the beam. b, Electrostatic force per unit length in the z direction, perpendicular to the sample plane, versus vertical distance d from the electrodes. The inset depicts a cross-section of the device and shows the electric field lines.

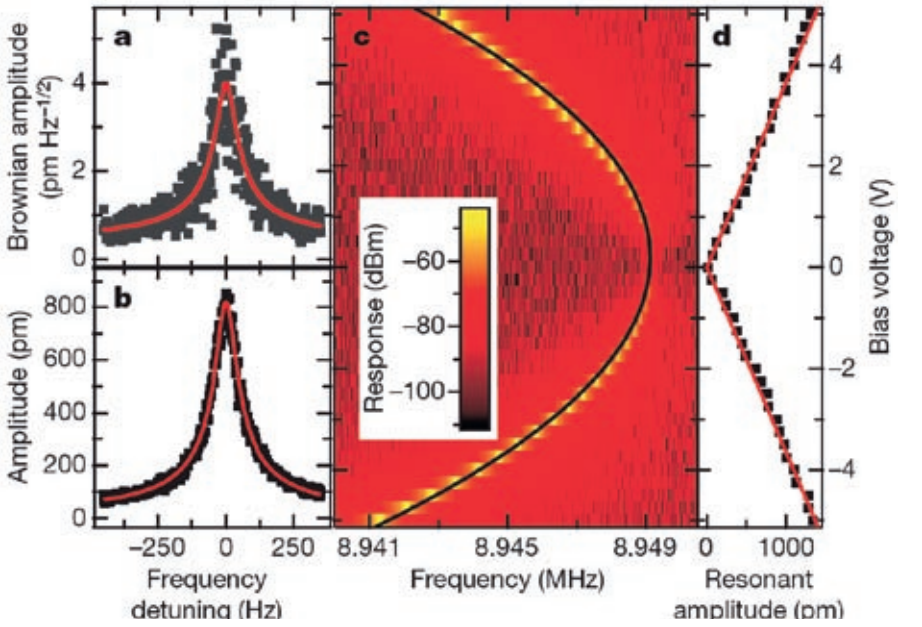


Figure 2: Response of a thermally or dielectrically actuated nanomechanical resonator at room temperature. a) Brownian motion without RF excitation which is employed to convert the measured signal into a vibration amplitude. b) Dielectrically driven oscillation with $V_{DC} = 1$ V and $V_{RF} = 0.2$ mV. c) and d) Response of the resonator as a function of frequency and DC bias voltage at $V_{RF} = 0.06$ mV. The resonance frequency in c) decreases quadratically with V_{DC}, while the resonant amplitude plotted in d) depends linearly on the DC bias voltage.

Q. P. Unterreithmeier, E. M. Weig, J. P. Kotthaus: Universal transduction scheme for nanomechanical systems based on dielectric forces; Nature 458, 1001 (2009)

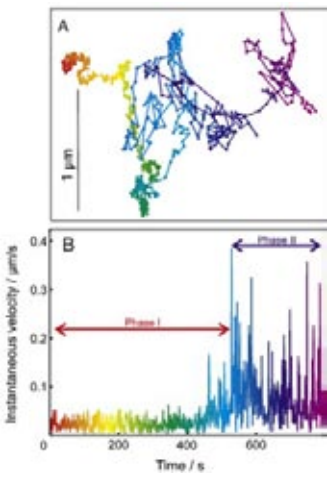
Weig: *http://www.nano.physik.uni-muenchen.de/nanomech/*

Kotthaus: *http://www.nano.physik.uni-muenchen.de/*

DYNAMICS OF MAGNETIC LIPOPLEXES STUDIED BY SINGLE PARTICLE TRACKING IN LIVING CELLS

Priv.-Doz. Dr. Christian Plank (TU Munich & University Hospital Rechts der Isar)
Prof. Christoph Bräuchle (LMU Munich)

Exhibiting novel and often surprising properties, nanoparticles are finding their way into an endless stream of equally innovative products. In medical therapies, for example, tiny nanovehicles could one day ferry drugs or even genes into cells. So far, the only way of testing these approaches has been to wait for the desired effect to show – the activation of a transported gene inside a cell for example. Under the direction of physico-chemist Prof. Christoph Bräuchle, a research group cooperating with Dr. Christian Plank has now used a highly sensitive microscopic technique to pursue individual nanoparticles as they make their way into target cells – in real-time and at high spatial and temporal resolution. They tested magnetic nanoparticles that could be used, among other things, in cancer therapy. This approach should also allow a better understanding of existing nanovectors as well as the development of new systems, as reported in the cover story of the July 2009 issue of the "Journal of Controlled Release". ➤



A) Trajectory of a magnetic complex attached to a HuH7 cell. The color of the trajectory changes with progressing time from red to green to blue. Phase I was observed until t=529 s, phase II was observed afterwards. B) Instantaneous velocity plot of the trajectory shown in A). The color coding corresponds to the one used for the trajectory in A). During Phase I the particle is uptaken into the cell. In phase II it diffuses in the cytoplasma inside an endosome.

A. M. Sauer, K.G. de Bruin, N. Ruthardt, O. Mykhaylyk, C. Plank, C. Bräuchle: Dynamics of magnetic lipoplexes studied by single particle tracking in living cells; Journal of Controlled Release 137(2), 136-145 (2009)

Plank: *http://www.plank-lab.net/*

Bräuchle: *http://www.cup.uni-muenchen.de/pc/braeuchle/index.html*

CHAPERONE MECHANCIS

Prof. Thorsten Hugel (TU Munich)

The molecular chaperone heat-shock protein 90 (Hsp90) is one of the most abundant proteins in unstressed eukaryotic cells. Its function is dependent on an exceptionally slow ATPase reaction that involves large conformational changes. To observe these conformational changes and to understand their interplay with the ATPase function, a single-molecule assay that allows examination of yeast Hsp90 dimers in real time under various nucleotide conditions was developed. This allowed to detect conformational fluctuations between open and closed states on timescales much faster than the rate of ATP hydrolysis. The compiled distributions of dwell times allow us to assign all rate constants to a minimal kinetic model for the conformational changes of Hsp90 and to delineate the influence of ATP hydrolysis. Unexpectedly, in this model ATP lowers two energy barriers almost symmetrically, such that little directionality is introduced. Instead, stochastic, thermal fluctuations of Hsp90 are the dominating processes. ➤

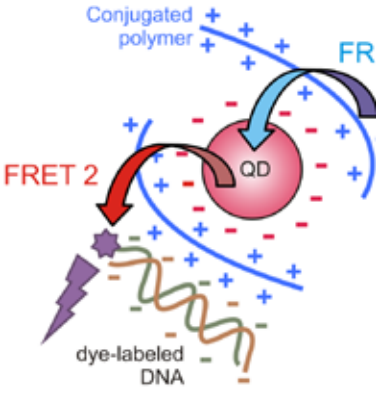
M. Mickler, M. Hessling, C. Ratzke, J. Buchner, T. Hugel: The large conformational changes of Hsp90 are only weakly coupled to ATP-hydrolysis; Nature Structural and Molecular Biology 16, 281 (2009)

http://cell.e22.physik.tu-muenchen.de/Hugel/

CASCADED FRET IN CONJUGATED POLYMER/QUANTUM DOT/DYE-LABELED DNA COMPLEXES FOR DNA HYBRIDIZATION DETECTION

Prof. Andrey Rogach (LMU Munich, now at City University of Hong Kong)
Prof. Jochen Feldmann (LMU Munich)

Water-soluble complexes of fluorescent conjugated polymer PDFD and CdTe quantum dots (QDs) have been specifically designed to provide a cascaded FRET for DNA hybridization detection. PDFD had two functions in the detection scheme: as a light harvesting antenna it enhanced the emission of QDs by the first level FRET, and inverted the sign of the surface charge of QDs thus providing a positively charged surface to allow negatively charged dye-labeled DNA to interact with the resulting complex. This interaction caused the second level FRET to infrared-emitting dye labelled on the probe DNA, providing a reliable signal-on sensing platform discriminating between complementary and non-complementary DNA. A detailed spectroscopic study offered a clear description of photophysical processes in the designed polymer/QD/DNA complex, providing an ample potential for further sensitivity and selectivity improvements. ➤



Polymer/QD/dye-labeled DNA complex used to detect DNA hybridization through a cascaded double FRET. Upon optical excitation of the polymer and QDs, energy transfer takes place from the polymer to the QDs (FRET 1) and from the QDs to the dye-labeled DNA (FRET 2).

G. Jiang, A. S. Susha, A. A. Lutich, F. D. Stefani, J. Feldmann, A. L. Rogach: Cascaded FRET in Conjugated Polymer/Quantum Dot/Dye-labeled DNA Complexes for DNA Hybridization Detection; ACS NANO 3, 4127 (2009)

Feldmann: *www.phog.physik.uni-muenchen.de*

Rogach: *www.ap.cityu.edu.hk/personal-website/webpage Rogach with photo.htm*

NEAR-FIELD CAVITY OPTOMECHANICS WITH NANOMECHANICAL RESONATORS

Dr. Eva Maria Weig and Prof. Jörg P. Kotthaus (LMU Munich)

Since Kepler's observation of comet tails in the 17th century, the radiation pressure of light has been known to exert a measurable force on matter. In the 20th century, it has been realized that the resulting optomechanical effects are strongly enhanced by a high finesse optical cavity, as it is e.g. the case in gravitational wave interferometers. The same physics applies to nanoscale mechanical resonators, which, due to their tiny mass, react strongly to light-induced back-action. In particular, large optomechanical coupling occurs when combining a high finesse optical cavity with a high Q mechanical nanoresonator. A generic example of such a system has been demonstrated in a collaborative study between the CeNS groups of Eva-Maria Weig and Jörg P. Kotthaus and the group of Tobias Kippenberg at the MPQ Garching using a hybrid approach: A silica microtoroid sustaining whispering gallery modes with optical finesses exceeding 200,000 is coupled to a high Q nanomechanical resonator realized by a doubly clamped high stress silicon nitride string.

Upon approaching the two systems, the resonator enters the evanescent field of the cavity, which gives rise to a pronounced cavity frequency shift while leaving the cavity linewidth unaffected (Fig. 1). This indicates purely dispersive optomechanical coupling, which can be employed to map out the Brownian position fluctuations of the resonator via the optical cavity transmission (Fig. 2). Due to the high Q and small mass of the nanomechanical resonator, as well as the large cavity finesse, a displacement sensitivity of 580 am/√Hz is achieved, which is below the resonator's expected zero-point fluctuations of 820 am/√Hz. Apart from the first demonstration of quantum-limited displacement sensing of a nanomechanical resonator, dynamical back-action mediated by the optical dipole force has been observed, leading to laser-like coherent nanomechanical oscillations. Even more, the cavity-enhanced radiation-pressure coupling between optical and mechanical degrees of freedom should allow for optomechanical cooling of the mechanical resonator, thereby approaching its quantum ground state. ➤

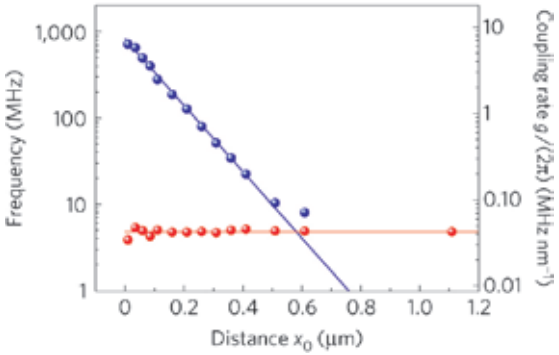


Figure 1: Negative optical frequency shift (blue) and linewidth (red) of a 58 μm diameter microtoroid cavity as a function of the distance to a doubly clamped silicon nitride string with dimensions of 110 nm x 800 nm x 25 μm. The data reveal purely dispersive coupling without introducing a measurable degradation of the microcavity's optical decay rate.

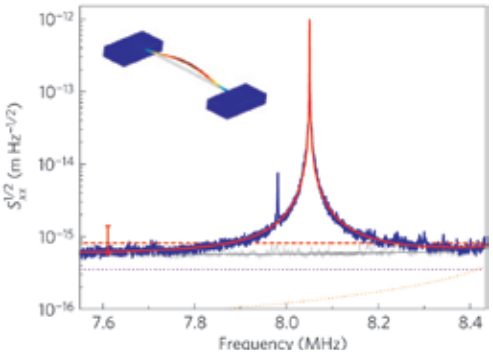


Figure 2: Room-temperature Brownian noise of the nanomechanical resonator with a fundamental resonance frequency of 8 MHz (inset). For an optical input power of 65 μW, the displacement imprecision reaches a value of 570 am/√Hz (grey line), which is 0.7 times the standard quantum limit, that is, the oscillator's expected zero-point fluctuations (red dashed line).

G. Anetsberger, O. Arcizet, Q. P. Unterreithmeier, R. Rivière, A. Schliesser, E. M. Weig, J. P. Kotthaus, T. J. Kippenberg: Near-field cavity optomechanics with nanomechanical oscillators; Nature Physics 5, 909 (2009)

Weig: *http://www.nano.physik.uni-muenchen.de/nanomech/*

Kotthaus: *http://www.nano.physik.uni-muenchen.de/*

FORCE SENSING MOLECULES AS NANO REPORTER FOR MOLECULAR EVENTS

Prof. Hermann E. Gaub (LMU Munich)

Force-based ligand detection is a promising method to characterize molecular complexes label-free at physiological conditions. Because conventional implementations of this technique, e.g., based on atomic force microscopy or optical traps, are low-throughput and require extremely sensitive and sophisticated equipment, this approach has to date found only limited application. A low-cost, chip-based assay which combines high-throughput force-based detection of DNA ligand interactions with the ease of fluorescence detection was invented here recently. Within a comparative unbinding force assay, many duplicates of a target DNA duplex are probed against a defined reference DNA duplex each. The fractions of broken target and reference DNA duplexes are determined via fluorescence. With this assay, we investigated the DNA binding behavior of various molecules known to interact with DNA. In particular, we demonstrated that artificial pyrrole-imidazole polyamides distinguish between D- and L-DNA and quantified the interaction of adenosine with its aptamer. These findings are in good agreement with single molecule force spectroscopy experiments. ➤

D. Ho, J. L. Zimmermann, F. A. Dehmelt, U. Steinbach, M. Erdmann, P. Severin, K. Falter, H. E. Gaub: Force-driven separation of short double-stranded DNA; Biophys J. 97, 3158 (2009)

D. Ho, C. Dose, C. H. Albrecht, P. Severin, K. Falter, P. B. Dervan, H. E. Gaub: Quantitative detection of small molecule/DNA complexes employing a force-based and label-free DNA-microarray; Biophys. J. 96, 4661 (2009)

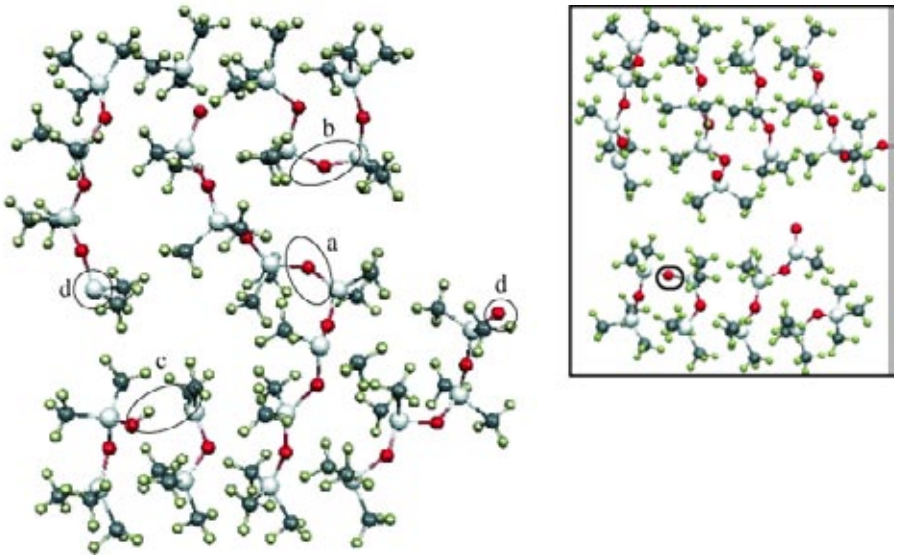
D. Ho, K. Falter, P. Severin, H. E. Gaub: DNA as a force sensor in an aptamer-based biochip for adenosine: Anal. Chem. 81, 3159 (2009)

Gaub: *http://www.biophysik.physik.uni-muenchen.de/*

ORIGINS OF MATERIAL FAILURE IN SILOXANE ELASTOMERS FROM FIRST PRINCIPLES

Prof. Christoph Bräuchle (LMU Munich)
Prof. Irmgard Frank (University of Hannover)

Siloxanes are versatile elastomers with an exceptional chemical and physical stability that allows them to be used as adhesives, coatings, and sealants in applications ranging from biomedical to aerospace. Although these materials are exceptionally strong, they are limited by the ease of propagation of cracks through the elastomer when subjected to tensile stress. Understanding these processes entails a full description of the electronic structure of a system during the process of bond rupture and the subsequent reactions between ruptured fragments to correctly determine the underlying chemistry. Information on the response of individual chemical bonds subjected to a tensile load is accessible via single-molecule atomic force microscopy (AFM) experiments, which can be interpreted with theoretical studies using Car–Parrinello molecular dynamics (CPMD) simulations. These CPMD studies provide valuable insights into the characteristics of bond rupture within single molecules, because a full electronic structure calculation is performed on the fly for a molecular dynamics trajectory, which allows a complete description of the stretching of an oligomer in the high-force regime. ➤



The products of the ruptured model system of siloxanes shown in detail with the final configuration of one of the simulations using the spin unrestricted BLYP functional in the inset (the reaction between neighboring fragments is highlighted). a) Two fragments react to form a siloxane oligomer with eight silicon atoms in the backbone. b) Two fragments react to cause a material break in the direction perpendicular to the applied force. c) Proton transfer occurs between fragments to neutralize the products. d) Two unreacted charged fragments.

E. M. Lupton, F. Achenbach, J. Weis, C. Bräuchle, I. Frank: Origins of Material Failure in Siloxane Elastomers from First Principles; ChemPhysChem 10, 119 (2009)

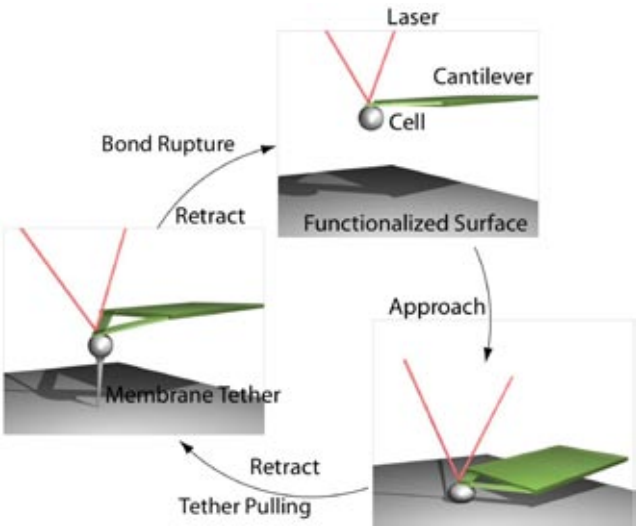
Bräuchle: *http://www.cup.uni-muenchen.de/pc/braeuchle/index.html*

Frank: *http://www.theochem.uni-hannover.de/gruppe/html/frank.html*

MECHANICAL INFLUENCES ON CELL ADHESION

Dr. Kay Gottschalk (LMU Munich, now at the University of Greifswald)

Cell adhesion and migration are fundamental processes in multicellular organisms. In these processes, cellular forces need to be transduced to the extracellular space or external forces are dissipated into the cell. This requires specialized receptors, which operate under force and form a clamp between intracellular structures and the extracellular matrix or other cells. One important class of these receptors are integrins. Integrins are bidirectional transmembrane signalling molecules and bidirectional transmembrane force-transducers. Working in a non-equilibrium environment, the mechanics of the integrins' nano-environment play a very important role in the force dissipation. We showed that the importance of the mechanical environment has a strong effect on adhesiveness. This effect equals the impact of affinity modulation. We furthermore extrapolated single molecular properties of integrins, measured by atomic force microscopy on living cells, to whole-cell behavior. This opens the way to a bottom-up, single-molecule based understanding of fundamental cellular processes. ➤



Principle of single-molecule measurements on living cells. A single cell is attached to an AFM cantilever and allowed to interact with a sparsely functionalized surface. The forces acting on the cantilever are measured by the deflection angle of a laser beam.

J. Schmitz, E. Manevich, M. Tschöpe, R. Alon, K. E. Gottschalk: Linking single integrin bond properties to cell adhesiveness at rapid contacts generated under external forces; Soft Matter, 5, 4141 (2009)

www.biophysik.physik.uni-muenchen.de/lsgaubstaff/kaygottschalk

http://www.hike-autoimmunity.de/content/de/home.aspx

DRUG NANOCARRIERS LABELED WITH NEAR-INFRARED EMITTING QUANTUM DOTS (QUANTOPLEXES): IMAGING FAST DYNAMICS OF DISTRIBUTION IN LIVING ANIMALS

Priv.-Doz. Dr. Manfred Ogris, Prof. Ernst Wagner and Prof. Jochen Feldmann (LMU Munich)
Prof. Andrey Rogach (LMU Munich, now at City University of Hong Kong)

Treatment of cancer with chemotherapeutic drugs is often accompanied by unwanted toxic side effects in healthy tissue and limited antitumoral activity. One major reason for this behavior can be explained with the distribution profile of the drug in the organism after its injection into the blood stream. Rapid elimination from the blood will prevent accumulation in the tumor and will lead to high concentrations of the drug in non target organs.

Macromolecular carrier systems are designed to direct their payload, like chemotherapeutics or therapeutic nucleic acids including DNA, into tumors. Knowing the distribution in the body of such intravenously injected carriers in the living organism in real time would be of great importance for the development of better tumor targeted formulation. In this study, near infrared emitting quantum dots (QDs) based on cadmium telluride were incorporated into virus sized synthetic gene carriers, forming so called quantoplexes. The QDs fluorescence in the near infrared allows tracing them in the living organism without being quenched by body tissues. After intravenous injection into mice rapid distribution events occurring within the first few minutes after injection could be monitored, like the redistribution of certain quantoplex formulations from lung to liver. Malignant tumors are often characterized by the formation of leaky blood vessels, which enable accumulation of macromolecular drugs circulating in the blood stream. When injected into tumor bearing animals, only quantoplexes shielded with the hydrophilic polymer PEG circulated in the blood stream for several minutes and were retained in the tumor tissue, whereas unmodified, positively charged quantoplexes aggregated in lung tissue without reaching the tumor. This system for real time near infrared imaging of quantoplexes now allows the development of various tumor targeted, macromolecular carrier systems by analyzing their distribution in the living organism in real time. ➤

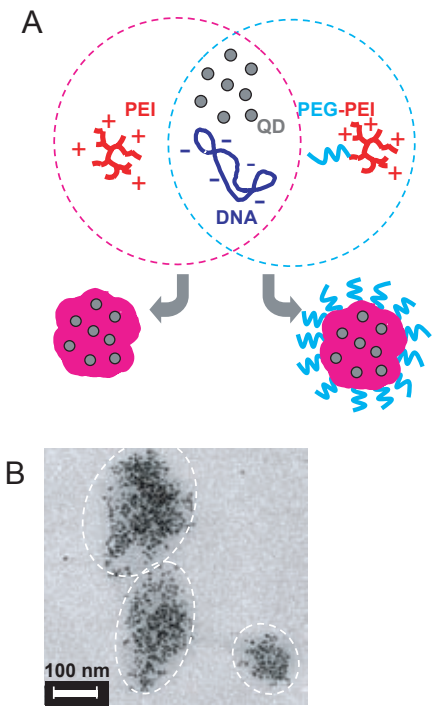


Fig 1: (A) Packing quantum dots into quantoplexes: Negatively charged near infrared emitting CdTe quantum dots interact (similar as plasmid DNA) with polycations like polyethylenimine (PEI) forming virus sized quantoplexes. Quantoplex formation with a conjugate of PEI and the hydrophilic polymer polyethyleneglycol (PEG) shields the particle from undesired interaction with blood components otherwise leading to rapid clearance from the bloodstream. (B) A transmission electron micrograph showing the 7 nm QDs incorporated into 200-300 nm quantoplexes appearing like raisins in a bun.

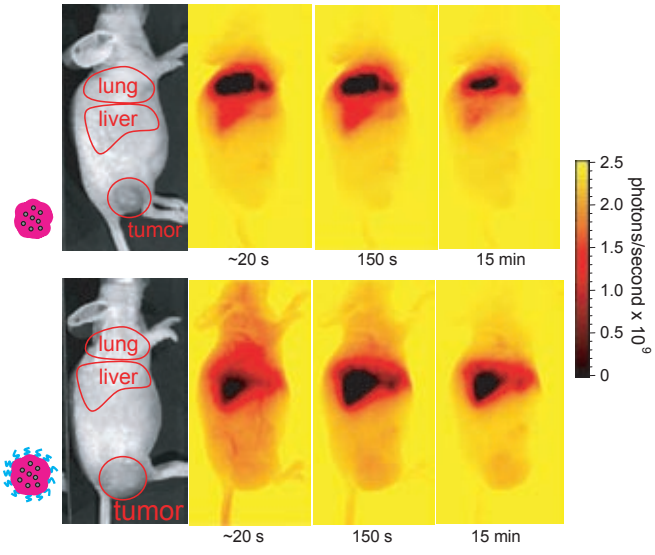


Fig 2: Quantoplexes intravenously injected into mice can be easily detected in the living animal with high temporal resolution. Without PEG shield they rapidly accumulate in the lung (top panel), whereas PEGylated quantoplexes allow short time circulation in blood and accumulation in an implanted tumor (lower panel).

A. Zintchenko, A.S. Susha, M. Concia, J. Feldmann, E. Wagner, A.L. Rogach, M. Ogris: Drug Nanocarriers Labeled with Near-infrared-emitting Quantum Dots (Quantoplexes): Imaging Fast Dynamics of Distribution in Living Animals; Mol. Ther. 17, 1849 (2009)

Ogris, Wagner: *www.cup.uni-muenchen.de/pb/aks/ewagner*

Feldmann: *www.phog.physik.uni-muenchen.de*

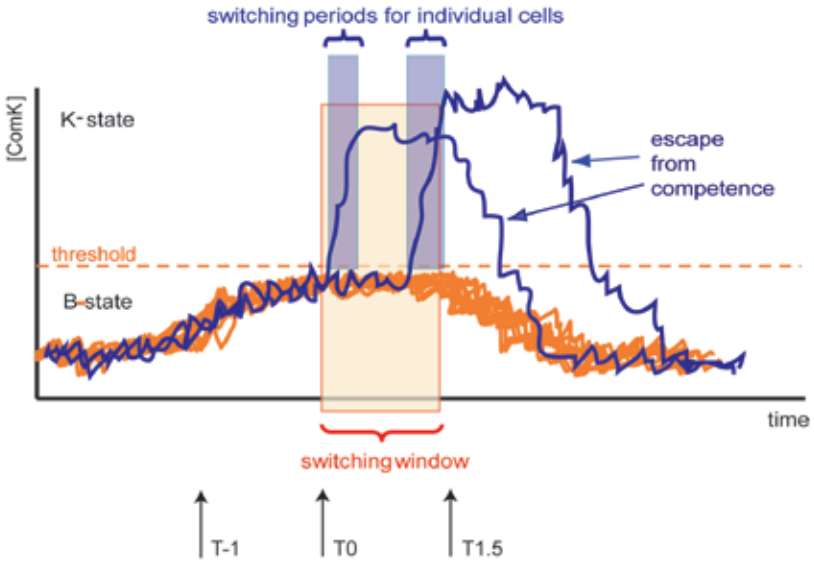
Rogach: *www.ap.cityu.edu.hk/personal-website/webpage Rogach with photo.htm*

STOCHASTIC SWITCHING TO COMPETENCE

Prof. Erwin Frey and Prof. Joachim O. Rädler (LMU Munich)

Distinct modes of gene expression enable isogenic populations of bacteria to maintain a diversity of phenotypes and to rapidly adapt to environmental changes. Competence development for DNA transformation in Bacillus subtilis has become a paradigm for a multimodal system which implements a genetic switch through a nonlinear positive feedback of a transcriptional master regulator. Recent advances in quantitative analysis at the single cell level in conjunction with mathematical modeling allowed a molecular level understanding of the switching probability between the noncompetent state and the competent state. It has been discovered that the genetic switching probability may be tuned by controlling noise in the transcription of the master regulator of competence, by timing of its expression, and by rewiring of the control circuit.

In an interdisciplinary collaboration between the Rädler group, the Maier lab (Münster) and the Frey group, the competence development in B. subtilis was studied. Experiments at the single cell level revealed three necessary requirements for bimodality concerning the master regulator ComK: autocatalytic feedback, noise in basal transcription, and temporal basal transcription regulation. Mathematical models allowed to describe the network as a stochastic dynamical system, corroborating the idea of "functional noise". It will be interesting to investigate whether the requirements described above are conserved throughout other systems that exhibit phenotypic variability. ➤



Mechanism for temporal regulation of noise-driven genetic switching. In the exponential growth phase ($T < T_0$) basal ComK levels (blue and orange) are far below the threshold that triggers the autocatalytic feedback for comK transcription. Due to quorum sensing and stationary phase sensing mechanisms basal ComK levels increase and fluctuate right below the threshold. Eventually, the ComK level in one or the other cell (blue) exceeds the threshold and the positive feedback is triggered. In the remaining cells, the ComK threshold triggering the positive feedback is not reached (orange). The period in which basal ComK expression is elevated is denoted as the switching window. Individual cells switch with an intrinsically defined switching period to a state with high level of ComK. After a certain period, individual cells escape the competent state.

M. Leisner, J.-T. Kuhr, J. O. Rädler, E. Frey, B. Maier: Kinetics of genetic switching into the state of bacterial competence; Biophys. J. 96, 1178-1188 (2009)

Frey: *http://www.theorie.physik.uni-muenchen.de/lsfrey/*

Rädler: *http://softmatter.physik.lmu.de/tiki-index.php*

NEW WATER-SOLUBLE TERRYLENEDIIMIDE DYES AND THEIR APPLICATIONS IN BIOLOGY

Prof. Christoph Bräuchle and Prof. Jens Michaelis (LMU Munich)

The photophysical properties of three new water-soluble terrylenediimide (WS-TDI) derivatives are investigated and their utilization in biological experiments is demonstrated. All three dyes exhibit bright fluorescence, as well as an extremely high resistance against photodegradation compared to other well-known fluorophores. Due to their different characteristics the three new WS-TDI derivatives are suitable for specialized biological applications. WS-TDI dodecyl forms non-fluorescent aggregates in water which can be disrupted in a hydrophobic environment leading to a monomeric fluorescent form. Due to its high lipophilicity WS-TDI dodecyl anchors efficiently in lipid bilayers with its alkyl chain and hence can be ideally used to image membranes and membrane-containing compartments in living cells. In contrast, the positively charged WS-TDI pyridoxy is a new type of chromophore in the WS-TDI family. It is fully solubilized in water forming fluorescent monomers and is successfully used to label the envelope of herpes simplex viruses. Finally, it is shown that a WS-TDI derivative functionalized with N-hydroxysuccinimide ester moiety (WS-TDI/NHS ester) provides a versatile reactive dye molecule for the specific labelling of amino groups in biomolecules such as DNA. ➤

C. Jung, N. Ruthardt, R. Lewis, J. Michaelis, B Sodeik., F. Nolde, K. Peneva, K. Müllen, C. Bräuchle: Photophysics of New Water-Soluble Terrylenediimide Derivatives and Applications in Biology; ChemPhysChem 10, 180 (2009)

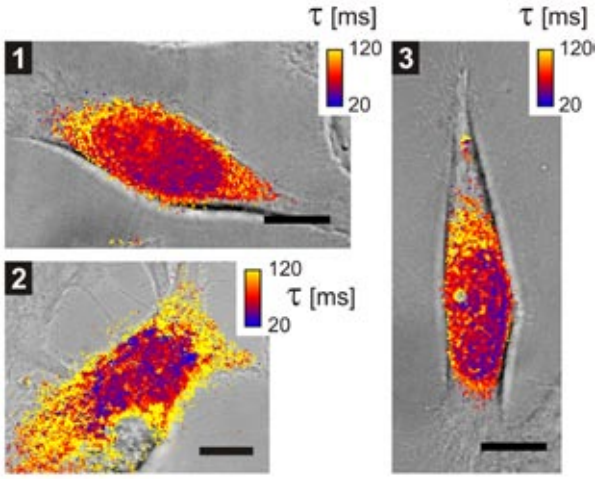
Bräuchle: *http://www.cup.uni-muenchen.de/pc/braeuchle/index.html*

Michaelis: *http://www.cup.uni-muenchen.de/pc/michaelis/*

MEASURING DNA KINETICS IN LIVING CELLS

Prof. Dieter Braun (LMU Munich)

The biology of cells is dominated by an intricate network of molecular interactions. Signaling and molecular processing form a complex network. To model these interactions, the speed of the chemical reactions is a crucial parameter. The measurement of the speed - or kinetics – of reactions requires however complex and specialized methods which are not applicable to reactions in living cells. Thus the reaction partners are typically synthesized and purified and allowed to react outside of the cell. That the kinetics inside cells might be totally different was always expected and feared, however methods were lacking to probe reaction kinetics in cell populations, let alone single cells or cellular compartments. Estimations from the measurement of diffusion coefficients indicated that the dense population of molecules modulate the speed of the reactions, referred to as molecular crowding. The scientists from the Braun group managed to probe reaction kinetics in living cells. A novel optical approach allows to see the reaction of DNA inside living cells and compare it with the situation outside of the cells. Surprisingly, the reaction is not slightly sped up as expected from molecular crowding, but differentially either faster or slower. For example, a 16-mer DNA is sped up 7-fold, however a 12-mer slowed down 5-fold as compared to the extracellular situation. "This came to a surprise", says Dieter Braun, "since we expected an overall gain in reaction speed inside cells. Apparently cells however modulate the reaction speed in a highly selective way." Ingmar Schön who conducted the demanding experiments says: "Surprisingly, we can use kinetics to probe molecular interactions. But more importantly, we can provide *in vivo* kinetic data for Systems Biology, the growing field of explaining cellular life with a network approach." The scientists are now in a position to probe large wide variety of molecular reactions in living cells, visualizing the heart beat of cellular networks. ➤



Measuring DNA Kinetics in living Cells. We image kinetics in vivo using a Lock-In approach. The cells are optically oscillated in temperature and fluorescence changes of a labelled DNA probe inside the cells are evaluated with a molecular lock-in approach. As result, images of the DNA kinetics are resolved. They show that kinetics is modulated by proteins while molecular crowding is a minor effect.

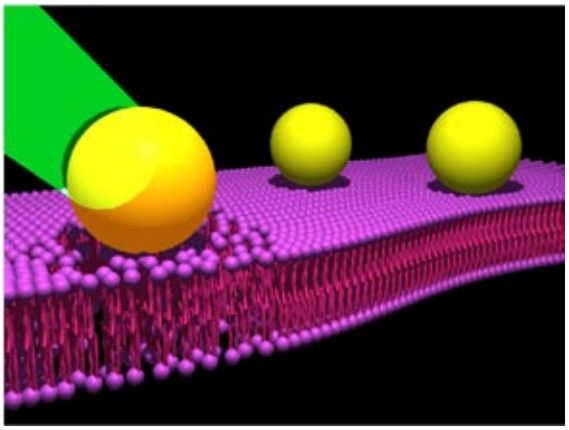
I. Schoen, H. Krammer and D. Braun: Hybridization Kinetics is Different Inside Cells; Proceedings of the National Academy of Sciences (PNAS), 106, 21649 (2009)

http://www.biosystems.physik.lmu.de/

GOLD NANOPARTICLES AS NANOSCOPIC SOURCES OF HEAT ON PHOSPHOLIPID MEMBRANES

Prof. Fernando D. Stefani (LMU Munich, now at University of Buenos Aires)
Prof. Jochen Feldmann and Prof. Joachim Rädler (LMU Munich)

The development of remotely controlled nanoscopic sources of heat is essential for investigating and manipulating temperature sensitive processes at the nanoscale. Here, we use single gold nanoparticles to rapidly deposit controlled amounts of heat in nanoscopic regions of defined size. This allows us to induce and control nanoscale reversible gel-fluid phase transitions in phospholipid membranes. We exploit the optical control over the phase transition to determine the velocity of the fluid phase front into the gel phase membrane and to guide the nanoparticles to specific locations. These results illustrate how single gold nanoparticles enable local thermodynamic investigation and manipulation on nanoscale (bio-) systems. ➤



Gold nanoparticles are attached to a phospholipid membrane. Upon illumination at their plasmon resonance, a nanoparticle heats up and induces locally the gel-fluid phase transition of a nanometric region of the membrane.

A. S. Urban, M. Fedoruk, M. R. Horton, J. O. Rädler, F. D. Stefani, J. Feldmann: Controlled nanometric phase transitions of phospholipid membranes by plasmonic heating of single gold nanoparticles; Nano Letters 9, 2903-2908 (2009)

Stefani: *http://nanomaterials-photonics.df.uba.ar/*

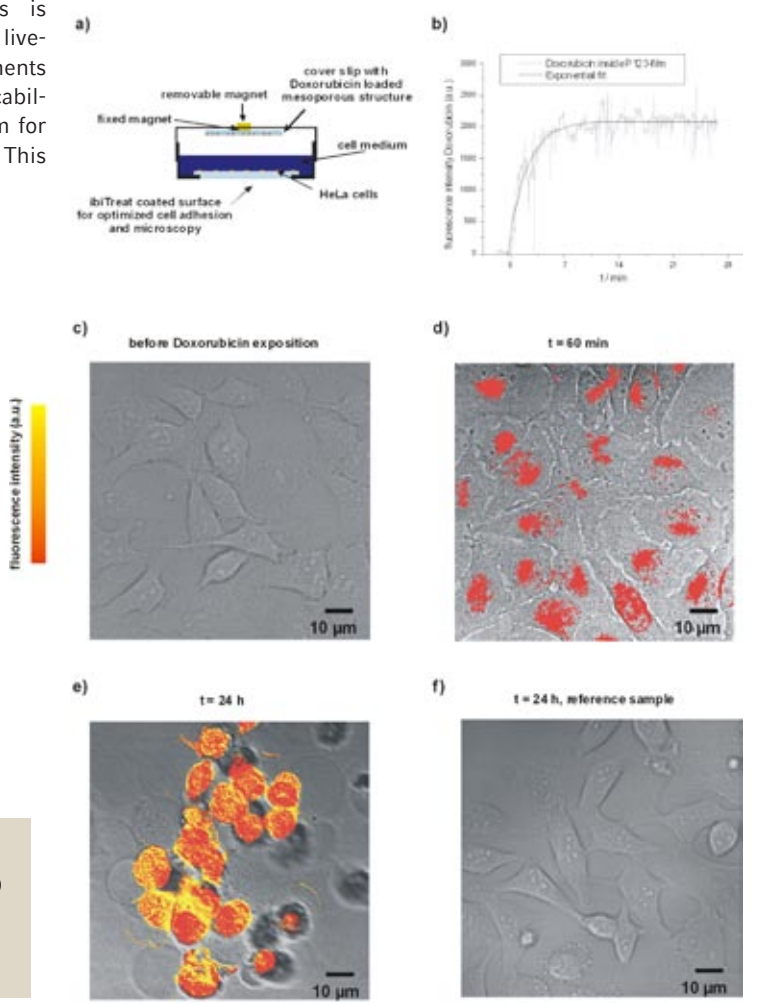
Feldmann: *http://www.phog.physik.uni-muenchen.de/*

Rädler: *http://softmatter.physik.lmu.de/tiki-index.php?page=Home*

NANOSTRUCTURED SILICA MATERIALS AS DRUG-DELIVERY SYSTEMS FOR CYTOSTATICS IN CANCER THERAPY

Prof. Christoph Bräuchle and Prof. Jens Michaelis (LMU Munich)

In cancer therapy, the administered cytostatics show a number of severe side-effects due to their toxicity. Side effects can be reduced by encapsulating the drug in a delivery-system, which protects the body from the toxic drug and prevents the decomposition of the drug prior to reaching the target cells. Mesoporous thin silica films are applied with nanometer-sized pores as drug carriers and the widely used anticancer drug Doxorubicin is incorporated. Through single-molecule based measurements, mechanistic insights into the drug diffusion inside the mesoporous film, which governs the drug-delivery at the target-site, can be obtained. Drug dynamics inside the nanopores is controlled by pore size and surface modification. The release kinetics is determined and live-cell measurements prove the applicability of the system for drug-delivery. This study demonstrates that mesoporous silica nanomaterials can provide solutions for current challenges in nanomedicine. ➤



(a-b) Drug release characterization. (a) Sample setup. The sample consists of a µ-Dish with cell medium and HeLa cells adhered to the bottom of the dish. On the upper side of the dish a cover slip with a Doxorubicin loaded mesoporous structure is held using magnets. Upon removing the magnet the sample is immersed into the cell medium, which can flush the pores of the delivery system and trigger the drug release. (b) Release kinetics of Doxorubicin from a Pluronic P123 templated thin film. The release was monitored via the rise of fluorescence intensity of Doxorubicin 50 µm above the bottom of the µ-Dish during time (grey curve). The black line shows an exponential fit to the data. (c-f) Live-cell measurements. Overlay of confocal transmission images (grey) and Doxorubicin fluorescence (red). Images (a) before, (b) 60 min and (c) 24 h after adding the Doxorubicin loaded delivery system are shown. (d) Image recorded 24 h after adding an unloaded delivery system as reference.

T. Lebold, C. Jung, J. Michaelis, C. Bräuchle: Nanostructured Silica Materials As Drug-Delivery Systems for Doxorubicin: Single Molecule and Cellular Studies; Nanoletters 9, 2877 (2009)

Bräuchle: *http://www.cup.uni-muenchen.de/pc/braeuchle/index.html*

Michaelis: *http://www.cup.uni-muenchen.de/pc/michaelis/*

ASSEMBLING NANOSTRUCTURES BELOW THE OPTICAL RESOLUTION

Prof. Hermann E. Gaub and Prof. Philip Tinnefeld (LMU Munich)

Bottom-up assembly at the level of individual molecules requires a combination of utmost spatial precision and efficient monitoring. "Cut-and-paste" single molecules is a consequence of high precision instruments that were developed recently (Stahl *et al.*, Gumpp *et al.*). The diffraction limit in optical microscopy has been overcome by several high resolution microscopy techniques. A combination of single-molecule cut-and-paste surface assembly, total internal reflection fluorescence microscopy and high precision atomic force microscopy can be used to deposit individual fluorophores in well-defined nanoscale patterns and also to monitor the process in real time with nanometer precision (Kufer *et al.*). Although the size of each pattern is well below the optical resolution of the microscope, the individual dyes are identified by localizing the centroids and detecting the photobleaching of the fluorophores. With this combination of methods, individual dyes or labelled biomolecules can be arranged at will for specific functions, such as coupled fluorophore systems or tailored enzyme cascades, and monitored with nanoscale precision. ➤

S. W. Stahl, E. M. Puchner, H. E. Gaub: Photothermal cantilever actuation for fast single-molecule force spectroscopy; Rev Sci Instrum. 80, 073702 (2009)

H. Gumpp, S. W. Stahl, M. Strackharn, E. M. Puchner, H. E. Gaub: Ultrastable combined atomic force and total internal reflection fluorescence microscope [corrected]; Rev Sci Instrum. 80, 063704 (2009). Erratum in: Rev Sci Instrum. 80, 109901 (2009)

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Gaub, Tinnefeld: *http://www.biophysik.physik.uni-muenchen.de/*

MODULATION OF PROTEIN PROPERTIES IN LIVING CELLS USING NANOBODIES

Prof. Heinrich Leonhardt and Dr. Ulrich Rothbauer (LMU Munich)

Green fluorescent proteins (GFPs) and variants thereof are widely used to study gene expression, protein localization and dynamics in living cells. The extensive use in cell biology research has necessitated the development of proteins with improved properties compared to the original GFP. Enhanced variants including the ubiquitous eGFP, with greater brightness and photostability, have been selected in screens or constructed by mutagenesis. Taking a different approach to altering the photophysical properties of GFP, Heinrich Leonhardt and Ulrich Rothbauer (CEO of LMU-spin-off ChromoTek) turned to nanobodies. These camelid-derived single-domain peptides have antigen-binding properties similar to those of antibodies, with the advantages of greater stability and small size as well as functionality in live cells. The researchers identified seven different nanobodies that bind GFP and looked for those that modulated GFP activity *in vitro*. Upon binding GFP, one nanobody (Minimizer) reversibly minimizes GFP fluorescence about five-fold and can be displaced by a second nanobody (Enhancer) causing a ten-fold increase in fluorescence. Structural analysis – done in collaboration with Axel Kirchhofer and Karl-Peter Hopfner from the LMU-GeneCenter – revealed that nanobody binding caused conformational changes in the chromophore environment. In the GFP-Enhancer complex, the chromophore was in the negatively charged state which increases the fluorescence absorption at 475 nm. Binding of Minimizer to GFP shifts the equilibrium towards the neutral state of the chromophore which drastically reduces the absorption of the bound GFP at 475 nm. This modulation of spectral properties of GFP by Enhancer and Minimizer could be recapitulated in live cells. The Enhancer can be used in a number of *in vivo* applications like e.g. monitoring the trafficking of GFP-tagged estrogen receptor in HeLa cells. Upon hormone induction the construct translocated into the nucleus, where it bound nuclear-localized Enhancer, resulting in increased GFP fluorescence. With this approach translocation events could be studied by simply measuring the fluorescence increase in real time. In summary the results show that nanobodies can be generated to recognize, induce and stabilize alternative protein conformations and thus enable studies of functional properties of specific protein conformations *in vitro* and *in vivo*. Future applications include the use of nanobodies to study signal transduction pathways or to boost signal intensities for super resolution microscopy. ➤

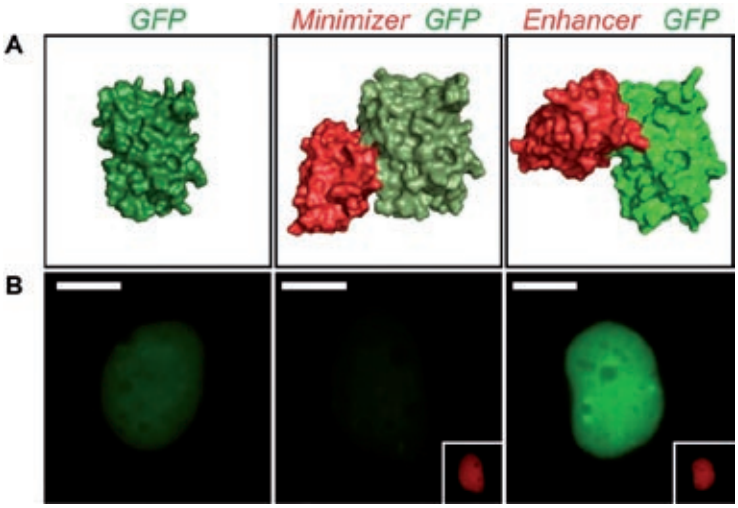

Figure 1: Modulation of protein properties with Nanobodies. (A) Structural surface representation of GFP (green; pdb-file 1EMB), GFP bound by "Minimizer" nanobody (red; pdb-file 3G9A) and GFP bound by "Enhancer" nanobody (red; pdb-file 3K1K). Both nanobodies induce subtle conformational changes in the chemical environment of the GFP chromophore, thereby altering its fluorescent properties towards decreased fluorescence intensity (Minimizer) or enhanced fluorescence intensity (Enhancer). (B) Fluorescence modulation in living cells. Shown are exemplary HeLa cells, expressing nuclear localized GFP, GFP and Minimizer (red), GFP and Enhancer (red). Scale bars represent 10 µm.

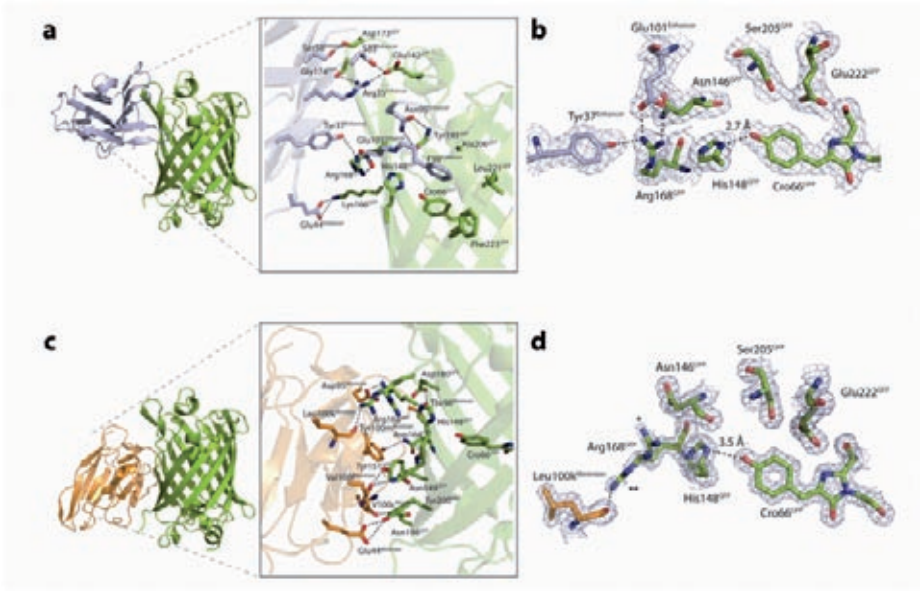

*Figure 2: Structures of the GFP-nanobody complexes. (a) Enhancer and (c) the Minimizer (light blue and orange ribbon model, respectively) recognize two different non-linear epitopes on the surface of the GFP ß-can (green ribbon model). The insets in (a) and (c) show details of the binding sites with selected residues and the GFP chromophore ($Cro66^{GFP}$) highlighted as sticks. Right panel: chromophore environment for the GFP-Enhancer (b) and GFP-Minimizer complexes (d), respectively, superimposed with 2Fo-Fc density maps (contoured at 1.0σ). Two alternative conformations of $R168^{GFP}$ are marked with * and **.*

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Rothbauer, Leonhardt: *http://sci.bio.lmu.de/epigenetics/index.html*

FLUCTUATING NANOMECHANICAL SYSTEM IN A HIGH FINESSE OPTICAL MICROCAVITY

Dr. Heribert Lorenz and Dr. Eva Maria Weig (LMU Munich)
Prof. Khaled Karrai (attocube systems AG)

The idea of extending cavity quantum electrodynamics experiments to sub-wavelength sized nanomechanical systems has been recently proposed in the context of optical cavity cooling and optomechanics of deformable cavities. Thus, while optomechanical coupling has been well-known in macro- and microscale mechanical systems such as gravitational wave detectors or AFM levers, the field of cavity nano-optomechanics has only recently taken stage. However, it has been shown that the resulting absorptive or dispersive optomechanical interaction based on photon-induced forces give rise to a highly sensitive readout of the position fluctuations of the resonator and interesting back-action effects.

Among the first cavity-nanoptomechanical experiments, a scheme developed at CeNS has been demonstrated which is based on a high finesse Fabry-Pérot cavity disturbed by a nanoresonator placed within its optical mode. An optical cavity with an extremely small mode volume is realized between two laser-ablated, Bragg-coated glass fiber ends forming its confining mirrors. A subwavelength nanomechanical resonator such as a carbon-based nanorod consisting of about 10^9 atoms mounted on a silicon lever can be introduced in the 40 μm gap between the fibers (Fig. 1), which will affect the cavity mode via the scattering of photons.

The optical transmission of the cavity is modified not only by the static position of the nanorod but also by its vibrational fluctuation (Fig. 2). The Brownian motion of the nanorod is resolved with a displacement sensitivity of 200 fm/√Hz at room temperature. Besides a broad range of sensing applications, cavity-induced manipulation of optomechanical nanosystems and back-action are anticipated. ➤

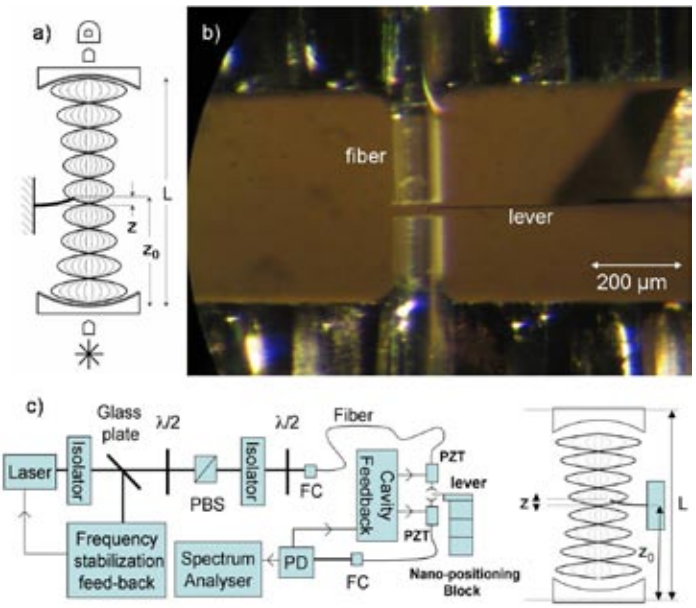

Figure 1: Nanorod vibrating in the microcavity resonantly probed by a laser. a) Schematics of nanorod at position z_0 in the microcavity and vibrating with an amplitude z. b) Optical micrograph of the host silicon lever plunged between the two fibre end-facets in order to position the nanorod in the cavity mode. c) Set-up schematics (PBS: polarizing beam splitter, FC: fibre coupler, PD: photodiode).

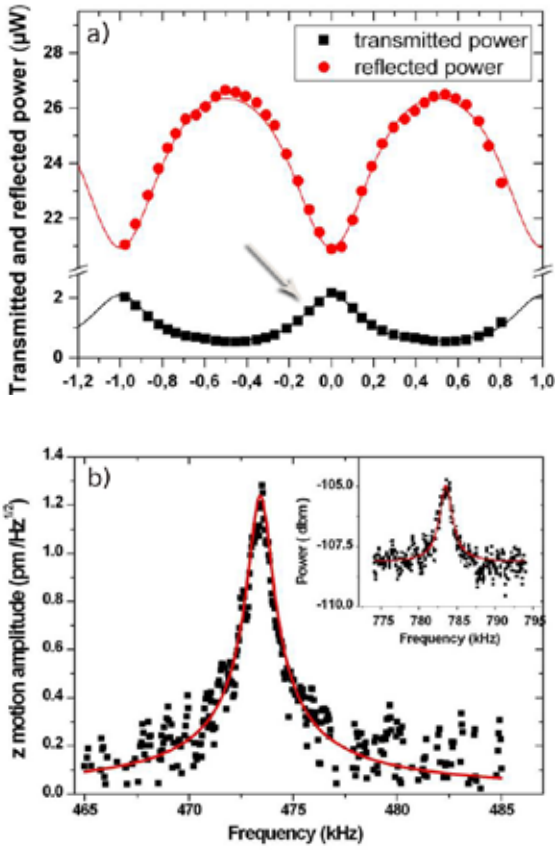

Figure 2: Perturbation of the cavity transmission by the nanorod. a) Optical power transmitted and reflected by the cavity at resonance as a function of the nanorod base position z_0 normalized to the laser wavelength λ (z_s being the average position of the lever, roughly in the middle of the cavity). The arrow indicates the operating point of maximum gradient dT/dz_0. b) Brownian motion amplitude spectrum z for the first flexural resonance of the nanorod. Inset: Transmission noise power spectrum around the frequency of the second flexural resonance of the nanorod, for a resolution bandwidth of 300 Hz of the spectrum analyzer.

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Weig: *http://www.nano.physik.uni-muenchen.de/nanomech/*

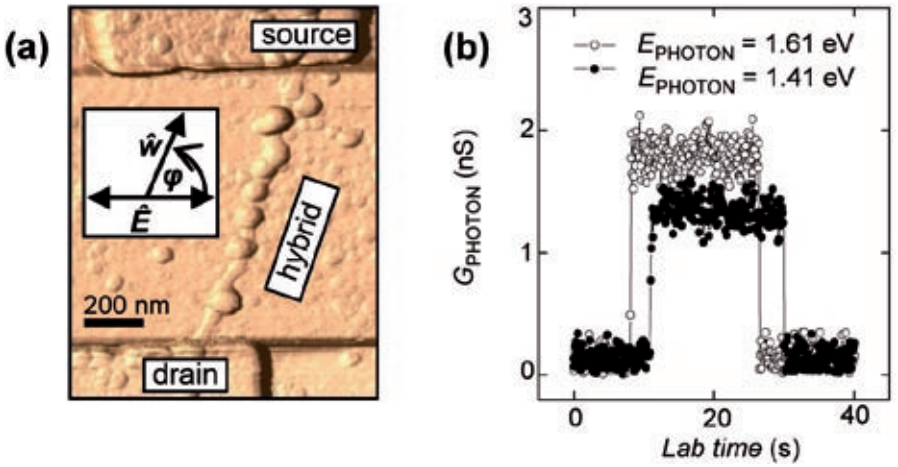
Lorenz: *http://www.nano.physik.uni-muenchen.de/*

Karrai: *http://www.attocube.de/*

QUANTUM DOT-CARBON NANOTUBE HYBRIDS

Prof. Alexander W. Holleitner (TU Munich)
Prof. Jörg P. Kotthaus and Prof. Achim Hartschuh (LMU Munich)

Carbon nanotubes (CNTs) have emerged as promising one-dimensional building blocks of nanoscale optoelectronic devices. Hybrid systems based on functionalized CNTs in particular hold interesting prospects in various fields such as optical sensing and photovoltaics. In this work, the Holleitner group functionalized CNTs with CdTe nanocrystals via molecular recognition in collaboration with the Hartschuh and the Kotthaus group. The resulting hybrid systems combine the adjustable optical properties of quantum dots with the exceptional transport characteristics of nanotubes. Optical spectra of the hybrids were found to consist of a superposition of Raman scattering from the carbon nanotubes, a unique signature used to retrieve structural information, and the quantum dot photoluminescence. We showed that the photoconductance of the hybrids can indeed be adjusted by the absorption characteristics of the nanocrystals. Surprisingly, the photoconductance of the hybrids exhibits a slow time constant of about 1 ms after excitation of the nanocrystals. The data are consistent with a bolometrically induced current increase in the nanotubes caused by photon absorption in the nanocrystals. Our results contribute to our understanding of hybrids and will help in designing novel functional nanosystems. ➤



(a) Atomic force microscope image of an individual nanotube-nanocrystal hybrid contacted by source and drain electrodes. (b) Typical photoconductance measurement of an ensemble sample made of nanotube-nanocrystal hybrids illustrating the optoelectronic sensitization for photon energies matching the nanocrystal absorption at 1.61 eV.

B. Zebli, H. A. Vieyra, I. Carmeli, A. Hartschuh, J. P. Kotthaus, A. W. Holleitner: Optoelectronic sensitization of carbon nanotubes by CdTe nanocrystals; Phys. Rev. B 79, 205402 (2009)

Hartschuh: *http://www.cup.uni-muenchen.de/pc/hartschuh/*

Kotthaus: *http://www.nano.physik.uni-muenchen.de/*

Holleitner: *http://www.wsi.tum.de/Research/HolleitnergroupE24/tabid/166/Default.aspx*

NEW CLICK METHODS FOR THE FUNCTIONALIZATION OF DNA AND PROTEINS

Prof. Thomas Carell, Prof. Thomas Bein and Prof. Hermann Gaub (LMU Munich)

In the framework of bionanotechnical research it is important to functionalize DNA proteins in a controlled fashion in two and three dimensions. One of the main research projects is to orient biomolecules in space. In the case of proteins it is afterwards possible to assemble whole enzyme cascades for example on long DNA strands. This may allow in the future to perform multi step transformations on DNA based templates. Currently the connection of proteins with DNA in order to generate such nano structures is a synthetic challenge. In order to solve this synthetic problem we are currently following two avenues. We have created DNA that contains specific metal complexation units. With such metal based pairs and complementary metal ions it is possible to assemble DNA structures on surfaces. The metal base concept was developed in the framework of SFB 486. With the help of Hermann Gaub it was possible to measure the strength of the complexing unit using modern AFM technology. The second approach that we follow is to develop mild chemical derivatisation methods for oligonucleotides so called click methods. We have just established new click modification protocols and with the help of Thomas Bein it was possible to click DNA strands to nano particles. These nanoparticles are mesostructures with large cavities. It was possible to control the release of drug molecules out of these cavities with the help of the DNA structures. ➤

E. Kaya, K. Gutsmiedl, M. Vrábel, M. Müller, P. Thumbs, T. Carell: Synthesis of threefold glycosylated proteins using click chemistry and genetically encoded unnatural amino acids; ChemBioChem 12, 2858-2861 (2009)

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K. Gutsmiedl, C. T. Wirges, V. Ehmke, T. Carell: Copper-free "click" modification of DNA via nitrile oxide-norbonene 1,3-dipolar cycloaddition; Org. Lett. 11, 2405-2408 (2009)

Carell: *http://www.cup.uni-muenchen.de/oc/carell/*

Bein: *http://bein.cup.uni-muenchen.de/index.php*

Gaub: *http://www.biophysik.physik.uni-muenchen.de/*

MANIPULATION OF FLUID BY MAGNETIC CHAINS AND CREATION OF ACTIVE 2D-SURFACES

Dr. Thomas Franke and Prof. Achim Wixforth (University of Augsburg)
Prof. Matthias Schneider (University of Augsburg, now at Boston University)

Superparamagnetic beads of micrometer size align in an external magnetic field and form extended chains. In a magnetic field gradient a force is acting on these chains. We have encapsulated such chains in lipid vesicles and have demonstrated to magnetically manipulate vesicles on a microfluidic chip. Upon application of a rotating magnetic field these chains can be used as micro-sized stirrers to enhance mixing on small scales. This is particular useful for dispersing colloidal nanoparticles. Moreover, vesicles can serve as picoliter containers to enclose reactants and biomolecules for chemical and biochemical reaction on lab-on-a-chip devices.

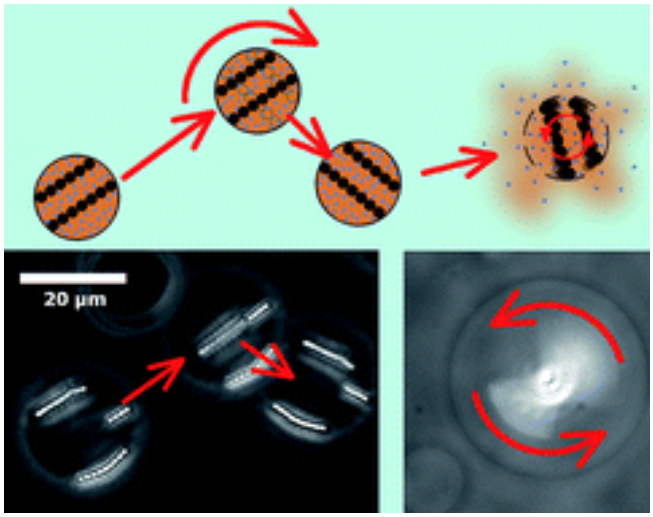

Fig.1: Superparamagnetic beads in giant unilamellar vesicles are used to facilitate magnetic manipulation, positioning, agitation and mixing of ultrasmall liquid volumes. Vesicles act as leakproof picoliter reaction vessels in an aqueous bulk solution and can be deliberately conveyed by an external magnetic field to a designated position. Upon application of an external magnetic field the beads align to form extended chains. In a rotating magnetic field chains break up into smaller fragments caused by the interplay of viscous friction and magnetic attraction. This process obeys a simple relationship and can be exploited to enhance mixing of the vesicle content and the outer solution or adjacent vesicle volumes exactly at the position of release.

This concept has been demonstrated together with R. Westervelt at Harvard. Using a hybrid integrated chip both magnetic and dielectrophoretic forces could be applied simultaneously. Holding the vesicle in place by dielectric forces and stretching it with magnetic forces furthermore allows the determination of its elastic material properties. After successful and robust controlling single magnetic chains we asked ourselves: Why not go further? Why not using a bunch of these magnetic chains dispersed on a surface to actuate larger liquid volumes? So, we decided to spread many of these magnetic beads on a surface and applied a rotating magnetic field. The rotational axis was tilted by 90 degrees to be parallel to the substrate surface. Immediately, the magnetic chains started propagating along the substrate. Many of the colloidal walkers form an active, quasi-2d layer and can be used to control the motion of cells or vesicles deposited on top of this active surface. This setup resembles very much of what is known as Cilia motion in biological systems. The coordinated beating of cell surface attached Cilia sweeps mucus and dirt out of the lungs or moves the ovum from the ovary to the uterus. In order to gain a better understanding of the motion of these "self-assembled colloidal walkers", simulations together with Alfredo Alexander-Katz from the MIT in Cambridge have been done.

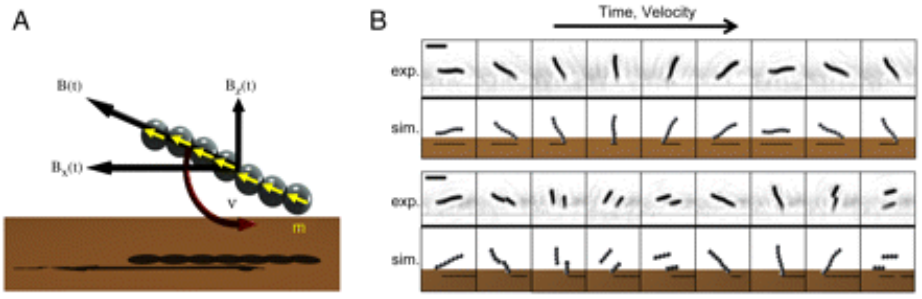

Fig.2: (A) The geometry of "surface walkers". Each chain is composed of superparamagnetic beads that move according to the dynamics of the magnetic field B that induces a magnetic moment m in each bead. In particular, we focus on rotation along the x-z plane at a frequency. (B) Top: The aggregate moves along the surface in both experiments (frames taken 16 ms apart in a 5 Hz rotating field, scale bar is 5 µm) and simulation upon confinement at the surface. Bottom: When the field rotation is raised to 7 Hz, the rotors fragment periodically. Notice that the agreement is excellent between both experiments and theory, even in the shape of the fragmented aggregates.

T. Franke, L. Schmid, D. A. Weitz, and A. Wixforth: Magneto-mechanical Mixing and Manipulation of Picoliter Volumes in Vesicles; Lab on a Chip 9, 2831 (2009)

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Franke: *http://www.physik.uni-augsburg.de/exp1/franke/franke.html*

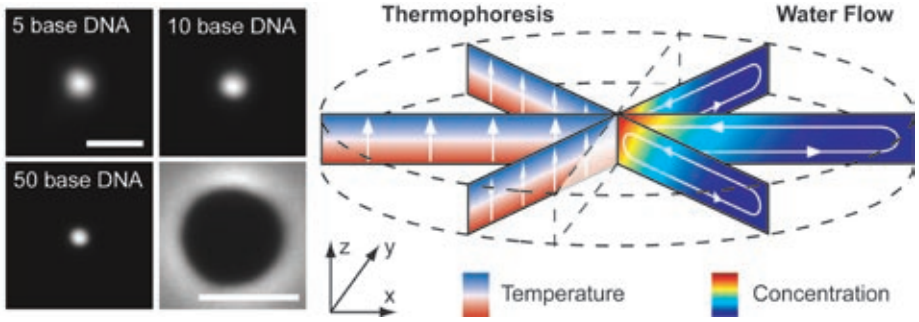
Wixforth: *http://www.physik.uni-augsburg.de/exp1/wixforth/wixforth.html*

Schneider: *http://www.bu.edu/me/people/faculty/pz/schneider/*

OPTICAL MOLECULE TRAP USING THERMOPHORESIS AND OPTOFLUIDICS

Prof. Dieter Braun (LMU Munich)

Molecules in fluids constantly stay in motion and are difficult to concentrate in one spot. Such measures are necessary, for instance, to trigger certain reactions or to investigate bonds between molecules and other substances. So-called molecular anchors, polymers for example at which the investigated molecules accumulate, are used for such tasks. These anchors can, however, affect the molecules and thus the experimental results. LMU biophysicists Dieter Braun and Franz Weinert now developed a non invasive optical molecule trap. „Our optical conveyor creates very quickly large concentration gradients, even for molecules that are only nanometers small" says Dieter Braun. "This provides us with an opportunity to characterize biological and other molecules." For their optical trap the scientists utilized thermal effects to transport molecules in a fluid. To start with, the so-called thermophoresis causes molecules in a temperature gradient to migrate from warm to cold areas. Additionally, the scientists use a thermoviscous fluid pump, which is based on the correlation between viscosity and temperature: Warm fluids have lower viscosity, exerting less attraction between their molecules, which in turn drift towards the colder area. By means of both effects, Braun and Weinert constructed a conveyor for molecules. An infrared laser creates hot spots at the bottom of the fluid container and the resulting temperature gradient causes the molecules to drift upwards. Moving the laser beam toward the center activates the thermoviscous pump, which transports the fluid to the container edge. Thus, an optically driven conveyor is formed which runs outward at the container bottom and inward on its surface. The molecules at the surface are transported to the center and accumulate there. This optical method enables scientists to investigate molecules undisturbed in their "natural habitat" namely a fluid. Moreover, the optical conveyer works well even for extremely small molecules. The researchers could, for instance, accumulate DNA fragments of only five bases length within three seconds to an over hundredfold concentration. The conveyor also acts as a selective tool – for instance to investigate certain molecular bonds. The start up enterprise NanoTemper Technologies GmbH, which was founded by Stefan Duhr and Philipp Baaske, already employs opto-thermal methods to verify bindings between pharmaceutical substances and biological molecules such as proteins. The optical molecule trap provides them with yet another means of characterising bio molecules. ➤



Optical Molecule Trap. By combining optical microflow with thermophoresis, the researchers can trap DNA down to 5 bases in a twodimensional sheet of water. The method does not require any structuring of the chamber and is solely driven by the dynamic heat pattern created with a laser.

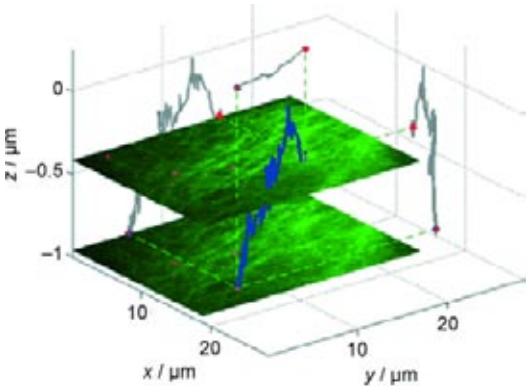
F. M. Weinert and D. Braun: An Optical Conveyor for Molecules; Nano Lett. 9, 4264 (2009)

Braun: *http://www.biosystems.physik.lmu.de/*

REAL-TIME NANOMICROSCOPY VIA THREE-DIMENSIONAL SINGLE-PARTICLE TRACKING

Prof. Christoph Bräuchle and Prof. Don C. Lamb (LMU Munich)

A new method for real-time, three-dimensional tracking of fluorescent particles was developed. The instrument is based on a laser-scanning confocal microscope where the focus of the laser beam is scanned or orbited around the particle. Two confocal pinholes are used to simultaneously monitor regions immediately above and below the particle and a feedback loop is used to keep the orbit centered on the particle. For moderate count rates, this system can track particles with 15 nm spatial resolution in the lateral dimensions and 50 nm in the axial dimension at a temporal resolution of 32 ms. To investigate the interaction of the tracked particles with cellular components, an orbital tracking microscope was combined with a dual-color, wide-field setup. Dual-color fluorescence wide-field images are recorded simultaneously in the same image plane as the particle being tracked. The functionality of the system was demonstrated by tracking fluorescent-labeled artificial viruses in tubulin-eGFP expressing HUH7 cells. The resulting trajectories can be used to investigate the microtubule network with super resolution. ➤



Tracking of artificial viruses: A 3D trajectory (blue) of an artificial virus (red) in a live HUH7 human hepatome cell transfected with eGFP-tagged tubulin (green) along with two wide-field images taken at different z-positions during the measurement. 2D projections of the 3D trajectory are shown in grey on the respective axes.

Y. Katayama, O. Burkacky, M. Meyer, C. Bräuchle, E. Gratton, D. C. Lamb: Real-time Nanomicroscopy via Three-Dimensional Single-Particle Tracking; ChemPhysChem 10, 2458 (2009)

Bräuchle: *http://www.cup.uni-muenchen.de/pc/braeuchle/index.html*

Lamb: *http://www.cup.uni-muenchen.de/pc/lamb/index.html*

CONFOCAL RAMAN SPECTROSCOPY AND IR SCATTERING NEAR-FIELD OPTICAL MAPPING OF RESIDUAL STRESS

Dr. Alexander M. Gigler (LMU Munich) and Prof. Robert Stark (LMU Munich, now at TU Darmstadt)
Prof. Rainer Hillenbrand (CIC nanoGUNE Consolider, San Sebastian, Spain)

Mechanical and residual strain in semiconductor materials play an important role in the design of devices. For example, strain can give rise to failure, in particular due to the collapse of high aspect-ratio features. One of the more robust semiconductor materials is silicon carbide (SiC). Local strain measurements are necessary for monitoring and optimization of fabrication processes. For this purpose, non-destructive and fast techniques for strain mapping are needed that require only minimum sample preparation. Precise local strain measurements can be achieved, for example, by electron backscatter diffraction. For routine analysis, however, optical methods are advantageous because they require less preparation. As the frequency of phonon modes is changing under external influences such as mechanical stress and strain, both infrared near-field microscopy and Raman spectroscopy are well suited techniques.

Nanoindents in silicon carbide (SiC) were analyzed by infrared (IR) scattering-type scanning near-field optical microscopy (s-SNOM) and confocal Raman microscopy. The images were interpreted in terms of local residual stress-fields. By comparing near-field IR and confocal Raman images, one finds that the stress-induced shifts of the longitudinal optical phonon-frequencies (LO) and the related shift of the phonon-polariton near-field resonance give rise to Raman and s-SNOM image contrasts. The spatial extension of the local stress-field around the nanoindent agrees well between both techniques. Thus, both methods ideally complement each other, allowing for the detailed analysis of stress-fields at e.g. material and grain boundaries, in micro-electro-mechanical-systems (MEMS), or in engineered nanostructures. ➤

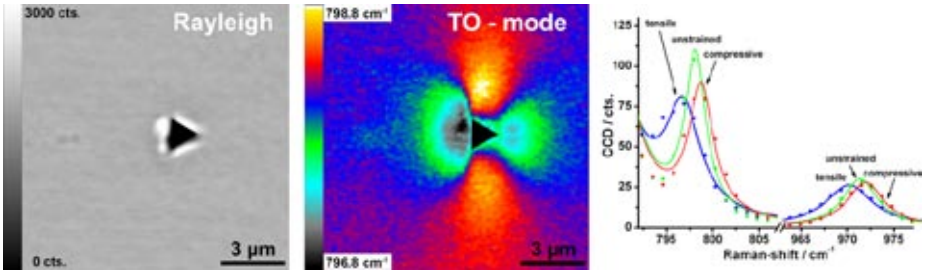


Figure: The left image shows the Rayleigh intensity map, i.e. elastically scattered light, of a locally stressed SiC sample. The map of the inelastically scattered photons is correlated with the mechanical stress in the material (central panel). Here, the photons are scattered at the transversal optical phonons of the crystal, which causes a line-shift of the corresponding Raman band. The spectral position of the phonon lines can be fitted by a Lorentzian curve. The graph on the right shows the spectra for tensile, neutral, and compressive stress for selected positions around the indent.

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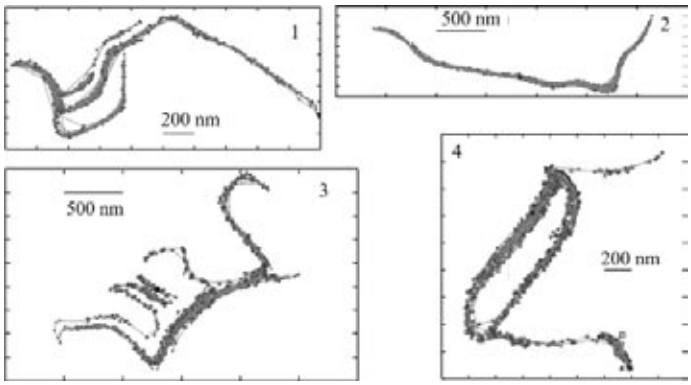
Stark: *http://www.nanobiomat.de/*

TUNING SINGLE-MOLECULE DYNAMICS IN FUNCTIONALIZED MESOPOROUS SILICA

Prof. Christoph Bräuchle, Prof. Thomas Bein and Prof. Jens Michaelis (LMU Munich)

Mesoporous silica materials are promising host structures for diverse applications in nanoscience. Many applications can profit significantly from the ability to influence guest dynamics in the host matrix. By using single-molecule fluorescence microscopy, the diffusion behavior of single terrylene diimide dye molecules in functionalized mesoporous silica films can be studied. It is demonstrated that, through variation of the chemical nature and density of the functional groups, the diffusion dynamics of the dye molecules, in the presence of the surfactant template, can be controlled precisely. ➤



Trajectories of single dye molecules from ethyl- (1 and 2) and propyl-functionalized (3 and 4) films.

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Michaelis: *http://www.cup.uni-muenchen.de/pc/michaelis/*

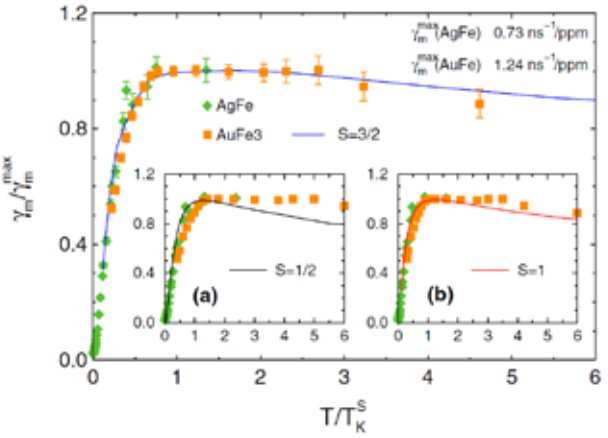
KONDO DECOHERENCE: FINDING THE RIGHT SPIN MODEL FOR IRON IMPURITIES IN GOLD AND SILVER

Prof. Jan von Delft (LMU Munich)

This work deals with a system that has been around for a very long time: iron impurities in gold or silver. It was discovered already back in 1934 that they cause an anomalous upturn in the resistance at sufficiently low temperature. This effect is now known as the Kondo effect, after Kondo managed to explain it in 1964 in terms of a simple model which assumed spin-flip scattering between localized magnetic moments, representing the iron atoms, and conduction electron spins.

Surprisingly, however, the details of Fe impurities in Au or Ag were until recently not quantitatively understood. The point is that the d-level states of iron impurities in gold or silver have a rather complex electronic structure, and it is difficult to determine which of the multiple bands, spin and orbital degrees of freedom play a role at low temperatures. In fact, it was not even known whether iron impurities have spin $^1/_2$, 1, $^3/_2$ or something else, let alone whether orbital degrees of freedom play a role.

To solve this puzzle, a large collaborative effort was launched, involving colleagues from Jülich, Cologne, Grenoble and Munich. Our Jülich colleagues used state-of-the-art band structure calculations to study the electronic structure of iron in gold and silver. Based on this, the Cologne colleagues came up with several "most likely" candidate models; the Munich group did state-of-the-art numerical renormalization group calculations to determine their transport properties, including the decoherence rate of other conduction electrons spin-flip-scattering of iron impurities, as measured in weak localization. Comparing the results to state-of-the-art experimental results from Grenoble, the proper model could conclusively be established, namely s=$^3/_2$ coupled to 3 delocalized bands. The final conclusion is not only that the correct model has now been found, but also that a very satisfying level of control has been achieved over all experimental and theoretical techniques employed. ➤



Comparison of measured (symbols) and theoretical (lines) results for the decoherence rate as function of temperature, for three fully screened Kondo models, with spin S = 1/2, 1 or 3/2. The best agreement is obtained for S=3/2.

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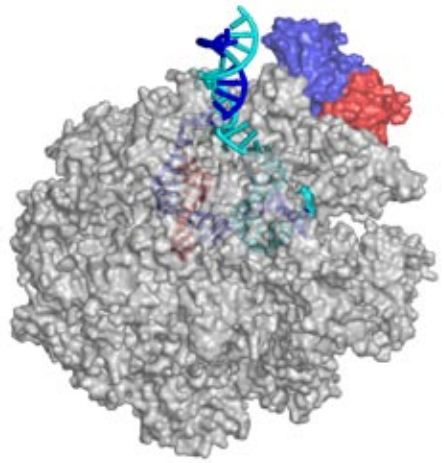
STRUCTURAL ANALYSIS OF RNA POLYMERASE II ELONGATIONS COMPLEXES USING NPS

Prof. Patrick Cramer and Prof. Jens Michaelis (LMU Munich)

The structural biology of eukaryotic RNA polymerases has in the past years allowed for a detailed near atomic view of key states of gene expression in eukaryotes. However, standard structural biology techniques lack the ability to map the conformation and dynamics of flexible domains within the biological complexes. Here, single molecule approaches can be instrumental for extending our understanding of the dynamic machinery involved. The Michaelis laboratory had recently developed a new method that allows the localization of flexible domains within larger biological complexes using a combination of single-molecule fluorescence resonance energy transfer, structural biology data and rigorous statistical data analysis based on Bayesian parameter estimation. This so called nano-positioning system (NPS) was now applied in a collaboration with the Cramer laboratory to determine the pathway of the non-template DNA within the polymerase elongation complex, as well as the position of the upstream DNA, thus completing the structural information of the elongation complex. Interestingly, the determined position of the non-template DNA can help to explain other published mutagenesis data and in addition has important implications for the structural transitions in the transition from transcription initiation to elongation. ➤



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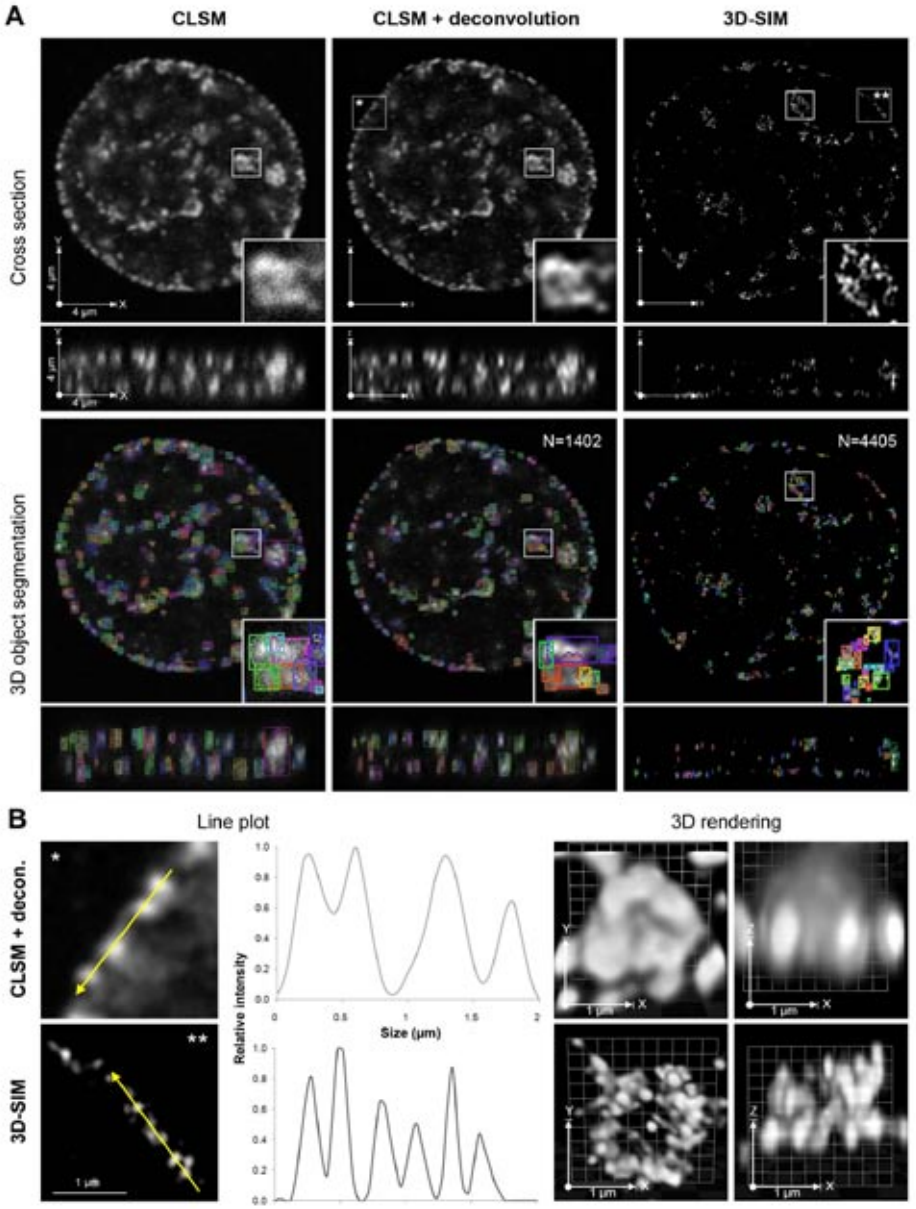
Cramer: *http://www.lmb.uni-muenchen.de/cramer/*

Michaelis: *http://www.cup.uni-muenchen.de/pc/michaelis/*

MEASUREMENT OF REPLICATION STRUCTURES AT NANOMETER SCALE RESOLUTION WITH 3-DIMENSIONAL STRUCTURED ILLUMINATION MICROSCOPY (3D-SIM)

Dr. Lothar Schermelleh and Prof. Heinrich Leonhardt (LMU Munich)

Three-dimensional structured illumination microscopy (3D-SIM) allows multi-wavelength optical sectioning of biological samples with a spatial resolution of ~ 120 nm in the xy plane and ~ 300 nm along the z-axis. DNA replication, similar to other cellular processes, occurs within dynamic macromolecular structures. Any comprehensive understanding ultimately requires quantitative data to establish and test models of genome duplication. In collaboration with M. C. Cardoso (TU Darmstadt), C. Cremer (University of Heidelberg) and colleagues, Lothar Schermelleh used super-resolution light microscopy to directly measure and compare the size and numbers of replication foci in mammalian cells. This analysis showed that replication foci vary in size from 210 nm down to 40 nm. Remarkably, spatially modulated illumination (SMI) and 3Dstructured illumination microscopy (3D-SIM) both showed an average size of 125 nm that was conserved throughout S-phase and independent of the labeling method, suggesting a basic unit of genome duplication. Interestingly, the improved optical 3D resolution identified 3- to 5-fold more distinct replication foci than previously reported. These results show that optical nanoscopy techniques enable accurate measurements of cellular structures at a level previously achieved only by electron microscopy and highlight the possibility of high-throughput, multispectral 3D analyses. ➤



Quantitative analysis of replication foci (RF) numbers after confocal laser scanning versus 3D-SIM super-resolution imaging. (A) DNA replication structures in mouse C2C12 after 30 min BrdU pulse labeling and immunostaining. Nuclei with replication pattern typical for mid-late S-phase are shown. A constrained iterative deconvolution was applied to the confocal (CLSM) image stack (column 2). Large RF at chromocenters consisted of 100-120 nm sized subdomains that could only be resolved with 3D-SIM (insets in first row). 3D object segmentation was applied to determine numbers and volumes of RF (second row), resulting in a several fold increase of segmented foci. (B) Intensity plot profile yielded about 2-fold smaller peak width (FWHM) of RF recorded with 3D-SIM compared to deconvolved confocal images. 3D volume rendering of a replicating chromocenter demonstrated the increased resolution in x, y and z-direction with 3D-SIM.

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DIPLOMA & MASTER THESES

Weko Abhinimpuno: *Growth and Characterization of $CaCO_3$ in a Lecithin Micelles and Emulsion System* (LMU, W. Schmahl, B. Nickel); **Arne Alex:** *Non-Abelian Symmetries in the Numerical Renormalization Group* (LMU, J. von Delft); **Sandra Amann:** *Einsatz von IR-spektroskopischen Untersuchungsmethoden zur Charakterisierung der Tierart und Fleischqualität* (LMU, K. Wiesner, A. Hartschuh); **Christian Argyo:** *Inorganic-Organic Core-Shell Nanoparticles – PEGylated Colloidal Mesoporous Silica* (LMU, T. Bein); **Lena Baier:** *Erzeugung und Untersuchung supramolekularer Nanostrukturen des Chelatkomplexes Alizarin-Krapplack mittels Rastertunnelmikroskopie* (Hochschule München, Stefan Sotier, Frank Trixler); **Julia Baldauf:** *Strukturabhängige Photolumineszenz einzelner CdSe-/CdS-Nanokristalle* (LMU, J. Feldmann); **Karl-Ulrich Bamberg:** *Anomalous Transport in heterogeneous Environments* (LMU, T. Franosch); **Veronika Beil:** *Design and Implementation of a Resistance Measurement System for Semiconducting Metal Oxide Thin Film Sensors* (LMU, TUM, U. of Augsburg, T. Bein); **Matthias Brandstetter:** *Kontaktieren von organischen und anorganischen Nanosystemen mittels Kohlenstoffnanoröhrchen* (TUM, A. Holleitner); **Andrea Buchfellner:** *Generierung und Charakterisierung von VHH-Domänen zum Nachweis primärer Antikörper* (LMU, U. Rothbauer); **Sophia Capito:** *Motility of living cells in an artificial quasi- 3D Environment* (LMU, D. Heinrich); **Polina Davydovskaya:** *Mikrokontaktdruck von Proteinen zur Oberflächenmodifikation* (LMU, R. Stark); **Florian Dehmelt:** *Molecular Force Balances as Biological Analog-to-Digital Converters* (LMU, H. Gaub); **Teresa Dennenwaldt:** *Transmissionselektronenmikroskopische Untersuchungen von Si-P-O-N-Verbindungen und Eisenoxid-Dünnschichten* (LMU, C. Scheu); **Mark Dethlefsen:** *Comparison of 2D hexagonal ordered cylindrical CTAB micelles at the solid-air interface and highly structured mesoporous domains on top of MCM-41* (LMU, C. Bräuchle); **Alexander Dobrinevski:** *Coexistence versus Extinction in Population Dynamics* (LMU, E. Frey); **Jonas Eggert:** *Two-Photon Fluorescence Correlation Spectroscopy for the Study of Molecular Interactions* (LMU, J. Rädler); **Thomas Faust:** *Nanomechanik zugverspannter Siliziumnitridresonatoren* (LMU, J. Kotthaus); **Hans Feckl:** *Nanostructured Titania for Photovoltaic Application* (LMU, T. Bein); **Michael Fedoruk:** *Optothermische Manipulationen von Phospholipidmembranen mittels Goldnanopartikel* (LMU, J. Feldmann); **Felix Gnerlich:** *Design von Metall-Salen Komplexen an Dilysin-Motiven zur selektiven Markierung von Proteinen* (LMU, T. Carell); **Matthias Grimm:** *Brownian Motion in Simple and Complex Fluid* (LMU, T. Franosch); **Markus Hanl:** *The Kondo exciton: non-equilibrium dynamics after a quantum quench in the Anderson impurity model* (LMU, J. von Delft); **Nicolai Hartmann:** *Räumliche Abstrahlungscharakteristiken von Kohlenstoffnanoröhren und deren Manipulation* (LMU, A. Hartschuh); **Mario Herzog:** *Virtual Thermal Gradient* (LMU, D. Braun); **Jan Heyder:** *Crossover from the Kondo Effect in Quantum Dots to the 0.7 Anomaly in Quantum Point Contacts* (LMU, J. von Delft); **Markus Heyl:** *Periodic time-dependent Kondo model* (LMU, S. Kehrein); **Florian Hinterholzinger:** *Oriented Growth of the Functionalized Metal-Organic Framework CAU-1 on –OH and –COOH- Terminated Self-Assembled Monolayers* (LMU, T. Bein); **Sandra Koch:** *Isolierung und DNA-Bindungsstudien des Schadenserkennungsproteins XPA/Rad14 in der Nukleotidexzisionsreparatur* (LMU, T. Carell); **Hubert Krammer:** *Investigation of mechanical and electrical properties of cells with Patch-Clamp-AFM* (LMU, H. Gaub); **Ilka Kriegel:** *Morphology correlated observation of charge transfer excitons in polymer/fullerene solar cells* (LMU, J. Feldmann); **Stefanie Krysiak:** *Dispersive sensing of biomolecules using optical microresonators* (LMU, B. Nickel); **Karoline Kurth:** *Coherent Anti-Stokes Raman Scattering-Microscopy for systematic studies of Lipid Storage Mechanisms in Caenorhabditis elegans* (LMU/Chalmers, A. Enejder, C. Bräuchle); **Janek Landsberg:** *Pattern Formation in Competing Bacterial Populations* (LMU, J. Rädler); **Lukas Lercher:** *Epigenetische Sequenzierung mit Hydroxylamin: Untersuchungen von 5-Methylcytosinaddukten* (LMU, T. Carell); **Jean Mahowald:** *Influence of the microarchitecture on transport processes in living cells* (LMU, D. Heinrich); **Christof Mast:** *Replication Trap for DNA* (LMU, D. Braun); **Dorothea Matschkal:** *Klonierung und Optimierung der Proteinexpression von tierischen Cryptochromen* (LMU, T. Carell); **Eva Melari Davies:** *Synthese und Charakterisierung von Silbernanodrähten sowie Plasmonenverstärkung von Fluoreszenzfarbstoffen* (LMU, C. Bräuchle); **Andrea Meyer:** *Quorum Sensing: Phasenübergänge in bakteriellen Netzwerken* (LMU, J. Rädler); **Caitlin Morgan:** *Characterization of Silicon Nanowires grown using Indium or Gallium as VLS Catalysts* (LMU, TUM, University of Augsburg, T. Bein); **Nikolaus Naredi-Rainer:** *Multi Parameter Fluorescence Spectroscopy - Setup, Assembly and Applications* (LMU, D. C. Lamb); **Carina Pelzl:** *Axonal Guidance by Surface Microstructuring for the Investigation of Vesicle Transport* (LMU, D. Heinrich); **Sebastian Pünzeler:** *Transduktion fluoreszenz-markierter Chromobodies in lebende Zellen* (LMU, U. Rothbauer); **Carmen Elena Quiroga:** *Density Functional Theory calculations of NiTi Shape Memory Alloys* (LMU, R. Pentcheva, W. Schmahl); **Farangis Ram:** *Exsolution in Perovskites: Experiments on $BaTiO_3$-$LaFeO_3$ and $BaTiO_3$-$CaTiO_3$ systems* (LMU, W. Schmahl, R. Pentcheva); **Philip Reineck:** *Thermophoresis of Single Stranded DNA* (LMU, D. Braun); **Johannes Rieger:** *Towards integrated nano-optomechanical systems with photonic crystal cavities* (LMU, Eva Weig); **Amandine Rojo:** *Synthesis and characterization of iron oxide nano particles* (LMU, W. Schmahl); **Sophia Rudorf:** *Self Assembly of Lipid-DNA Complexes-A Fluorescence Correlation Spectroscopy Study* (LMU, J. Rädler); **Della Sevilla:** *Structure Determination of nanosclae Ni4Ti3 xsolutions in single crystal Ni-rich NiTi shape memory alloy* (LMU, W.Schmahl); **Verena Schittler:** *Nanopartikel in lebenden Zellen: Magnetfeldunterstützte Inkorporation und 3D-Transport Analyse* (LMU, D. Heinrich); **Daniel Schlesinger:** *Nonperturbative Renormalization Method for Reaction-Diffusion Processes* (LMU, E. Frey); **Katrin Schneider:** *Analysis of cell cycle dependent kinetics of Dnmt1 by FRAP and kinetic modeling* (LMU, L. Schermelleh, H. Leonhardt); **Alexander Schödel:** *Oriented Nanoscale Films of Metal-Organic Frameworks* (LMU, T. Bein); **Johannes Schulz:** *Randomwalk auf einem Gitter mit Gedächtnis - Stromumkehr im reversiblen Burnt-Bridge-Model* (LMU, E. Frey); **Lothar Sims:** *Herstellung und Charakterisierung von organischen Solarzellen* (LMU, Lukas Schmidt-Mende); **Thomas Sirtl:** *Surface-mediated Self-Assembly vs. Polymerization* (LMU, M. Lackinger); **Stefan Stanglmeier:** *Experimente am Neutronenreflektometer REFSANS am FRMII zur Untersuchung von substratgestützten Membransystemen* (LMU, B. Nickel); **Ingo Stein:** *Steroid Binding to a DNA Three-Way Junction Visualized by Multicolor Single-Molecule Spectroscopy* (LMU, P. Tinnefeld); **Christian Späth:** *Aufbau eines 2-Photonen Fluoreszenz-Korrelations-Spektroskopie Mikroskops* (LMU, J. 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