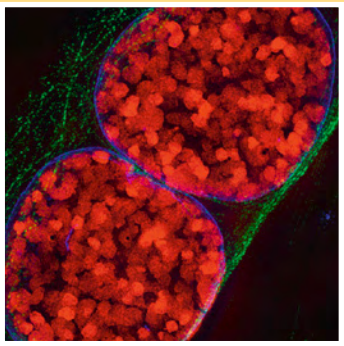
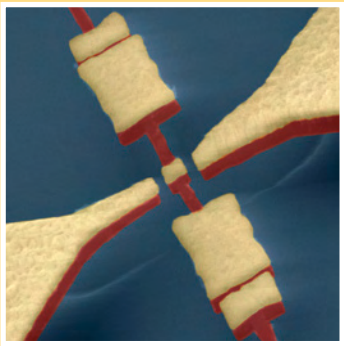
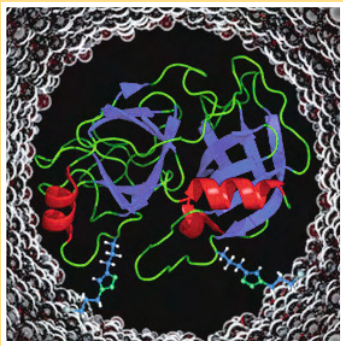
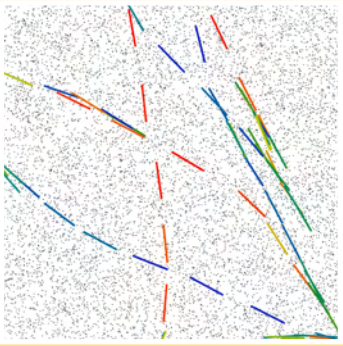
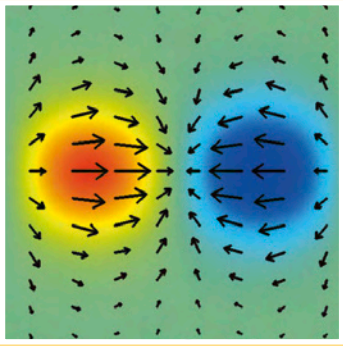
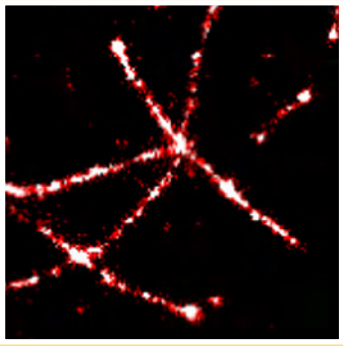
Center for NanoScience

ANNUAL REPORT 2008

CeNS
Center for NanoScience | LMU

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WELCOME

Dear Members of CeNS,
Dear Friends and Mentors!

The year 2008 has been very exciting, enjoyable and fruitful for CeNS; more than ever. Have a look at the pages 4 and 5, introducing our new members: open faces, full of enthusiasm, ready to accept challenges, primed to succeed. They are fresh blood for CeNS, providing airy ideas, novel approaches and paradigm changes. Several members received offers from other institutions which some of them turned down and some accepted - but all kept their CeNS membership and we are proud to still count on them.

CeNS is also especially proud of its numerous awardees! Many members had been granted exclusive honors and page 7 gives only a brief summary. Furthermore, our established spin-off companies continued their successful growth but moreover, our junior founders with their contagious innovative spirit could already convince several juries of business competitions and national contests. As a result they earned several renowned prizes and spurred the foundation of new companies by CeNS members. We are all looking forward to experience the future fruits of this avalanche effect!

In 2008, CeNS also dared to experiment with new meeting formats. Together with the Swiss Nanoscience Institute (SNI) in Basel, we invited junior scientists from all over the world to San Servolo, Venice, to explore nano-solutions for global challenges (page 10). What an eye-opening experience!

And then at the very heart of our activities: Science! Most enjoyably, the number of collaborative, interdisciplinary projects has further increased as much as the number of articles in high impact journals, witnessing the beneficial synergies enabled by the trans-disciplinary bridge of CeNS.

All these successes stimulate our continuous efforts to push for an even livelier cooperation between the best research groups in Munich.

All in all, even after celebrating its 10th anniversary, CeNS still makes much SeNSe and the future looks bright!

Prof. Hermann E. Gaub
Spokesman of CeNS, LMU Munich

NEW MEMBERS

PROF. MATTHIAS CHRISTANDL

LMU Munich

Jun.-Prof. Matthias Christandl joined the LMU as Junior Professor for theoretical and mathematical physics in April 2008. He studied physics at the ETHZ in Zurich and at the Royal Institute of Technology in Stockholm from 1997 to 2002. In 2006, he earned his PhD at the University of Cambridge in the group of Artur Ekert with a thesis entitled "The Structure of Bipartite Quantum States: Insights from Group Theory and Cryptography". Following his PhD he was elected Thomas Nevile Research Fellow at the Magdalene College Cambridge and worked as a PostDoc at the Department of Applied Mathematics and Theoretical Physics in Cambridge. Having accepted a call from the LMU, he now works on theoretical aspects of information processing in quantum mechanical systems aiming at the implementation of secure encryption by using individual quantum bits.

www.asc.physik.uni-muenchen.de/quantuminfo

DR. ANN FORNOF

LMU Munich

Dr. Ann Fornof joined the LMU Munich as postdoctoral research fellow in the group of Prof. Hermann Gaub in October 2007. In 2008, she has been awarded an Alexander von Humboldt Fellowship which will last until 2010. Dr. Fornof is broadly interested in structure-property relationships of synthetic polymers. Her work at LMU Munich is focused on studying the relationship between polyelectrolyte adhesion and surface potential with single-molecule force spectroscopy. Ann Fornof received her PhD in Macromolecular Science and Engineering at Virginia Tech in Prof. Tim Long's group, where her work focused on polymer branching and its influence on non-covalent interactions. After completion of her PhD, she was an IBM postdoctoral fellow for one year at IBM, Almaden Research Center.

www.biophysik.physik.uni-muenchen.de

PROF. ULRICH GERLAND

LMU Munich

Prof. Ulrich Gerland took up an appointment as Associate Professor (W2) in theoretical physics at the Arnold-Sommerfeld Center of the LMU. He is broadly interested in biological physics, with particular focus on single-molecule biophysics and the interplay of molecular interactions in the context of biological functions such as gene regulation. He did his undergraduate and graduate studies in physics at the Universities of Dortmund, Heidelberg, and Paris. His thesis work, with Hans Weidenmüller at the MPI in Heidelberg, was in the area of mesoscopic physics and quantum chaos. He then spent his first PostDoc year in the group of Gerd Schön at the University of Karlsruhe, where he worked with Jan von Delft on the Kondo effect in quantum dots. His keen interest in biological systems emerged during an extended postdoctoral stay with Terry Hwa at the University of California at San Diego, where he worked on RNA folding, gene regulation and molecular evolution. His research continued in this general direction during his stay as Emmy Noether group leader at the LMU Munich (2003-2006) and as Associate Professor at the University of Cologne (2006-2008).

www.theorie.physik.uni-muenchen.de/lsfrey

DR. DORIS HEINRICH

LMU Munich

Dr. Doris Heinrich is interested in biophysics of living cell dynamics and works as a group leader at the chair of Prof. J. Rädler. She graduated with a Master's Degree in Laser-Physics from the University of Texas at Austin/USA. She received her PhD in Semiconductor Physics from the Technische Universität München in the group of Prof. Abstreiter, WSI. Then, she performed her postdoctoral research in Munich, Los Angeles and Heidelberg with Prof. Sackmann, investigating the mechanical properties of the microtubule/actin cross-talk of living cells. Afterwards, she worked as a Business Consultant with McKinsey & Company on several projects in France, the Near-Middle East and the USA.

www.softmatter.physik.uni-muenchen.de

DR. FRANK JÄCKEL

LMU Munich

Dr. Frank Jäckel studied Physics at Humboldt University Berlin (Germany) and Catholic University Leuven (Belgium) from 1996 to 2001. He received his doctorate from Humboldt University Berlin in 2005 where he studied the self-assembly and electronic properties of conjugated molecules by scanning tunneling microscopy under the supervision of Prof. Jürgen P. Rabe. Starting in 2006 Dr. Jäckel worked in the group of Prof. W. E. Moerner at Stanford University (USA) as a postdoc on optical properties of gold bowtie nanoantennas. In June 2008 he joined the group of Prof. Jochen Feldmann at Ludwig-Maximilians-Universität München as Assistant where he works on nanoplasmonics and -photonics as well as single-molecule spectroscopy.

www.phog.physik.uni-muenchen.de

DR. LOTHAR SCHERMELLEH

LMU Munich

Dr. Lothar Schermelleh studied Biology at the LMU Munich, where he also performed his doctoral work under supervision of Prof. Thomas Cremer. He established fluorescence labeling and live cell imaging techniques to study nuclear architecture and the dynamic organization of chromosomes in mammalian cells. After receiving his doctoral degree in 2003 he joined Prof. Heinrich Leonhardt as Assistant. Since then his scientific interest turned towards the functional characterization of DNA methyltransferases with a particular focus on advanced photobleaching techniques and kinetic modeling as well as superresolution light microscopy.

http://anthropologie.bio.lmu.de/forschung/epigenetik/

PROF. CHRISTINA SCHEU

LMU Munich

Before accepting the call for an associate professorship at the LMU Munich, Prof. Christina Scheu has worked at the Montanuniversität Leoben in Austria as a group leader for "Nano and Micro Analytics". Her research focussed on the structural and chemical analysis of materials with high spacial resolution, mainly exploring the chemistry, bonds and structure of interfaces, segregations and nanocrystalline phases using versatile methods of transmission electron microscopy (TEM). The physicist Christina Scheu has joined the LMU Munich in June 2008 as ordinary professor at the Department for Chemistry and Biochemistry in Großhadern. Her field of research is "Transmission Electron Microscopy of Nanostructures".

www.cup.uni-muenchen.de/pc/scheu

DR. FERNANDO D. STEFANI

LMU Munich

Dr. Fernando Stefani studied Materials Engineering in Buenos Aires, Argentina. He carried out his diploma work at the MPI for Polymer Research in Mainz in the group of Prof. W. Knoll where he continued working as PhD student and postdoctoral fellow. During this period, Fernando Stefani investigated the photophysics of single molecules and quantum dots and received the Otto Hahn Medal of the Max Planck Society in 2005. Next, Dr. Stefani moved to the group of Prof. Niek van Hulst at the Institute of Photonic Sciences in Barcelona, Spain. There he worked on two main projects. First, extending the application of ultrafast spectroscopy and coherent control to the nano-scale and in particular to single-molecules. Second, scaling down the radio-wave antenna concepts to the optical regime to manipulate light at the nano-scale. Since March 2008, Fernando Stefani is Assistant in the group of Prof. Jochen Feldmann where he continues his research on the photophysics of single molecules and nano-particles.

www.phog.physik.uni-muenchen.de

DR. FRANK TRIXLER

LMU Munich

Dr. Frank Trixler, is currently a postdoctoral fellow in the group of Prof. Heckl, where he leads the Organic Semiconductor group at the Department of Earth and Environmental Sciences, Section Crystallography (LMU), and at the Center for New Technologies (ZNT), NanoLab, Deutsches Museum. After completing his diploma study in Business Administration and Management at the University of Applied Sciences Munich, Frank Trixler studied Crystallo-graphy at the LMU Munich. He received his Ph.D. in the group of Prof. Wolfgang Heckl with his work on a deposition method for organic semiconductors enabling nanoscale controllable self-assembly. His current research is focused on the development of approaches suitable for ambient conditions to grow complex semiconductor monolayers and nanostructures.

www.nano.geo.uni-muenchen.de/SW

DR. EVA WEIG

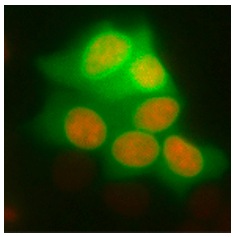
LMU Munich

Dr. Eva Weig studied physics at LMU Munich and the University of Oxford. During her PhD research in the group of Jörg Kotthaus she investigated the interplay of single electron transport and the confined phonon spectrum of freely suspended lateral quantum dots. After finishing her PhD in 2004, she moved on to a postdoc position at the University of California in Santa Barbara. Working in the groups of Andrew Cleland and John Martinis, her research on Josephson phase qubits and superconducting coplanar waveguide resonators was focused on quantum information technology. In April 2007, Eva Weig returned to Munich where she took up a research group leader role in the Kotthaus lab. Her group is investigating the mechanical properties of solid state nanostructures. Her areas of research interest range from dissipation mechanisms of nanomechanical systems over cavity optomechanics of nanoscale resonators to nanoelectromechanical charge transport.

www.nano.physik.uni-muenchen.de/nanomech

NEWS

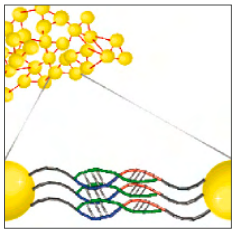
Having received many national and regional awards in the past (e.g. GO-Bio Award, EXIST-Seed Program, MBPW), the CeNS Associates Dr. Ulrich Rothbauer, Dipl.-Biol. Katrin Schmidthals and Dr. Kourosh Zolghadr founded their company **Chromotek** in 2008. The company develops versatile lab tools for proteome research (nanotraps) and fluorescent nanoprobes called Chromobodies® to target and trace antigens in living cells. Due to their small size, their high stability and a very good compatibility with living cells, they can be used, e.g., for pharmaceutical drug development and biomedical research.



chromotek
new tools for better research

http://www.chromotek.com/

The scientists of **nanostove** (Dr. Joachim Stehr, Dr. Federico Bürsgens and Dipl. Biotech. Lars Ullerich) are developing a high-throughput tool offering a much cheaper DNA analysis than possible with conventional techniques. In 2008, they received substantial state funding for starting their business via the program EXIST-Forschungstransfer. The technology is based on binding the DNA sample to small gold nanoparticles which are then heated up by a laser pulse. Using this approach, the melting curve of the attached DNA can be recorded within milliseconds, which is much faster than using conventional techniques.



nanostove

http://www.nanostove.de/

MEMBERS' NEWS

Alex Högele accepted a call as Junior Professor (W1) at the Ludwig-Maximilians-University (LMU) Munich.

Jens Ebbecke accepted a call from the University of Southern Denmark in Sonderborg as Associate Professor.

Thorsten Hugel accepted a call as Associate Professor (W2, tenure track) at NIM and the Department of Physics of the TU München.

Ulrich Gerland accepted a call as Associate Professor (W2) at the Arnold-Sommerfeld Center for Theoretical Physics of the Ludwig-Maximilians-University (LMU) Munich.

Jens Michaelis accepted a call from the Ludwig-Maximilians-University (LMU) Munich as Associate Professor (W2, tenure track) at the Department of Chemistry and Biochemistry.

Hermann Gaub declined a call from the Cavendish Laboratory at the University of Cambridge, U.K.

Andrey Rogach received a call for a Full Professorship at the City University of Hong Kong, China.

AWARDS

>>> The Bayer Science & Education Foundation presented the **Otto-Bayer-Award** to **Prof. Thomas Carell** for his research on light-induced DNA damage. He was additionally elected Member of the German Academy of Sciences "Leopoldina". >>> **Junior-Prof. Matthias Christandl** won the **PhD Award of the German Physical Society (DPG)** for his doctoral thesis entitled "The Structure of Bipartite Quantum States: Insights from Group Theory and Cryptography". >>> **Prof. Patrick Cramer** was rewarded with the **Familie-Hansen-Preis** of the Bayer Science & Education Foundation and received the **Bijvoet Medal** of the University of Utrecht. Moreover, he was appointed Member of the scientific advisory board of the Bavarian state government. >>> The **Alexander-von-Humboldt Foundation** has granted a postdoctoral fellowship to **Dr. Ann Fornof**. >>> **Prof. Peter Hänggi** was honored by the Humboldt University in Berlin with the degree of **Doctor honoris causa**. >>> The German Federal Government bestowed **Prof. Wolfgang Heckl**, General Director of the German Museum, the "**Bundesverdienstkreuz am Bande**" (Cross of the Order of Merit). >>> **Dr. Fritz Keilmann** received the **Kenneth J Button Prize** "for outstanding contributions to the science of the electromagnetic spectrum". >>> **Prof. Jörg P. Kotthaus** was appointed **Research Professor** by the Ludwig-Maximilians-University in the framework of the excellence program LMU*excellent*. >>> **Dr. Florian Marquardt** was given the **Walter-Schottky Award** 2009 of the German Physical Society (DPG). >>> **Prof. Don C. Lamb** was named **Watkins Visiting Professor** of the Wichita State University (USA) for the fall semester of 2008. >>> **Prof. Heinrich Leonhardt** received the **Binder-Innovation-Award** of the German Society for Cell Biology (DGZ). >>> **Dr. John Lupton** won a Fellowship of the **David and Lucile Packard Foundation** "to develop and apply optical techniques in the study of the physical properties of nanoscale structures". >>> **Dr. Andrey Rogach** has been appointed **Adjunct Professor** at Trinity College Dublin. >>> **Prof. Ulrich Schubert** is the recipient of an **Invention Award** of the Dutch Polymer Institute (DPI). >>> **Dr. Eva Weig** was selected for the **Fast Track Program** of the Robert-Bosch-Foundation. >>> CeNS Associates Dr. Federico Bürsgens and Dr. Joachim Stehr were given substantial funding by the German Government in the framework of the **EXIST-Forschungstransfer** for the creation of their company **NanoStove**. Furthermore they were among the winners of the **Munich Business Plan Contest** (MBPW). >>> The CeNS spin-off company **Attocube Systems AG** achieved several **Entrepreneurship and Technology Awards** (Deutscher Gründerpreis, Münchner Gründerpreis, Deloitte Technology Fast 50 Award) and was chosen for the German-wide contest "**Ort im Land der Ideen**". >>>

SMALL IS BEAUTIFUL

The successful CeNS spin-off company attocube systems AG was founded in 2001 by the two CeNS members Dr. Dirk Haft and Prof. Khaled Karrai. The product portfolio of the dynamic young company includes nanometer-precise positioning tools and scanning probe microscopes for extreme environments. In 2008, the management team won many prizes and started a joint partnership with the company Wittenstein AG who purchased 74% of attocube systems. Prof. Karrai, Chief Technical Officer (CTO) of attocube systems, is a founding member of CeNS and was Associate Professor at the LMU Munich from 1995 to 2006.

Prof. Khaled Karrai, you co-founded attocube systems in 2001, at a time when you were Associate tenured Professor at the LMU Munich. What was your motivation to become an entrepreneur and what was your initial business idea?

The initial business idea is still the present goal of our business: instrumentation to explore the nano-world under extreme physical conditions. The instrumentation ranges from positioning solutions to scanning probe microscopes. Extreme physical conditions are cryogenic temperatures, very high magnetic and electric fields, ultra high vacuum or even full liquid immersion. The development of such tools seemed to be a robust market niche which turned out to be true.

Initially as a faculty of CeNS I was more interested in the idea of helping a start-up to find its roots in our research labs and help it grow using the multitude of ideas and original instrumentations we developed. The opportunity to think about starting a company based on our own development was offered to almost every Diploma and PhD student who graduated from the group and this since the early 90's. The real trigger of the venture was eventually Dirk Haft who at that time was a young and very entrepreneurial PhD candidate. He was the first to act on the opportunity - this was in 1999. He motivated a couple of graduate students and me to join him in participating in the Munich Business Plan Competition in 2000. I was really impressed when our team won the 1st prize after 9 months of very hard work. Today, Dirk Haft is the CEO of atto**cube** systems — the young student of the early days is a dynamic and visionary entrepreneur now and we are all very proud of him!

My motivation to become an "entrepreneur"? I do not have an easy answer ready to such a question but here is an attempt: I definitely loved being part of the motivated and successful research team I had the privilege to supervise at the LMU Munich. But at the same time I found at atto**cube** systems an equally motivated and talented team. You can imagine how difficult it was to leave the first in order to join the second! What tipped the decision was probably the prospect of learning something fundamentally new to me together with the atto**cube** team, namely aspects of business management in conjunction with overcoming industrial technological challenges that I would not have encountered otherwise. By the way: I would wish this experience to many entrepreneurial scientists and colleagues, but in my view even today, there is still a gap between university and industry, and I understand the hesitation an established scientist would have facing the choice between academia and entrepreneurship.

Which role did CeNS play in the foundation of attocube systems?

When we started our plan to set up a company CeNS was still a very young structure collecting a group of pioneers working on nanoscience. The role CeNS played (and still plays) was to offer a very stimulating and motivating atmosphere for start-up companies that was needed so much. Many of the great discussions delineating the future of atto**cube** took place during the first CeNS conference in Venice. Here again the atmosphere created by CeNS played a very positive role opening our eyes for the great opportunities of the world of research in nanoscience and nanotechnologies.

Did you receive any external funding for starting your company? When did you reach break-even?

In 2001, a team of four of us won the first prize in the Munich Business Plan Contest endowed with 25'000 € and that was our starting budget. Dirk Haft also met very early with Dr. S. Reineck who at the moment is president of the board of directors of atto**cube**. He was one of the first active shareholders with experience in industry and participated with a similar modest funding to start the company. The first two staff members were also partly supported by the "Flügge-Programme". We were already break-even in the first few months.

How many employees has attocube systems at present and how many of them are physicists?

There are about 30 employees and nearly half of them are physicists.

Who are your major customers and to which countries do you export your products?

Our customers are evenly distributed across Europe, America (North and South) and Asia (Japan, Taiwan, China, India). They are mostly researchers at Universities and research institutions. However, the number of industrial clients among our customers is increasing.

In September 2008, the company Wittenstein AG purchased 74% of attocube systems. What are your expectations regarding this partnership and what changes will this imply?

This merger was a strategic partnership for both, atto**cube** systems AG and Wittenstein AG. Entering the industrial market with scientific instrumentations requires more than having the "perfect product"; it also requires to master many processes such as production processes, quality related processes, services and distribution processes that are specific to robust and established industries. Having a strong partnership in this area is fundamental to reach this goal. An industrial customer usually examines the credentials of a supplier company quite carefully and this well beyond the technical specifications of the products offered. The industrial customers need to know that they deal with a robust and trustworthy provider who could provide support over decades if necessary. Small start-ups evidently suffer from a lack of long history and experience. Wittenstein AG offers the proper backing and synergies atto**cube** needed to address industrial customers. In return atto**cube** provides access to new technologies and new business ideas in nanotechnologies that will become important in

the near future in order to fulfill the customers' expectations for precision positioning in the sub-micrometer range as well as analytical measurement devices required for the exploration of the nanoworld.

Which qualities does a researcher need to become a successful entrepreneur and what would you advise those who plan to start a business?

In fact I realized that the qualities required are very similar to the ones required in order to be a good researcher: visions, passion, obsession and … hard work. As in the field of research, success is closely related to strong teams. But there is a difference: in the entrepreneurial field there is only room for team players: the losses due to individualistic behavior are so high for any company that this inefficient attitude is corrected almost immediately. I am not long enough in the field to provide you with a recipe for success as entrepreneur, but the first thing would be to sharpen your skills identifying the right people, understanding their strengths and weak points, and to focus on organizing strong teams and networks while at the same time developing a vision for what the world needs from you. But you see, this would apply to science as well. Don't be in love with your technology but rather be obsessed with what your technology would enable and frequently test your ideas for reality; check against the real needs of the market - if you found a customer this means that you passed the test! If you have a first prototype that offers some new applications to the user, don't wait for your product to be perfect because it will never get perfect... get it in the market first and use the market as the perfect test ground: it will immediately tell you what you need to improve. But then you have to face the criticism and react to it quickly in order not to disappoint the customer. ➤

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*Dirk Haft (left, CEO) and Khaled Karrai (right, CTO) of atto**cube** systems.*

GLOBAL CHALLENGES & NANO

With the goal to raise the awareness of the next generation of nanoscientists to the global challenges of our world, CeNS organized a workshop jointly with the Swiss Nanoscience Institute (SNI), addressing these problems looming on the horizon. As a key technology of this century, nanotechnology is expected to play a leading role in the development of solutions for our global challenges. Raising the awareness for these emerging challenges, particularly amongst the future generation of scientists, seems essential for the development of successful solution strategies. Since these global challenges will require internationally consorted efforts, the creation of a network of those scientists who will sculpt our scientific and technological future seems essential.

To initiate such a network, CeNS and SNI invited 40 senior PhD students and postdoctoral researchers from all over the world to a workshop under the motto "Global Challenges and how Nanotechnology can help". The event was held at the Venice International University on the island of San Servolo from April 20th to 24th, 2008. The organizers, Prof. Hermann Gaub (CeNS) and Prof. Christoph Gerber (SNI) put a particular emphasis on inviting students from developing and threshold countries and establishing ethnic and gender balance. As co-organizing institutions, the Abdus Salam Institute for Theoretical Physics in Trieste, the Chinese Academy of Sciences and the Indian Institute of Technology in Madras were integrated and sent their chosen delegates. At the workshop, the multicultural group of participants discussed the global challenges as research opportunities and tried to identify those topics on which nanotechnological solutions could be developed. This process was enabled by several rounds of group discussions which were summarized and shared with the other participants by short presentations of each subgroup. At the end of the event, several small teams came up with ideas of nanotechnological contributions to a specific global problem they were particularly concerned with. These intensive discussions were also prolonged into the evening which the participants enjoyed in the charming streets of Venice, thus strengthening their network which was established during the day.

www.cens.de/calendar/past-events/workshop-global-challenges ➤

CeNS WORKSHOP VENICE

The CeNS workshop in Venice in 2008 was held from September 29th to October 3rd under the title: "Complex Nanosystems: Assembly, Control and Functionality". The event brought together more than 120 young researchers and experienced scientists from physics, chemistry, biology and medicine to discuss about latest scientific advances in the field of nanosciences.

Internationally renowned researchers from Japan, the USA, Canada and Europe as well as scientists from CeNS were invited for lectures on topics ranging from molecular machines, bio-mineralization, artificial viruses to quantum dots, optomechanics and spintronics. The scientific program was enriched by stimulating poster presentations of the junior nanoscientists from CeNS whereby some of the posters were selected for short oral presentations. Thanks to the enchanting atmosphere of Venice, the lively discussions between participants and speakers of the workshop were extended far beyond the official schedule, fostering and initiating research cooperations within CeNS and worldwide. ➤

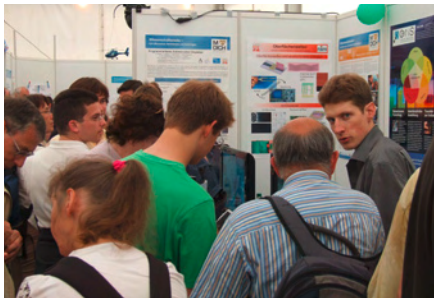
JUNIOR NANOTECH NETWORK - JNN '08

How can one maximize the transfer of knowledge between PhD students from different institutes and countries in an efficient, economic and enjoyable way? To do so, Prof. Hermann Gaub (CeNS) and Prof. Peter Grütter from McGill University in Montréal, Canada, developed a scheme for a PhD student exchange program which is based on the idea that each participant teaches his/her specific scientific topic to his/her peer students and at the same time receives teaching from all other participants. This project named "Junior Nanotech Network" was launched in 2006 and its success led to its second round in 2008 where PhD students in nanosciences from McGill University and CeNS joined together for an intensive 3-weeks program composed of lectures and laboratory works. To guarantee social integration of the guests, the visiting researchers were housed at the homes of their local exchange partners. This close interaction fostered the scientific and intercultural exchange and created a strong network between the participating nanoscientists.

www.cens.de/calendar/past-events/jnn ➤

"OIS IS NANO" — EVERYTHING IS NANO!

At the celebration of the 850th birthday of Munich, CeNS was invited to offer insights into the world of nanotechnology by interactive experiments. Together with the Nanosystems Initiative Munich (NIM), a team of junior scientists showed nano-experiments and explained the basics of nanosciences to the numerous highly interested citizens of Munich who visited the joint booth of



CeNS and NIM during the two days of the celebration. Besides experiments on how to produce electricity from raspberries and sunlight, how to manipulate and mix nano-droplets and a demonstration of the functioning of an atomic force microscope, Prof. Christina Scheu and Prof. Bianca Hermann gave introductory talks about nanosciences to a large, attentive audience. Thanks to the motivated, very competent young researchers who presented a small insight into nanoscience, this event was a great success for CeNS and NIM. ➤

CeNS MEETS INDUSTRY '08

Once a year, CeNS invites representatives from industry to present their company and employment possibilities to the CeNS community. At the meeting in 2008, the following speakers gave insights into their company and their jobs: Dr. Johannes Averdung (Evonik Degussa GmbH), Dr. Petra Denk (E.ON Energie AG), Dr. Jan Van Hoeymissen (IMEC), Dr. Ferdinand Kühner (Linde AG) and Dr. Werner Stock (Roche Diagnostics GmbH). The event was followed by the traditional summer party where about 140 CeNS members took the opportunity to discuss with the speakers and to strengthen the network of CeNS members and alumni in an informal setting. ➤

ENTREPRENEURSHIP SEMINAR

In collaboration with the Entrepreneurship Center of the LMU, the International Doctorate Program NanoBioTechnology offered their members a three-day introduction into entrepreneurship covering many aspects, especially the business plan and the early financing of start-ups. The seminar mixed theory, guest lectures and practical exercises, featuring successful entrepreneurs and specialists who shared their knowledge and experience with the participants. ➤

IDK-NBT SUMMER SCHOOL

During three summer days in July, about 20 PhD students of the International Doctorate Program NanoBioTechnology of the Center for NanoScience stayed at the beautiful location of "Haus Aiterbach" at lake Chiemsee. There, the multicultural group of students took advantage of the time spent together to exchange new scientific ideas, strengthen their network and to practice their presentation skills. To put a special emphasis on the personal engagement and motivation of the students, the program of the summer school was planned by the PhD students themselves, under the guidance of the speaker of the doctorate program, Prof. Joachim Rädler.

The scientific schedule consisted of short presentations of each PhD student, giving a comprehensive and diverse overview on the different research topics that are investigated by the participants in the framework of their doctoral thesis. The presented subjects were discussed afterwards in smaller groups where the participants could develop multidisciplinary research concepts, initiate scientific collaborations and exchange knowledge. Complementary to the students' presentations, the invited guest speaker, Dr. Fernando D. Stefani shared his experience in scientific research and discussed academic career options with the participants of the summer school.

At the end of the three days, the participating PhD students were enthusiastic about their summer school and praised the efficient exchange of scientific knowledge and personal experience that took place within the multidisciplinary group. ➤

CeNS 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

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. Since 2008, the lectures of the series are recorded and are available online for the members of CeNS.
www.cens.de/calendar/lecture-series

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.

PATENTS

J. Stehr, T. A. Klar, J. Feldmann, C. Hrelescu, W. Parak, G. Raschke, R. Sperling, M. Wunderlich, K. Kürzinger, D. Heindl, A. Nichtl: *Process for detecting nucleic acids;* PCT/EP 2008/056505

D. Koenig, Joerg P. Kotthaus: *Vorrichtung und Verfahren zum Ladungstransfer;* DE 10 2007 034 072 B3

Q. Unterreithmeier: *Hochfrequenzantrieb und Detektion elektromechanischer Systeme;* submission no. 08013200.4-1233

K. Zolghadr, O. Mortusewicz, U. Rothbauer, H. Leonhardt: *Fluorescent two-hybrid assay to study protein interactions in living cells;* EP 08 00 0297.5

J. T. Delaney, U. S. Schubert: *Method for generation of metal surface structures and use of silver complex for forming surface patterns;* PCT/EP 2008/003481

J. T. Delaney, U. S. Schubert: *Macroporous polymeric crosslinked materials, method for manufacture thereof and use;* EP 08018399.9

P. Kröber, J. T. Delaney, U. S. Schubert: *Method of enhancing the contrast of surfaces and use thereof;* EP 08020154.4

G. Romero, J. J. García-Ripoll, and E. Solano: *Photodetection and Photocounting of single microwave photons;* SPA 200802933

P. Tinnefeld, M. Sauer: *Method for improvement of photostability of fluorescent dyes used for labeling DNA and other biomolecules;* PCT Int. Appl., 55pp. WO 2009003948

A. Wixforth, T. Franke, L. Schmid: *Bläschen, sowie Verfahren zur Herstellung und Manipulation von Bläschen;* DP 10 2008 005 673.1

PHD THESES

Karla de Bruin: *Internalization and photoinduced endosomal release of polyplexes studied on a single cell level* (LMU, Christoph Bräuchle); **Poornachandra Sekhar Burada:** *Entropic transport in confined media* (Universität Augsburg, Peter Hänggi); **Alex Darga:** *Sorption isotherms of volatile molecules on micro- and mesoporous nanosized siliceous materials based on acoustic wave devices. Determination of corresponding isosteric heats of adsorption* (LMU, Thomas Bein); **Roland Doll:** *Decoherence of spatially separated quantum bits* (Universität Augsburg, Sigmund Kohler and Peter Hänggi); **Jörn Dunkel:** *Relativistic Brownian Motion and Diffusion Processes* (Universität Augsburg, Peter Hänggi); **Carolin Fella:** *Dynamic and effective gene vectors via pH-sensitive PEG-shielding* (LMU, Ernst Wagner); **Hendrik Van Heyden:** *Silico-Aluminophosphates; Synthesis and Application for Heat Storage and Transformation* (LMU, Thomas Bein); **Yoshihiko Katayama:** *3D particle tracking in cellular systems* (LMU, Don Lamb and Christoph Bräuchle); **Johann Kecht:** *Colloidal Porous Nanoparticles – Synthesis and Functionalization of Nanostructured Aluminosilicates and Silicas* (LMU, Thomas Bein); **Veronika Knorr:** *pH-sensitive linkage for controlled disassembly of gene vectors* (LMU, Ernst Wagner); **Johannes Kobler:** *Thin Films from Porous Nanoparticles* (LMU, Thomas Bein); **Daniel König:** *Nano-mechanischer Einzel-Elektronen-Transistor* (LMU, Jörg P. Kotthaus and Eva Weig); **Martin Kroner:** *Resonant photon-exciton interaction in semiconductor quantum dots* (LMU, Alexander Holleitner and Khaled Karrai); **Stefan Kufer:** *AFM-basierte Assemblierung biomolekularer Bausteine auf Festkörperoberflächen* (LMU, Hermann E. Gaub); **Christian Leirer:** *Dynamik und Struktur in der Phasenkoexistenz von Lipidmembranen* (Universität Augsburg, Achim Wixforth and Matthias F. Schneider); **Madeleine Leisner:** *Genetic switching into the competent state - Bacillus subtilis: a single cell approach* (LMU, Joachim Rädler); **Robert Lugmaier:** *Kraftspektroskopie an molekularen und supramolekularen biologischen Strukturen* (LMU, Martin Benoit and Hermann E. Gaub); **Moritz Mickler:** *Kinetik des ATPase-Zyklus von Hsp90 in Einzelmolekülexperimenten* (TUM, Thorsten Hugel); **Tobias Munk:** *Complex Transport Processes in Suspensions of Stiff Polymers* (LMU, Thomas Franosch and Erwin Frey); **Elias Puchner:** *Einzelmolekül-Mechanoenzymatik* (LMU, Hermann E. Gaub); **Huihong Qian:** *Tip-enhanced near-field optical spectroscopy on single-walled carbon nanotubes* (LMU, Achim Hartschuh); **Tobias Reichenbach:** *Dynamic Patterns of Biological Systems: From Transport to Species Diversity* (LMU, Erwin Frey); **Moritz Ringler:** *Plasmonische Nahfeldresonatoren aus zwei biokonjugierten Goldnanopartikeln* (LMU, Jochen Feldmann); **Clemens Rössler:** *Elektronische und optische Eigenschaften freitragender Nanostrukturen* (LMU, Jörg P. Kotthaus and Stefan Ludwig); **Verena Russ:** *Novel degradable pseudodendritic oligoamines for in vitro and in vivo gene delivery* (LMU, Ernst Wagner); **Julia Schmitz:** *Cell Adhesion mediated by the Integrin VLA-4* (LMU, Kay Gottschalk and Hermann E. Gaub); **Alenka Schwerdt:** *Hyperthermia for release of macromolecular therapeutics in animal model studies* (LMU, Ernst Wagner); **Felix Sedlmeier:** *Interfacial water - structure, waves and films* (TUM, Roland Netz); **Christian Sendner:** *Interfacial Polymer and Water Dynamics* (TUM, Roland Netz); **Ioana Serban:** *Nonlinearities in the quantum measurement process of superconducting qubits* (LMU, Frank Wilhelm and Jan von Delft); **Kumudesh Sritharan:** *Application of Surface Acoustic Waves* (SAW) for chemical and biological analysis (Universität Augsburg, Achim Wixforth and Matthias F. Schneider); **Joachim Stehr:** *Gold-Nanopartikel als Nano-Heizplatten für optothermisches DNA-Schmelzen* (LMU, Jochen Feldmann); **Daniel Steppich:** *The Physics of von Willebrand Factor* (vWF) (Universität Augsburg, Achim Wixforth and Matthias F. Schneider); **Stephan Wörmke:** *Single Molecule Spectroscopy on Native and Reconstituted Peridinin-Chlorophyll-Protein Light-Harvesting Complexes* (LMU, Christoph Bräuchle); **Ayhan Yurtsever:** *Nanotribological surface characterization by frequency modulated torsional resonance mode AFM* (LMU, Robert Stark); **Julia Zimmermann:** *Dissociation properties of biomolecules under an externally applied force* (LMU, Hermann E. Gaub)

DIPLOMA & MASTER THESES

Irvan Afandi: *Electrical characterization of silicon nanowires as novel channel materials for field effect transistors* (Universität Augsburg, Achim Wixforth and Henning Riechert); **Bizan Balzer:** *Haftung und Reibung von Einzelpolymeren auf Festkörperoberflächen in wässrigem Medium* (TUM, Thorsten Hugel); **Daniel Beckmeier:** *In-situ study of electronical properties of pentacene transistors during growth* (LMU, Joachim Rädler and Bert Nickel); **Alexander Buchner:** *Bose-Fermi-Kondo-Modell* (LMU, Stefan Kehrein); **Stefan Bössinger:** *Entwicklung eines mikrofluidischen AFM-Hybridaufbaus zur Untersuchung von Adhäsionsphänomenen* (Universität Augsburg, Achim Wixforth and Matthias F. Schneider); **Bor Kae Chang:** *Characterization of deformation and motion of red blood cells in linear shear fields* (Universität Augsburg, Achim Wixforth and Thomas Franke); **Peter Colberg:** *Parallelization of Molecular Dynamics Simulations on Graphics Processing Units* (LMU, Thomas Franosch and Erwin Frey); **Benjamin Ehlers:** *Kompetitiver Hapten Immunoassay mit Goldnanopartikeln* (LMU, Jochen Feldmann); **Barbara Englert:** *Mesoscopic Shelving Readout of Superconducting Qubits in Circuit Quantum Electrodynamics* (LMU, Enrique Solano); **Mohammad A. Fallah:** *SAW induced acoustic streaming in microchannels of different geometry* (Universität Augsburg, Achim Wixforth and Thomas Franke); **Katja Falter:** *Differential Force Measurements on Nucleic Acid Aptamers – Analysis of the Affinity of Aptamers to their Ligands* (LMU, Hermann E. Gaub); **Florian Feil:** *Untersuchungen hexagonaler und lamellarer mesoporöser Strukturen mit Terrylendiimid-Farbstoffen als molekulare Sonden* (LMU, Christoph Bräuchle); **Andreas Fischer:** *Funktionalisierte Nanopartikel als Drug-delivery-Systeme* (TUM, Fritz Simmel); **Carsten Forthmann:** *Entwicklung eines Mikroskopie-Verfahrens mit nicht beugungsbegrenzter optischer Auflösung auf der Basis von generierten Dunkelzuständen* (LMU, Philip Tinnefeld); **Daniel Fuhrmann:** *Akusto-optische Untersuchungen von Quantenstrukturen auf II-IV Halbleiter-Basis* (Universität Augsburg, Achim Wixforth and Jens Ebbecke); **Géraldine Haack:** *Faster Gates for Quantum Computing and Simulations in Circuit QED* (LMU, Enrique Solano); **Patrick Heißler:** *Einflüsse magnetischer Felder auf konjugierte Polymere* (LMU, Jochen Feldmann); **Samira Hertrich:** *Röntgenreflektivitätsmessungen an substratgestützten Membranen* (LMU, Joachim Rädler and Bert Nickel); **Holger Hesse:** *Direct imaging of neurofilament proteins and aligned networks using microchannel methods* (LMU, Joachim Rädler); **Steven Huth:** *Ausrichtung von Kohlenstoffnanoröhren mit Dielektrophorese* (Universität Augsburg, Achim Wixforth and Jens Ebbecke); **Axel Kammerer:** *Anomalous transport in heterogeneous materials* (LMU, Thomas Franosch); **Jörg Kinzel:** *Niederdimensionaler Ladungstransport in dünnlagigen Graphensystemen* (Universität Augsburg, Achim Wixforth and Jens Ebbecke); **Michael Konrad:** *Trennung chiraler Objekte in Mikroströmungen* (Universität Augsburg, Achim Wixforth and Thomas Franke); **Jonas Kraus:** *Hydrodynamics in nano- and microscale* (LMU, Thomas Franosch); **Wolfgang Kügel:** *Untersuchungen an RNA Polymerase II Elongationskomplexen mit einer Optischen Pinzette* (LMU, Jens Michaelis); **Carolin Leonhardt:** *Kraftspektroskopie an menschlichen und murinen Thrombozyten und Melanomzellen mit dem AFM* (LMU, Martin Benoit and Hermann Gaub); **Thomas Limmer:** *Optische Spektroskopie an einzelnen kolloidalen CdSe/CdS Tetrapod Heterostrukturen* (LMU, Jochen Feldmann); **Christine Lux:** *AC-Starkeffekt Messungen an einzelnen ladungsdurchstimmbaren Quantenpunkten* (LMU, Alexander Holleitner and Khaled Karrai); **Anindya Majumder:** *Low contact resistance for dielectrophoretically aligned carbon nanotubes* (Universität Augsburg, Achim Wixforth and Markus Regler); **Norma Minar:** *Photovoltaic Devices* (LMU, Thomas Bein); **Michael Müller:** *Switching Phenomena in a Disordered System of Two Coupled Quantum Wires* (LMU, Jörg P. Kotthaus and Stefan Ludwig); **Edward Platt:** *WKB Analysis of Tunnel Coupling In a Simple Model of a Double Quantum Dot* (LMU, Frank Wilhelm and Joseph Paldus); **Melanie Riederer:** *Synthese von funktionalisierten mesoporösen Silica-Strukturen in den Poren von Aluminiumoxid-Membranen* (LMU, Thomas Bein); **Boris Schaefer:** *Non-affine elasticity of biopolymer networks* (LMU, Erwin Frey); **Stefan Schwalb:** *Charakterisierung des Resonanzverhaltens piezoelektrisch getriebener nanomechanischer Resonatoren aus zugverspanntem Siliziumnitrid* (LMU, Eva Weig); **Alexander Schwemer:** *Purcelleffekt in nanoskopischen Plasmon-Resonatoren* (LMU, Jochen Feldmann); **Philip Severin:** *Differentielle Kraftmessungen von Protein-DNA-Wechselwirkungen* (LMU, Hermann E. Gaub); **Christian Späth:** *Aufbau eines 2-Photonen Fluoreszenz-Korrelations-Spektroskopie Mikroskops* (LMU, Joachim Rädler); **Olav Stetter:** *Stimulation von Säugetier-Neuronen mit TiO_2/Al_2O_3/Si-Kondensatoren* (LMU, Joachim Rädler); **Johannes Stigler:** *Nanoparticle-Cell-Interaction* (LMU, Joachim Rädler); **Tobias Stögbauer:** *Phasenseparation und Genexpression in substratgebundenen Liposomen* (LMU, Joachim Rädler); **Mathias Strackharn:** *Aufbau eines kombinierten TIRF-AFM-Mikroskops und Durchführung von Einzelmolekül-Experimenten* (LMU, Hermann Gaub); **Daniela Taubert:** *Wechselwirkungseffekte in parallelen und seriellen Doppelquantenpunktstrukturen* (LMU, Jörg P. Kotthaus and Stefan Ludwig); **Juan Torreno-Pina:** *Interaktionen zwischen Rad26 und RNA Polymerase II Elongationskomplexen untersucht mittels Einzelmolekülspektrokopie* (LMU, Jens Michaelis); **Kordelia Troll:** *Thermoresponsive Mizellen aus amphiphilen Diblockcopolymeren* (LMU, Joachim Rädler); **Martin Tschöpe:** *Entwicklung eines AFMs für Screening-Anwendungen* (LMU, Martin Benoit and Hermann Gaub); **Anton Winkler:** *Renormalization arguments on species coexistence far from equilibrium* (LMU, Erwin Frey) ➤

HABILITATIONS

Dr. Stefan Ludwig: From glasses to coupled quantum dot devices
(Prof. Jörg P. Kotthaus)

Dr. Bert Nickel: *An experimental study of the structure and function of organic thin films and biomembranes*
(Prof. Joachim Rädler)

Dr. Jens Ebbecke: *Nanoacoustics on semiconductor quantum structures*
(Prof. Achim Wixforth)

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Optical detection of single-electron spin resonance in a quantum dot

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Nano-mechanical single-electron shuttle

Nano positioning system

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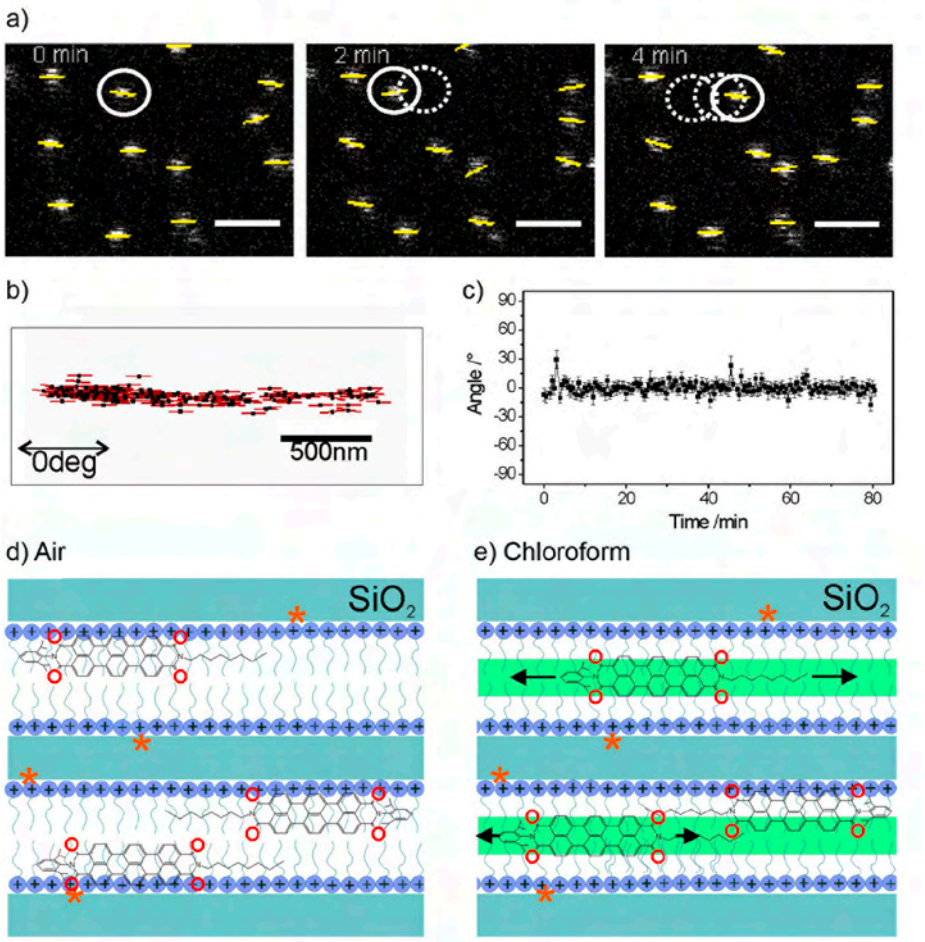
Organophosphonate-based PNA functionalization of silicon nanowires for label-free DNA detection

SELECTED RESEARCH PROJECTS

DIFFUSION OF ORIENTED SINGLE MOLECULES WITH SWITCHABLE MOBILITY IN NETWORKS OF LONG UNIDIMENSIONAL NANOCHANNELS

Prof. Thomas Bein (LMU Munich)
Prof. Christoph Bräuchle (LMU Munich)
Prof. Irmgard Frank (Gottfried-Wilhelm-Leibniz-Universität Hannover)
Prof. Jens Michaelis (LMU Munich)

Mesoporous host materials form one of the key materials in nanotechnology, because their nanometer sized channels provide room for guest species at the molecular level. Applications of these pore systems include novel drug delivery materials, catalysts, scaffolds for conducting nanoscale wires and chromatography. For most of these examples a good understanding and control of the diffusion of guest molecules within the nanometer-sized channels are required. Single dye molecules incorporated into a mesoporous matrix can act as highly sensitive reporters of their environment. Here, single TDI molecules are used incorporated as guests into hexagonal mesoporous films containing highly structured domains. The dye molecules allow us to map the size of these domains which can extend to over 100 µm. Investigation of the translational and orientational dynamics via single molecule fluorescence techniques gives structural as well as dynamical information about the host material. A switching effect between stop and go of the guest molecules was discovered using dry air or a saturated atmosphere of chloroform above the mesoporous film. In addition, single molecule measurements with very high positioning accuracy (down to 2-3 nm) could be conducted revealing the presence of defects like dead ends closing the pores or small openings in the silica walls between neighboring channels, where molecules can change from one channel to the next. A statistical analysis demonstrates that the diffusion of TDI in the mesoporous film cannot be described with a 1D-random diffusion but is more complicated due to the presence of adsorption sites in which the TDI molecules can be occasionally trapped. ➤



Parallel orientation and diffusion of single TDI molecules in a highly ordered domain. a) Sequence of fluorescence images showing linear diffusion of single TDI molecules in a chloroform atmosphere extracted from a time series. Scale bar: 2 µm. b) Trajectory extracted from the molecule marked with the white circle in a). c) Calculated angular time trajectory of the same molecule. d) Sketch of TDI molecules immobilized in the mesoporous film in air atmosphere. The stars indicate active silanol groups. e) TDI molecules in the mesoporous film in the presence of chloroform. The solvent provides a lubricant for the molecular movement.

Christophe Jung, Johanna Kirstein, B. Platschek, Thomas Bein, M. Budde, Irmgard Frank, Klaus Müllen, Jens Michaelis, Christoph Bräuchle; J. Am. Chem. Soc. 130, 1638 (2008)

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

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

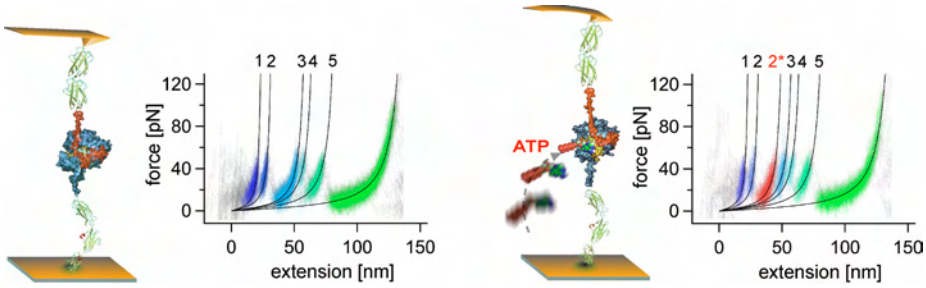
Frank: *http://www.theochem.uni-hannover.de/*

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

ENZYMES UNDER FORCE

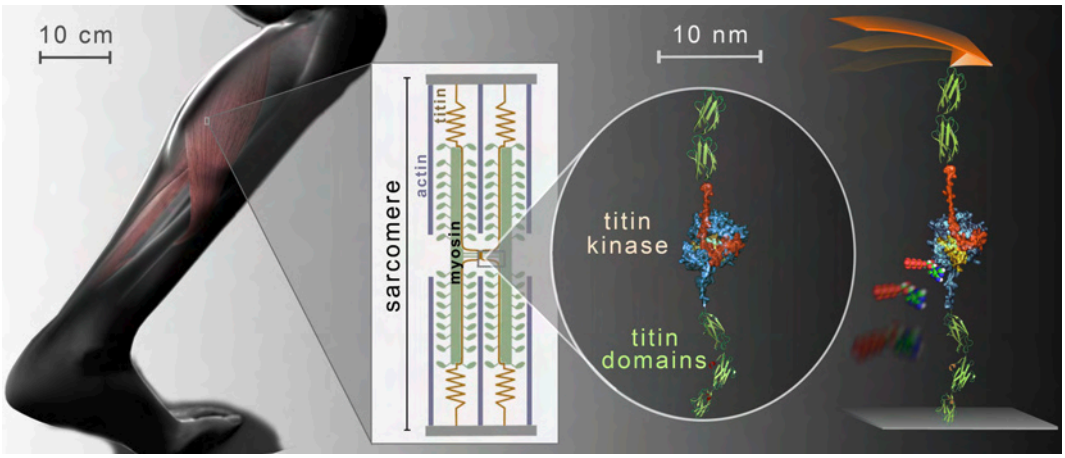
Prof. Hermann E. Gaub (LMU Munich)

Biological responses to mechanical stress require strain-sensing molecules, whose mechanically induced conformational changes are related to signaling cascades mediating changes in cell and tissue properties. In vertebrate muscle, the giant elastic protein titin is involved in strain sensing via its C-terminal kinase domain at the sarcomeric M-band and contributes to the adaptation of the muscle in response to changes in mechanical strain. The enzymatic activity is regulated in a unique dual autoinhibition mechanism by a C-terminal regulatory tail, blocking the ATP binding site and tyrosine autoinhibition of the catalytic base. In this project, AFM-based single-molecule force spectroscopy, molecular dynamics simulations, and enzymatics were applied to study the conformational changes during strain-induced activation of the titin kinase. Mechanical strain activates ATP binding before unfolding of the structural titin domains, and the kinase can thus act as a biological force sensor. Furthermore, the steps in which the autoinhibition of the titin kinase is mechanically relieved at low forces were identified, leading to binding of the cosubstrate ATP and priming the enzyme for subsequent autophosphorylation and substrate turnover.



Comparing barrier densities in titin kinase unfolding experiments reveals two unfolding pathways of the kinase (red).

Applying increasing mechanical tension to the titin kinase a stepwise unfolding is recorded in force extension traces. However, since the energy barriers of the folding potentials are often close to the thermal energy, both the extensions and the forces at which these barriers are overcome are subject to marked fluctuations. Therefore, the classical force extension traces are an inadequate representation despite widespread use, particularly when large populations of proteins need to be compared and analyzed. In this project, it turned out that contour length, independent of fluctuations and alterable experimental parameters, is a more appropriate variable than extension. By transforming force extension traces into contour length space, histograms are obtained that directly represent the energy barriers. In contrast to force extension traces, such barrier position histograms can be averaged to investigate details of the unfolding potential. The cross-superposition of barrier position histograms allows to detect and visualize the order of unfolding events. In contrast to the sequential unfolding of bacteriorhodopsin, the two main steps in the unfolding of the enzyme titin kinase are independent of each other. The potential of this new method for accurate and automated analysis of force spectroscopy data and for novel automated screening techniques is proved in this project. ➤



Muscle protein under tension: Upon stretching the titin kinase, which acts as the force sensor of the muscle, the binding site of this molecule opens up and enables the small ATP molecules to bind to it. The thereby triggered chemical signal controls the growth and repair of the muscle.

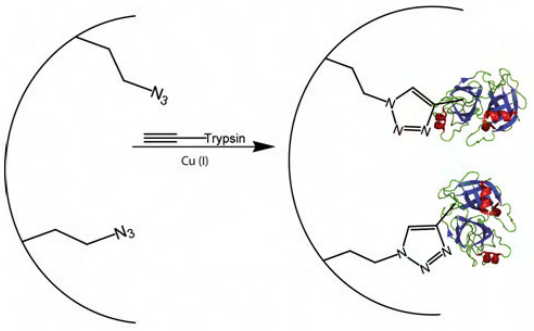
Elias M. Puchner, A. Alexandrovich, A. L. Kho, U. Hensen, L. V. Schäfer, B. Brandmeier, F. Gräter, H. Grubmüller, Hermann E. Gaub, M. Gautel; PNAS 105, 13385 (2008)

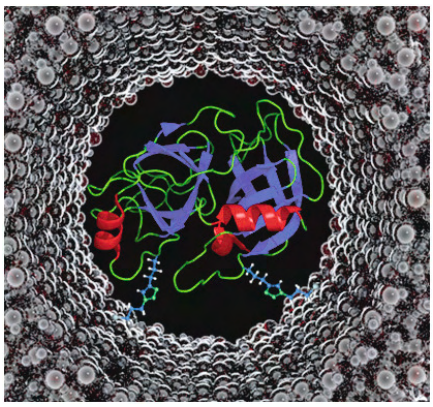
Gaub: *http://www.biophysik.physik.uni-muenchen.de/*

CLICK CHEMISTRY FOR HIGH-DENSITY BIOFUNCTIONALIZATION OF MESOPOROUS SILICA

Prof. Thomas Bein (LMU Munich)
Prof. Ernst Wagner (LMU Munich)

Supported enzymes on mesoporous solids such as mesoporous silica have many possible applications in biotechnology, including synthesis and purification of fine chemicals and catalysis for green chemistry. However, it has been shown that non-covalent interactions between mesoporous silica materials and proteins are too weak to prevent the absorbed biomolecules from leaching out of the pore system during reaction, thus leading to relatively low loading levels and low activity. Therefore, the challenge of covalently attaching active, functional biomolecules at the large internal surface of periodic mesoporous materials has attracted increasing attention. Despite these growing research efforts, so far the stability and the attachment density as well as the biological activity achieved with various functionalization strategies have not met expectations. The groups of Ernst Wagner and Thomas Bein collaborate to address these challenges. In a recent paper they present the covalent attachment of the enzyme trypsin to the internal surface of large-pore SBA-15 silica spheres. Using click chemistry based on the reaction of azide-functionalized mesoporous silica with acetylene-modified enzyme for the covalent surface-attachment of the enzyme, they have demonstrated an important milestone on the way to highly efficient, biofunctional materials in applications such as green chemistry, chromatography, and nanomedicine. The high, covalent enzyme functionalization density under simultaneous retention of substantial enzyme activity and the absence of leaching demonstrate the promising potential of this novel approach. ➤





Covalent attachment of trypsin into the mesoporous system of large pore SBA-15 achieved by click chemistry.

Andreas Schlossbauer, D. Schaffert, J. Kecht, Ernst Wagner, Thomas Bein;
J. Am. Chem. Soc. 130, 12558 (2008)

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

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

NON-LINEAR DYNAMICS IN OPTO-MECHANICAL SYSTEMS

Prof. Khaled Karrai (attocube systems & LMU Munich)
Dr. Florian Marquardt (LMU Munich)

The intriguing idea of cooling a mechanical resonator with light has received considerable interest over the last years. Similar to laser cooling of single atoms, a part of the vibration energy of a cantilever can be transferred into photon energy and carried away by light. In collaboration between F. Marquardt and K. Karrai, the inverse effect - exciting cantilever vibration by illumination - was explored.

In an experiment dominated by bolometric forces, strong nonlinear behavior of the cantilever motion was achieved. Although the basic instability has been observed by now in a number of experiments, it was recently realized theoretically that the nonlinear dynamics of this system can become highly nontrivial, leading to an intricate attractor diagram. We present an experiment that traces this diagram and offer a detailed analysis and comparison against theory. As an unexpected feature, we observe the simultaneous excitation of several mechanical modes of the cantilever, leading to coupled nonlinear dynamics. The comparison with theory has revealed the onset of multimode dynamics at large power, with two mechanical modes of the cantilever participating in the radiation-driven self-sustained oscillations. These effects could find applications in highly sensitive force or displacement detection. ➤

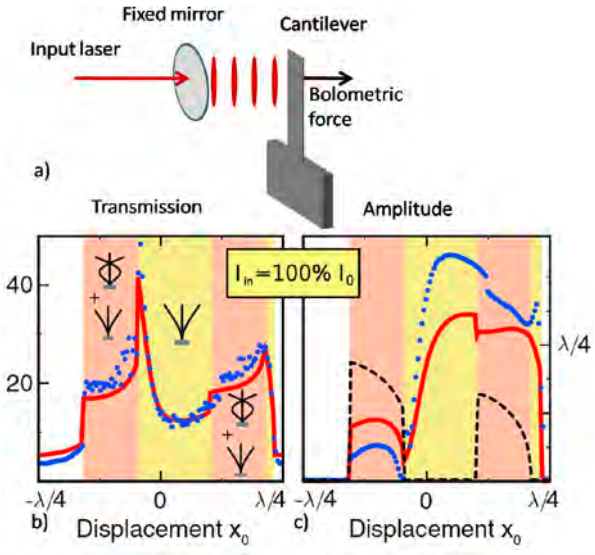


Fig. a) Coupling mechanical modes of a cantilever with optical modes of a cavity: a cantilever is subjected to light induced forces by a standing light wave trapped in a cavity. Fig. b) and c) show the optical transmission of the cavity and the cantilever amplitude with cantilever displacement.

Constanze Metzger, Max Ludwig, Clemens Neuenhahn, Alexander Ortlieb, Ivan Favero, Khaled Karrai, and Florian Marquardt; PRL 101, 133903 (2008)

Karrai: *http://www.nano.physik.uni-muenchen.de/~karrai/*

Marquardt: *http://homepages.physik.uni-muenchen.de/~Florian.Marquardt/*

MICROSCALE FLUID FLOW FROM OPTOTHERMAL EXPANSION

Prof. Dieter Braun (LMU Munich)
Priv.-Doz. Thomas Franosch (LMU Munich)

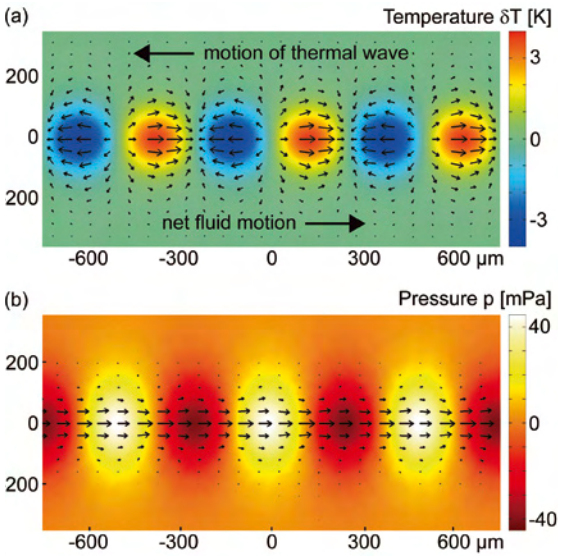
Spatial confinement of a liquid changes its flow behavior markedly since the importance of surface forces relative to the volume forces increases as the confinement becomes smaller. Recently, flow at the scale of millimeters and below has attracted significant attention, stimulated by the rapid advances to manipulate and to control small-scale devices. Since microfluidic flow often is essentially at zero Reynolds number, viscous drag overwhelms the inertial effects of the fluid giving rise to peculiar flow behavior.

The collaboration has proposed a new experimental set-up that circumvents most of the encountered difficulties in microfluidics by relying on an all optical pumping. The new effects makes use of the thermal expansion of a fluid combined with a temperature-dependent viscosity that introduces nonlinearities in the Navier-Stokes equations unrelated to the convective momentum current. The couplings generate the possibility for net fluid flow at the microscale controlled by external heating. This novel thermomechanical effect is investigated for a thin fluid chamber by a numerical solution of the Navier-Stokes equations and analytically by a perturbation expansion. A demonstration experiment confirms the basic mechanism and quantitatively validates our theoretical analysis. ➤

Franz M. Weinert, J. A. Kraus, Thomas Franosch, Dieter Braun;
Phys. Rev. Lett. 100, 164501 (2008)

Braun: *http://www.biosystems.physik.uni-muenchen.de*

Franosch: *http://www.theorie.physik.uni-muenchen.de/lsfrey/members/group_leaders/*



Finite-element solution for a temperature wave in the co-moving frame. (a) The temperature profile is indicated by the color scale and the arrows refer to the induced velocity flow. (b) The corresponding pressure modulation (color scale) and the solenoidal component of the flow.

GOLD NANOSTOVES FOR MICROSECOND DNA MELTING ANALYSIS

Prof. Jochen Feldmann (LMU Munich)
Prof. Thomas A. Klar (Technical University Ilmenau)
Prof. Wolfgang J. Parak (Philipps University Marburg)

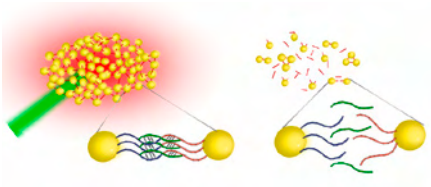
Gold nanoparticles are used as nanoscopic stoves. This allows for thermo-optic melting of DNA double strands, which is an important method for DNA analysis. With the help of these nanostoves, Stehr et al. showed that a single base mismatch can be detected in a melting cycle of less than a millisecond. In cooperation of the groups of CeNS members J. Feldmann, T. Klar and W. Parak as well as Roche Diagnostics GmbH, Penzberg, an ultrafast DNA melting technique has been explored. Gold nanoparticles of 10 nm diameter have been functionalized with two different oligonucleotide 15-mers. Both together are complimentary to a single strand 30-mer DNA target. If the target is present, the gold nanoparticles form clusters of some thousand nanoparticles. Importantly, these clusters show a different extinction in the red spectral range compared to freely floating gold nanoparticles. Therefore, the extinction at 650 nm can be used to monitor whether the target DNA is hybridized or not. This has been used to investigate the melting temperature of DNA targets. Classically, an aqueous solution containing gold nanoparticles and target DNA is heated and the melting temperature is determined by a change of the extinction at 650 nm. This, however, requires the whole solution to be heated, a relatively slow process because not only the DNA's, but also the water's temperature must be increased. In their recent experiments, Stehr et al. have now shown that a pulsed green laser can heat the nanoparticle clusters within 500 nanoseconds and induce DNA melting within a few microseconds. DNA showing a single base mismatch (a single nucleotide polymorphism, SNP) can be clearly distinguished from perfectly matching DNA within one millisecond. SNP detection plays a central role in the screening of SNP based hereditary diseases, drug intolerance or in the search for antibiotic-resistant bacteria. ➤

Joachim Stehr, Calin Hrelescu, Ralph A. Sperling, Gunnar Raschke, M. Wunderlich, A. Nichtl, D. Heindl, K. Kürzinger, Wolfgang J. Parak, Thomas A. Klar, Jochen Feldmann;
Nano Letters 8, 619 (2008)

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

Klar: *http://tu-ilmenau.de/fakmn/Experimentalphysik-I.975.0.html*

Parak: *http://www.physik.uni-marburg.de/de/forschung/biophotonik*



A green laser pulse heats a cluster of gold nanoparticles, cross-linked with hybridized DNA. Subsequently, the DNA melts and the clusters disintegrate. Clusters cross-linked with single base mismatched DNA need less optical heating power to disintegrate.

FUNCTIONAL ARCHITECTURE OF RNA POLYMERASE I

Prof. Patrick Cramer (LMU Munich)

Synthesis of ribosomal RNA (rRNA) by RNA Polymerase I (Pol I) is the first step in ribosome biogenesis and a main regulatory switch in cell growth. Pol I transcription accounts for 60 % of all nuclear transcription, resulting in up to 80 % of total RNA in a cell. Ribosome biogenesis is also highly affected by growth factors, oncogenes and tumor suppressors, suggesting a major influence on cancer growth. Despite the progress in obtaining the atomic structure of the RNA Polymerase II (Pol II) elongation complex, a complete atomic model for Pol I is still missing.

As described in Kuhn et al., 2007 and Geiger er al., 2008, it was possible to determine the functional architecture of Pol I by a combination of cryo-electron microscopy (cryo-EM) and X-ray crystallography, which resulted in a Pol I homology model. Additionally biochemical experiments revealed new functional aspects of the enzyme, like the internal cleavage activity and the elongation-stimulatory effect of A49/34.5, a Pol I specific subcomplex. Therefore the Pol I enzyme performs functions, which, in the analogous Pol II system, are dependent on the external transcription factors TFIIF and TFIIS. Despite the significant process in obtaining structural and functional information on Pol I, the complete structure of the enzyme is still missing. Further structural information on A49/34.5 could lead to a more sophisticated understanding of the subcomplex-dependent mechanism of elongation-stimulation. Additionally, a complete structural model of Pol I could not only explain the internal cleavage activity of Pol I, but might also give an insight in the evolutionary development of Pol I in comparison with other RNA polymerases. ➤

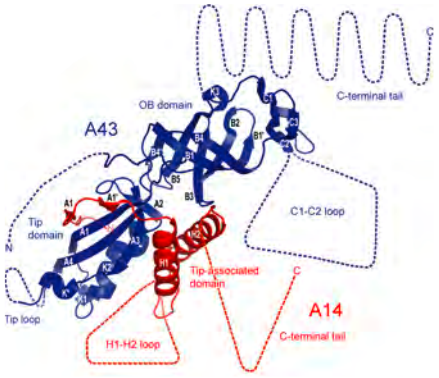


Fig. 1: Crystal structure of yeast RNA Polymerase I subcomplex A14/A43.

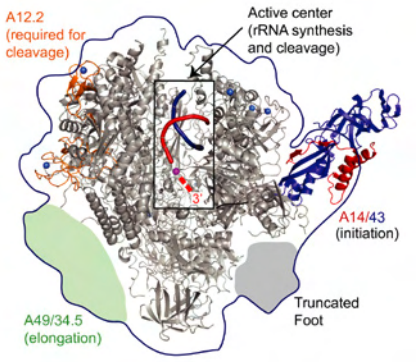


Fig. 2: Hybrid structure and functional architecture of Pol I.

Claus-D. Kuhn, Sebastian R. Geiger, S. Baumli, M. Gartmann, J. Gerber, S. Jennebach, T. Mielke, H. Tschochner, R. Beckmann and Patrick Cramer; Cell 131, 1260 (2007)

Sebastian R. Geiger, Claus.-D. Kuhn, Christoph Leidig, Jörg Renkawitz and Patrick Cramer; Acta Cryst. F64, 413 (2008)

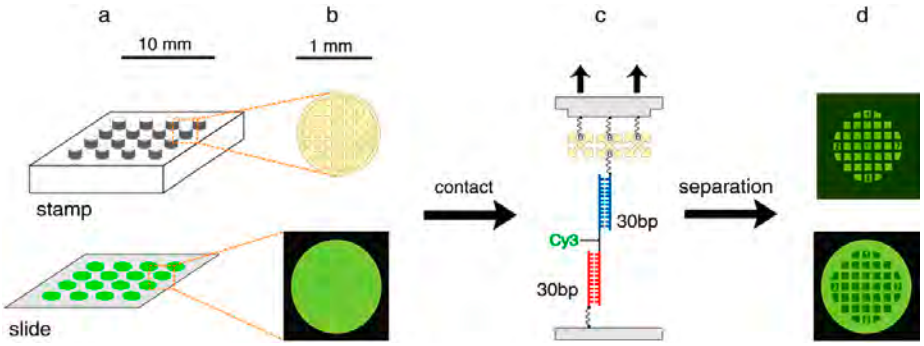
Cramer: *http://www.lmb.uni-muenchen.de/cramer/*

MOLECULAR FORCE BALANCE

Prof. Hermann E. Gaub (LMU Munich)

The molecular force balance develops towards a high throughput force detection device. By design intermolecular forces can be measured highly parallel and fast but at high force resolution. The data from AFM force spectroscopy are collected in a linear manner one molecule by one molecule with a high resolution in force and distance. The force balance focuses on high resolution of unbinding forces together with high statistics.

Strand separation of double-stranded DNA, a crucial step for essential cellular processes such as recombination and transcription was studied. In particular the impact of different pulling directions and different force-loading rates on the unbinding process of short double-stranded DNA was analyzed. At loading rates above 9 x 10(5) pN/s, a marked difference arose in rupture probability for pulling the duplex in 3'-3' direction compared to a 5'-5' direction, indicating different unbinding pathways. A mechanism is proposed by which unbinding at low loading rates is dominated by nondirectional thermal fluctuations, whereas mechanical properties of the DNA become more important at high loading rates and reveal the asymmetry of the phosphoribose backbone. This model explains the difference of 3'-3' and 5'-5' unbinding as a kinetic process, where the loading rate exceeds the relaxation time of DNA melting bubbles. ➤



Contact and separation of stamp and slide of the force balance. (a) silicone stamp with 16 contact pads and glass slide with 16 spots of molecular force balances. (b) A single pad with a microstructure of elevated rectangular contact areas covered with streptavidin (yellow) and a fluorescence image of a single spot (green). (c) Coupling of a single biotinylated force balance (representing a multitude of balances at one contact area) to streptavidin on the stamp. (d) Fluorescence image of stamp and spot after separation indicates which of the two bonds competing for the fluorophore was stronger: The dark rectangular prints in the spot indicate where contact has been established and the fluorescence read out quantifies how many balances have coupled to the stamp.

Christian H. Albrecht, Gregor Neuert, Robert A. Lugmaier, Hermann E. Gaub; Biophys J. 94, 4766 (2008)

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

NANOQUAKES ARE STIRRING UP MICROFLOWS

Dr. Zeno v. Guttenberg (Olympus Advalytix)
Prof. Peter Hänggi (University of Augsburg)
Dr. Matthias Schneider (University of Augsburg)
Prof. Achim Wixforth (University of Augsburg)

At small scales, fluids behave quite different. Physical effects, being negligible in the world of the daily life become more and more dominant when things get tiny. Surface tension for example beats gravity. Inertia means nothing. Squeezed into micron size tubes, water suddenly appears as viscous as honey, making controlled pumping a difficult task. Swimming and propulsion requires special techniques, which have been successfully tackled by bacteria and other creatures living under microflow conditions. Even simple exercises like the mixing of two fluids resemble the kneading of a pizza dough if working in the microfluidic regime. Mixing, however, is extremely important for microfluidic applications like a complete lab on a chip. Without mixing, all reactions rely on slow diffusion processes only.

Launching and sweeping narrow beams of surface acoustic waves on a piezoelectric substrate, CeNS scientists at the University of Augsburg now gave a twist to resistive microflows: Being the nanometer analogue of an earthquake, a surface acoustic wave transmits part of its energy to the fluid, creating intense streaming in an externally controllable direction and amplitude. This way, complex spatio-temporal flow patterns are excited in the liquid, enabling the controlled folding of the tiny material lines and induce rapid mixing - just like a baker would roll and fold the pastry. Theoretically well described and understood, optimum mixing conditions now may be predicted and designed for a given microfluidic device: an acoustically controlled laboratory on a chip. ➤

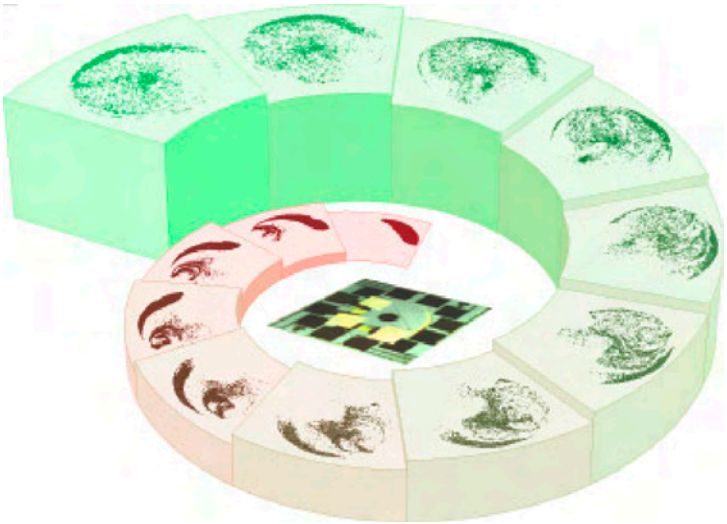


Fig. 1: Spatio-temporal evolution of the mixing process in an acoustically driven mixer chip.

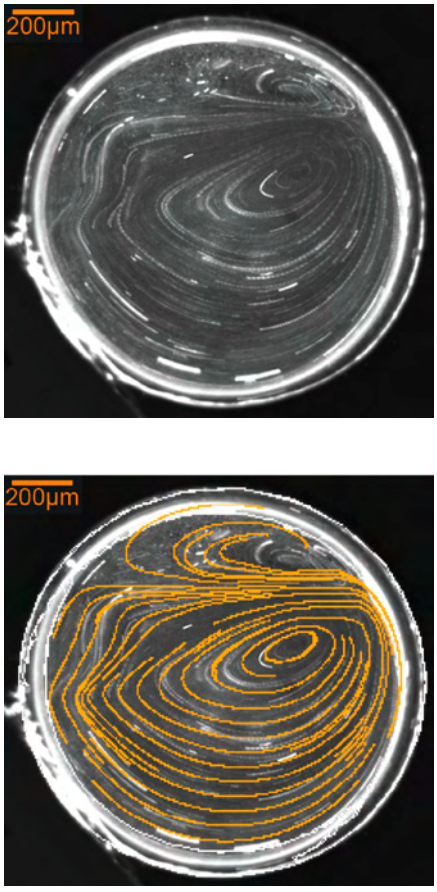


Fig. 2: Experimental (top) and calculated flow profile (down) on a mixer chip for a given moment in time.

Thomas Frommelt, Marcin Kostur, Melanie Wenzel-Schäfer, Peter Talkner, Peter Hänggi, Achim Wixforth;
Phys. Rev. Lett. 100, 034502 (2008)

Guttenberg: *http://www.advalytix.com/*

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

Schneider, Wixforth: *http://www.physik.uni-augsburg.de/exp1/*

NANOMEDICINE AND DRUG DELIVERY: PHOTOINDUCED ENDOSOMAL RELEASE OF NANOMETER-SIZED POLYPLEXES AS GENE CARRIERS

Prof. Christoph Bräuchle (LMU München)
Prof. Ernst Wagner (LMU München)

In the development of macromolecular drug and gene delivery, endosomal release appeared to be a bottleneck for successful delivery and transfection. In order to overcome this barrier, different approaches are under investigation. Photosensitizers such as porphyrins or porphyrin-related compounds can be used to photochemically disrupt the endosomal membranes and to overcome this bottleneck. These porphyrins bind to the cell membrane and are internalized into the cell via endocytosis. Illumination with light of a defined wavelength results in excitation of the photosensitizer to its singlet state with following intersystem crossing to its triplet state. This excited state is then quenched by triplet oxygen such that singlet oxygen is produced, which disrupts the membrane by chemical damage. In this study a detailed observation of photosensitizer release in real time with live cell imaging is conducted showing the opening of the endosomal membrane and the release of the DNA into the cytosol in great detail. ➤

Karla de Bruin, Carolin Fella, Manfred Ogris, Ernst Wagner, Nadja Ruthardt, Christoph Bräuchle; J. Contr. Release 130, 175 (2008)

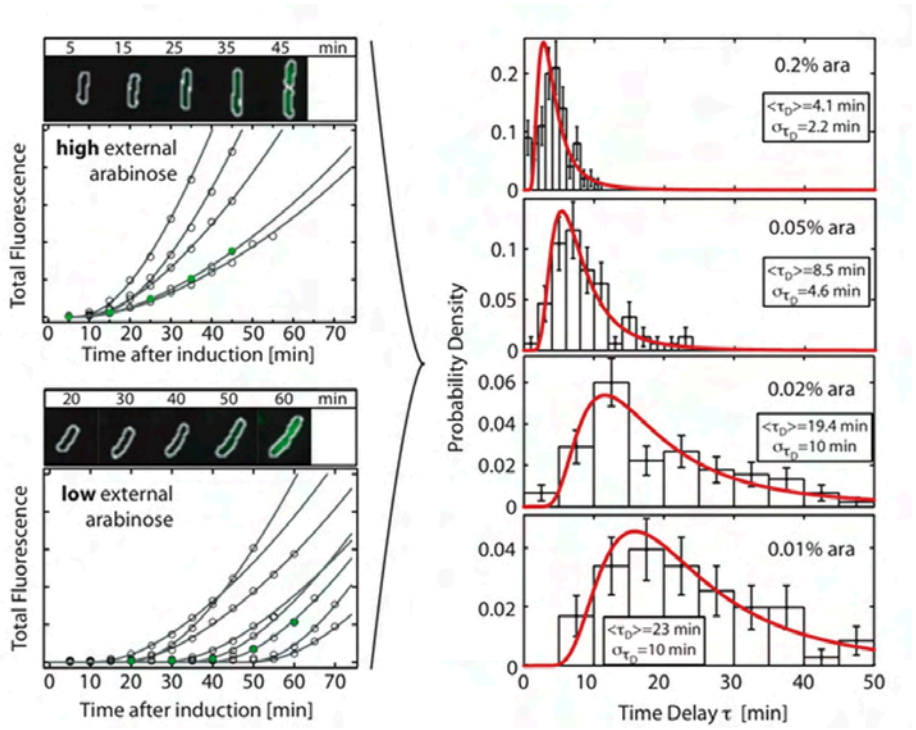
Bräuchle: *http://www.cup.uni-muenchen.de/pc/braeuchle/*

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

TIMING AND DYNAMICS OF SINGLE CELL GENE EXPRESSION IN THE ARABINOSE UTILIZATION SYSTEM

Prof. Ulrich Gerland (LMU Munich)
Prof. Joachim Rädler (LMU Munich)

In the recent years it became increasingly recognized that the gene expression level of genetically identical bacteria can vary strongly across a population. One prominent example is the arabinose utilization system of E. coli, which displays a stochastic "all or nothing" response at intermediate levels of arabinose, where the population divides into a fraction catabolizing the sugar at a high rate (ON state) and a fraction not utilizing arabinose (OFF state). As previous research was focused on the stationary distributions of gene expression, our aim was to study this decision process in individual cells, focusing on the dynamics of the transition from the OFF to the ON state. Using time-lapse fluorescence microscopy, the Rädler group discovered that under subsaturating sugar concentrations the onset of gene expression varies strongly from cell-to-cell (left figure). Through independent characterization of the GFP maturation process, we could separate the lag time caused by the GFP reporter from the intrinsic activation time of the arabinose system. The resulting distribution of intrinsic time delays scales inversely with the external arabinose concentration (right figure), and is compatible with a detailed stochastic model for arabinose uptake developed in the Gerland group. The combination of the experimental and theoretical results, which were in very good agreement, led us to the conclusion that the heterogeneous timing of gene induction is causally related to a broad distribution of uptake proteins at the time of sugar addition. In a typical environment where the arabinose availability may fluctuate, such temporal disorder of gene induction could provide selective advantages for the colony as a whole: For instance, it might be beneficial to prevent costly synthesis of the arabinose system in all cells of a population when the sugar level is only moderate and may soon be depleted. Our analysis indicates that the delay time distribution of the system can be readily tuned over evolutionary timescales, by adjusting the burst frequency and burst size of the uptake proteins. ➤



Single cell induction kinetics of the arabinose utilization system (left) and distributions of delay times (right) for different inducing arabinose concentrations (bars: experiment; red: model).

Judith A. Megerle, Georg Fritz, Ulrich Gerland, Kirsten Jung, Joachim O. Rädler; Biophysical Journal 95, 2103 (2008)

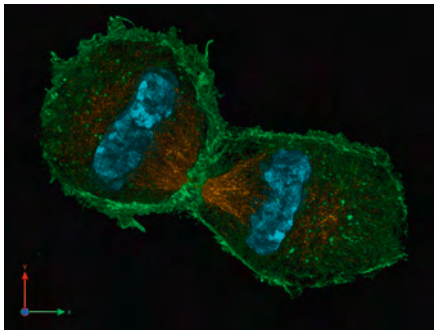
Gerland: *http://www.physik.uni-muenchen.de/~gerland*

Rädler: *http://softmatter.physik.lmu.de/*

MULTICOLOR SUPERRESOLUTION IMAGING WITH 3-DIMENSIONAL STRUCTURED ILLUMINATION MICROSCOPY

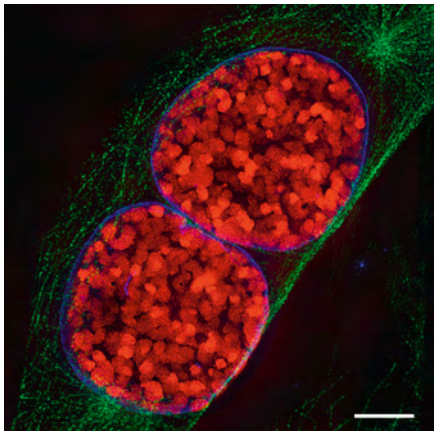
Prof. Heinrich Leonhardt (LMU Munich)
Dr. Lothar Schermelleh (LMU Munich)

Fluorescence light microscopy enables multicolor visualization of cellular components with high specificity but its utility has until recently been constrained by the intrinsic limit of spatial resolution, that is ~250 nm in the xy plane and ~600 nm along the z-axis. Recent developments such as stimulated emission depletion (STED) microscopy and stochastic localization microscopy (STORM/PALM) have made possible to bypass the diffraction barrier of optical resolution. An alternative approach uses three-dimensional structured illumination (3D-SIM) to improve lateral as well as axial resolution by a factor of two below the diffraction limit.

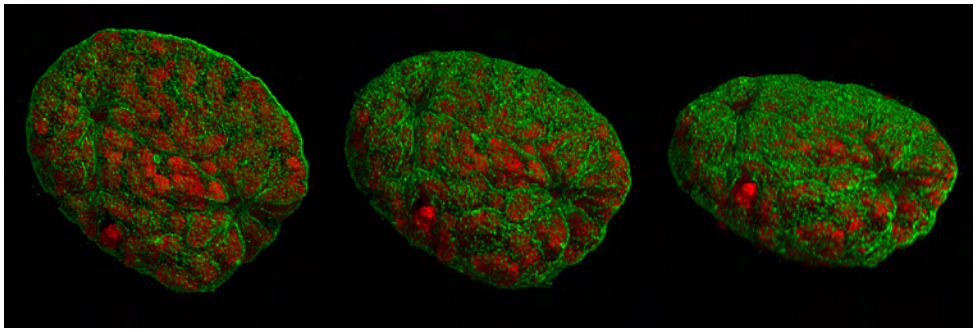


3D representation of two mouse daughter nuclei in a late stage of cell division (telophase), imaged with 3D-SIM. The spindle apparatus (anti-tubulin immunostaining, orange), the actin cytoskeleton (phalloidin staining, green) and chromatin (DAPI-staining, cyan) are visualized.

This technology has been implemented in a specially designed microscope platform, termed OMX, which provides unprecedented sensitivity and mechanical stability. In collaboration with John Sedat and colleagues (University of California, San Francisco), Lothar Schermelleh has applied the OMX prototype on a wide variety of biological structures, in particular in the mammalian cell nucleus to explore the potential of the 3D-SIM technology. By simultaneously imaging chromatin, nuclear lamina and the nuclear pore complex (NPC), several features could be observed that escape detection by state-of-the-art conventional microscopy. Single NPCs could be resolved that colocalized with channels in the lamin network and peripheral heterochromatin. Moreover, distinct NPC components could be mapped and double-layered invaginations of the nuclear envelope in prophase could be detected that were previously seen only by electron microscopy. The results clearly demonstrate the potential of the OMX microscope for multi-wavelength optical sectioning of biological samples with sub-diffraction resolution that will allow new insights in biological structures and will help to narrow the gap between light and electron microscopy. ➤



Light-optical section through two mouse cell nuclei in prophase, recorded with 3D-SIM. Condensed chromosomes are red, the nuclear envelope blue and microtubules are green. Scale bar is 5 µm.



3D-representation of a mouse cell nucleus from different angles recorded with 3D-SIM. The cell is in an early stage of cell division (prophase). The chromosomes (red) are already condensed, to be later distributed to the daughter cells. The surrounding nuclear envelope (green) shows prominent invaginations and first disruptions.

Lothar Schermelleh, P. Carlton, S. Haase, L. Shao, L. Winoto, P. Kner, B. Burke, M. C. Cardoso, D. A. Agard, M. G. L. Gustafsson, Heinrich Leonhardt, J. W. Sedat; Science 320, 1332 (2008)

Leonhardt, Schermelleh: *http://sci.bio.lmu.de/epigenetics/*

BACKACTION OF A CHARGE DETECTOR ON QUANTUM DOT QUBITS

Priv.-Doz. Stefan Ludwig (LMU Munich)

Coupled quantum dot (QD) systems are one possible approach to solid-state based quantum computing. Most read-out schemes for qubits in coupled quantum dots rely on using a biased quantum point contact (QPC) as charge detector. It has been shown that such a biased QPC emits non-equilibrium energy quanta which can be absorbed by the QDs, thereby causing decoherence. The backaction of such a detector on double and triple quantum dots has been investigated in several samples. It is seen in the measurement signal as telegraph noise, i.e. fluctuations of the electron number charging the QDs. If those fluctuations are slow enough, they can be observed in a low frequency detection scheme. This condition is fulfilled in a serial triple QD if the charge of the central QD fluctuates (Fig. 1). A similar situation can arise in a serial double quantum dot if one of the tunneling barriers between a quantum dot and the adjacent lead is closed. This QD can then only be charged via the other QD which again leads to slow and therefore observable tunneling processes. By varying the bias voltage of the QPC, the influence of the detector on the tunneling rates could be demonstrated (Fig. 2). While telegraph noise could only be observed in bounded regions of the stability diagram due of the finite bandwidth of the detector, fluctuations with higher tunneling rates are expected to occur in other regions as well. ➤

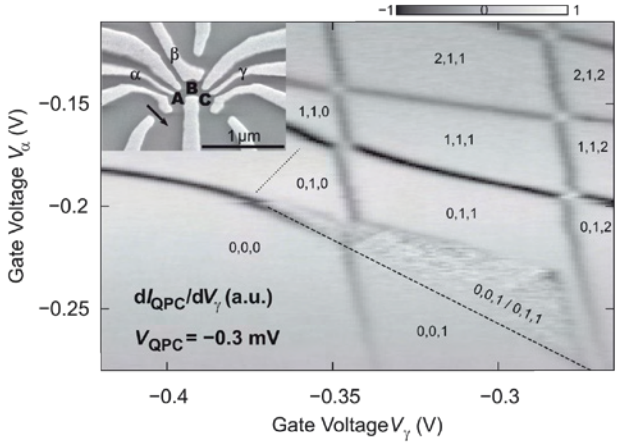


Fig 1: Charge stability diagram of a triple quantum dot measured with a QPC used as charge detector. Triples of integers denote electron numbers in the three QDs. A triangular region of telegraph noise is visible. Inset: micrograph of sample structure.

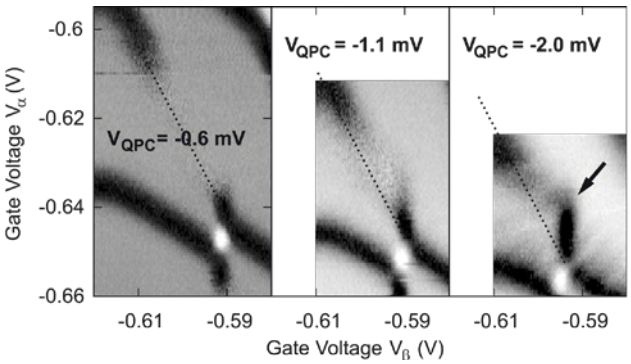


Fig 2: Part of a charge stability diagram of a double quantum dot with one tunnel barrier closed, measured with three different QPC bias voltages V_{QPC}. A higher bias voltage causes changes in the tunneling rates, leading to a distortion of the charging lines.

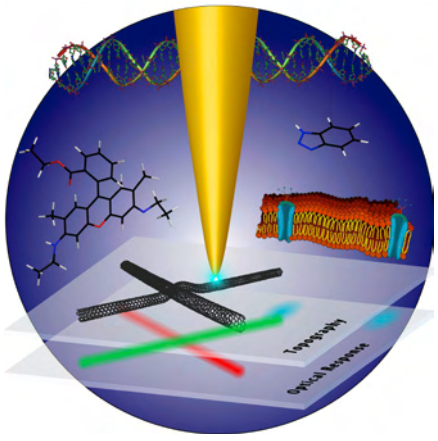
Daniela Taubert, Michel Pioro-Ladrière, Daniel Schröer, Daniel Harbusch, Andrew S. Sachrajda, Stefan Ludwig; Phys. Rev. Lett. 100, 176805 (2008)

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

NANOSCALE OPTICAL IMAGING OF ELECTRONIC AND VIBRONIC STATES IN CARBON NANOTUBES

Prof. Achim Hartschuh (LMU Munich)

We explored the electronic and vibronic properties of single-walled carbon nanotubes using tip-enhanced near-field optical microscopy (TENOM). This technique provides both high spatial resolution of about 10 nm and enormous local signal enhancement and is ideally suited for the investigation of single nanostructures on surfaces. In 2008 we reported on the correlation between highly localized photoluminescence and charged defects in single nanotubes (Nature Mat. 7, 878). In combination with detailed conventional Raman spectroscopic investigations as part of an international effort, we revealed the renormalization of phonon and electron band energies near charged defects in these materials. Using TENOM we also visualized the local optical response of nanotubes to DNA-wrapping (Nano Lett. 8, 2706) and short-ranged energy transfer between individual nanotubes (Nano Lett. 8, 1363). Our findings are of great importance for nanotube applications in electronic, photonic and sensing devices. ➤



TENOM has developed into a powerful and versatile tool for surface analysis and provides detailed spectroscopic information through the observation of Raman scattering and photoluminescence. By combining nanometer-scale spatial resolution and ultrahigh detection sensitivity, the technique is ideally suited to the study of single nanoobjects and trace amounts of different materials.

I. O. Maciel, N. Anderson, M. A. Pimenta, Achim Hartschuh, Huihong Qian, M. Terrones, H. Terrones, J. Campos-Delgado, A. M. Rao, L. Novotny, A. Jorio; Nature Materials 7, 878 (2008)

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

THE NONLINEAR FANO EFFECT

Prof. Khaled Karrai (attocube systems & LMU Munich)

The Fano effect is very well known from spectroscopy on atoms, since it was explained by U. Fano in 1961. It arises when quantum interference takes place between two competing optical pathways, one connecting the energy ground state and an excited discrete state, the other connecting the ground state with a continuum of energy states. The nature of the interference changes rapidly as a function of energy, giving rise to characteristically asymmetric lineshapes. Whereas Fano's original theory applies to the linear regime at low power, at higher power a laser field strongly admixes the states and the physics becomes rich, leading for example to a remarkable interplay of coherent nonlinear transitions. We report experiments that access the nonlinear Fano regime by using semiconductor quantum dots which allow both the continuum states to be engineered and the energies that lie originally in the deep ultraviolet, to be rescaled to the near infrared. In Fig.1 differential transmission spectra of a quantum dot for different laser excitation powers are shown (a-f). The quantum dot was weakly coupled to a continuum of states and the characteristic Fano shape of the resonance gets more pronounced with increasing excitation power. We developed a general theory that explains the non-linear Fano effect and the corresponding, calculated spectra are shown in Fig.1 (g-l). ➤

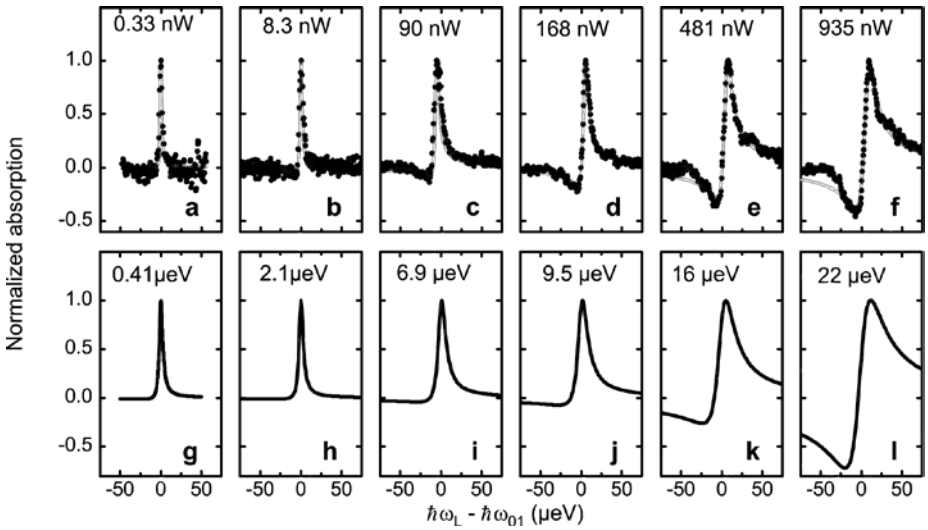


Fig. 1: Differential transmission spectra of the non-linear Fano effect observed on a single quantum dot, weakly coupled to a continuum of states (a-f). The corresponding calculated spectra are shown in (g-l). The excitation power and corresponding Rabi energy is given respectively.

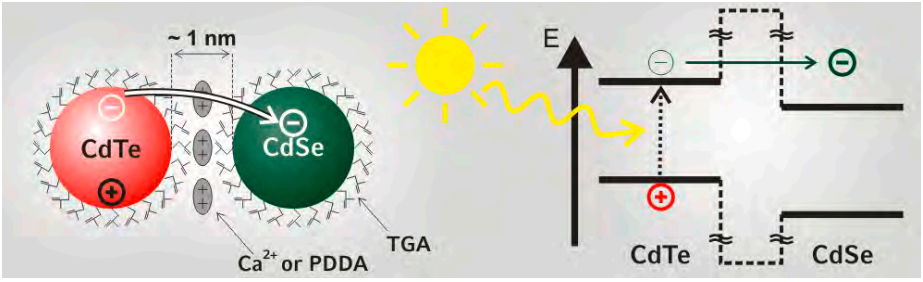
Martin Kroner, A. O. Govorov, S. Remi, Benjamin Biedermann, Stefan Seidl, A. Badolato, P. M. Petroff, W. Zhang, R. Barbour, B. D. Gerardot, Richard J. Warburton, and Khaled Karrai; Nature 451, 311 (2008)

Karrai: *http://www.nano.physik.uni-muenchen.de/~karrai/*

CHARGE SEPARATION IN TYPE II TUNNELING STRUCTURES OF CLOSE-PACKED CdTe AND CdSe NANOCRYSTALS

Dr. Enrico Da Como (LMU Munich)
Prof. Jochen Feldmann (LMU Munich)
Dr. Andrey Rogach (LMU Munich)

The possibility to convert solar energy into electrical power resides in the ability to design nanostructures where efficient light induced charge separation and transfer occurs. Semiconductor nanocrystals are considered as ideal absorbers across the visible spectral range and offer great advantages for easy solution processing. The design of solar cells exclusively made of nanocrystals is however limited, because of the necessity to create ordered structures with a well defined energy landscape. Gross and co-authors have demonstrated that photoinduced charge transfer takes place in two types of electrostatically bound type II nanocrystal structures: first, clusters of nanocrystals held together by Ca(II) ions in aqueous solution, and second, thin films of nanocrystals created by layer-by-layer deposition in combination with polyelectrolytes. In both types of structures, the insulating organic ligands on the nanocrystal surfaces and/or the polymer monolayers act as tunneling barriers between nanocrystals. An efficient quenching of photoluminescence and a reduced emission life time for CdTe nanocrystals in both types of type II hetero-structures has been observed, being an indication of spatial charge separation of the photo-excited electron-hole pairs due to tunneling of charge carriers. This work paves the way to the realization of nanocrystal-based solar cells, obtained with low-cost solution processing techniques. ➤



Photoinduced charge separation of electrons and holes in type II alignment of closely packed CdTe and CdSe nanocrystals held together by electrostatic interactions with positively charged Ca(II) ions or PDDA polyelectrolyte molecules.

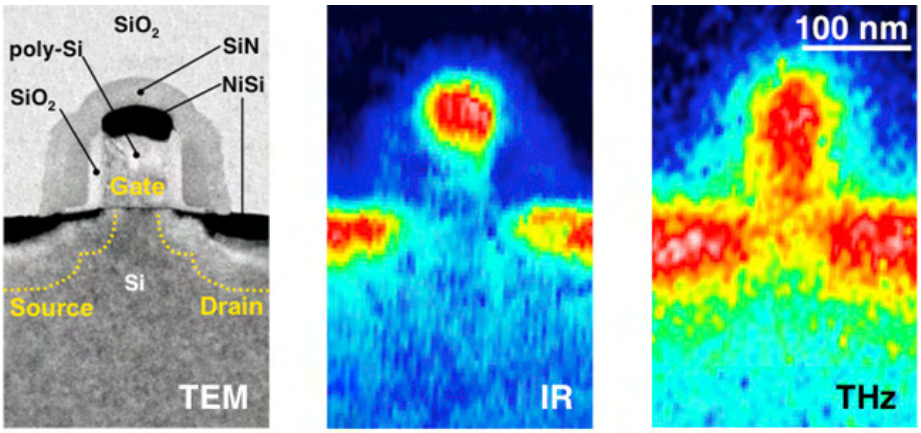
Dieter Gross, Andrei S. Susha, Thomas A. Klar, Enrico Da Como, Andrey L. Rogach, Jochen Feldmann; Nano Lett. 8, 1482 (2008)

Da Como, Feldmann, Rogach: *http://www.phog.physik.uni-muenchen.de/*

THz-NANOSCOPY OF NANOSTRUCTURED ELECTRONIC DEVICES

Dr. Rainer Hillenbrand (Max-Planck-Institut für Biochemie & Cooperative Research Center nanoGUNE, San Sebastian, Spain)
Dr. Fritz Keilmann (Max-Planck-Institut für Quantenoptik)

Ultrahigh-resolution (40 nm) near-field microscopy was demonstrated using 2.5 THz illumination, at 118 µm wavelength. This was made possible by the extreme THz field concentration at the metallic probe tip. The THz nanoscope thus exceeds the diffraction limit of resolution by a factor of 2000. Its 40 nm resolving power matches the needs of modern nanoscience and technology.
Since THz inspection offers a 100-fold increased sensitivity for conductivity mapping of semiconductors (compared to infrared inspection at 10 µm wavelength), this technique was applied to state-of-the-art transistors of the 65 nm-technology that before had been analyzed with a transmission electron microscope (TEM) by Infineon AG. Strikingly, the THz images reveal mobile carriers at concentrations around 10^{18}cm^{-3} (that is one mobile carrier for each 100,000 Si atoms) which are essential for practical transistor functionality but are not visible in TEM. The simultaneous and quantitative mapping of both materials and carrier concentrations with nanoscale resolution opens an enormous industrial application potential for the THz near-field microscope. Mobile-carrier sensitivity should make THz nanoscopy highly desirable for quality assurance and analysis of failure mechanisms in semiconductor device industry. In addition, fundamental physics research of conducting materials should benefit in general: the non-contact, non-invasive and quantitative mapping of mobile carriers with nanoscale resolution should trigger crucial insights regarding open scientific questions from the areas of superconductors, low-dimensional conductors, and correlated conductors. ➤



THz goes Nano: THz near-field image (right) of a single industrial transistor structure of the 65 nm technology (Infineon AG) reveals the central device components source, drain and gate and also visualizes the distribution of mobile carriers below the metallic NiSi contacts. For comparison, a TEM image (left) and an infrared near-field image (middle) of the transistor show the metallic NiSi contracts but not the mobile carriers.

Andreas J. Huber, Fritz Keilmann, J. Wittborn, J. Aizpurua, Rainer Hillenbrand; Nano Lett. 8, 3766 (2008)

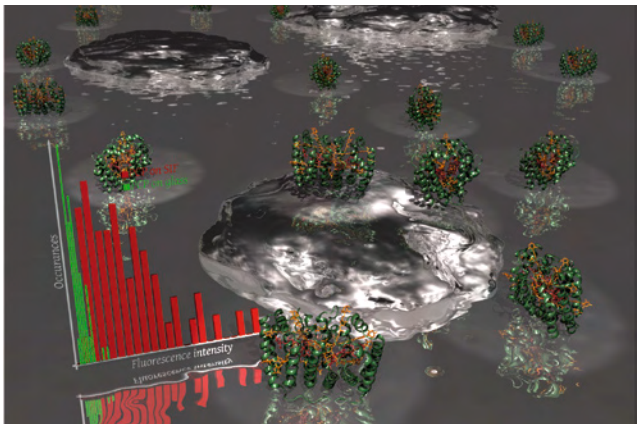
Hillenbrand: *http://www.nanogune.eu*

Keilmann: *http://www.attoworld.de/people/senior.html*

METAL-ENHANCED FLUORESCENCE OF CHLOROPHYLLS IN SINGLE LIGHT-HARVESTING COMPLEXES: A STEP TO A BIOMIMETIC APPROACH FOR EFFICIENT SOLAR ENERGY COLLECTION

Prof. Christoph Bräuchle (LMU München)
Prof. Achim Hartschuh (LMU München)

Ensemble and single-molecule spectroscopy demonstrates that both emission and absorption of a photosynthetic antenna complex - peridinin-chlorophyll-protein (PCP) - can be largely enhanced through plasmonic interactions. The groups of Christoph Bräuchle, Achim Hartschuh and Hugo Scheer (Department of Biology, LMU) find up to 18-fold increase of the chlorophyll fluorescence for complexes placed near silver metal nanoislands. This enhancement, which does not destroy the protein structure, is observed when exciting either chlorophyll or carotenoid and is attributed predominantly to an increase of the excitation rate in the antenna. The enhancement mechanism comes from plasmon-induced amplification of electromagnetic fields inside the complex. This result is an important step toward applying plasmonic nanostructures for controlling the optical response of complex biomolecules on the one hand and improving the design and functioning of artificial light-harvesting systems on the other hand. Particularly appealing is the prospect to use such artificial light-harvesting systems in a biomimetic approach to efficient solar energy collection. The hybrid system would combine the evolutionary improvement of the biological component with the enhancement effects obtained by nanotechnology. ➤



Scheme of PCP complexes on silver nanoislands. Plasmon-induced amplification of electromagnetic fields inside the complexes leads to metal-enhanced fluorescence up to 18-fold (histogram).

S. Mackowski, Stephan Wörmke, A. J. Maier, T. H. P. Brotosudarmo, Hayk Harutyunyan, Achim Hartschuh, A. O. Govorov, H. Scheer, Christoph Bräuchle; Nano Lett. 8, 558 (2008)

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

Hartschuh: *http://www2.phys.chemie.uni-muenchen.de/hartschuh*

LIGHT DRIVEN MICROFLUIDICS

Prof. Dieter Braun (LMU Munich)

The Braun lab explores methods to optically drive fluid flow. We could demonstrate that light can be used to pump water along arbitrary paths on the microscale and showed that thermophoresis in strong thermal fields creates a fluid flow around particles which can be used to attract particles into colloidal crystals. Alongside efforts - together with Stefan Duhr and Philipp Baaske - were to help to further commercialize biomolecule analytics with thermal fields with their spinoff company Nanotemper Technologies.

Light driven microfluidics. A laser scanning microscope can be used to drive fluid along arbitrary paths at the microscale.

The thermal expansion of a fluid combined with a temperature-dependent viscosity introduces nonlinearities in the Navier-Stokes equations unrelated to the convective momentum current. The couplings generate the possibility for net fluid flow at the microscale controlled by external heating. Especially interesting is that fluid can be moved along arbitrary paths by a simple laser scanning microscope. Selected parts of a fluid film were pumped along the path of a moving warm spot which is generated by the repetitive motion of an infrared laser focus. With this technique, we remotely drove arbitrary two-dimensional fluid flow patterns with a resolution of 2 µm. Pump speeds of 150 µm/s were reached in water with a maximal temperature increase in the local spot of 10 K. Various experiments confirmed that the fluid motion indeed resulted from the dynamic thermal expansion in a gradient of viscosity. We pumped nanoparticles over millimeters through a gel and all-optically created a dilution series of DNA and biomolecules by aliquotation and mixing between untreated and unstructured, disposable microscope cover slips. Optical remote control allows a well defined and highly unexpected microcontrol of fluids. ➤

Franz M. Weinert, Dieter Braun; J. Appl. Phys. 104, 104701 (2008)

Braun: *http://www.biosystems.physik.uni-muenchen.de*

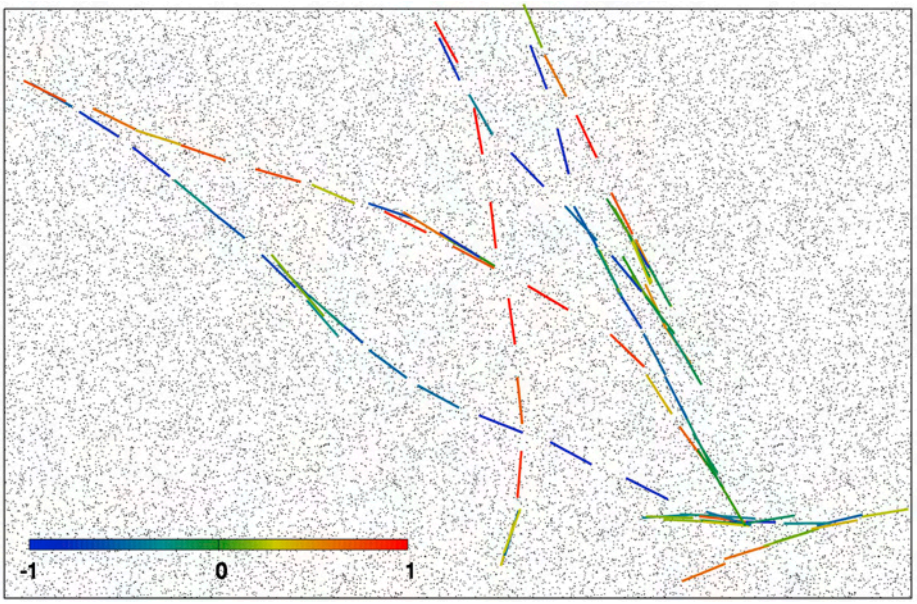
ENHANCED DIFFUSION OF NEEDLE LIQUIDS

Priv.-Doz. Thomas Franosch (LMU Munich)
Prof. Erwin Frey (LMU Munich)

Systems composed of stiff, thin fibers (needles) show complex dynamic behavior, while their equilibrium properties correspond to those of an ideal gas. As the fibers move and rotate, they collide with each other and strongly hinder their motion mutually. An intriguing phenomenon is the enhancement of translational diffusion as the density is increased. Such a behavior contradicts the experience that transport becomes slow in dense complex liquids.

Extensive computer simulations of a minimal model show that this effect can be attributed to a spacious zigzag motion of the fibers, where the paths they trace resemble the tracks of an ice skater. An unambiguous power-law increase of the diffusion coefficient is found over several orders of magnitude. The zigzag motion itself is explained in terms of the persistence of longitudinal momentum, which becomes apparent in a two-step decay of the velocity-autocorrelation function. Via a Green-Kubo relation, the persistence time is proportional to the diffusion coefficient and diverges with the same power law. Although the exponent of the power law is not yet fully rationalized, simple scaling arguments are provided to capture the fundamental mechanism of the zigzag motion.

One axiom of the kinetic theory of gases is the hypothesis of molecular chaos, which Boltzmann called "Stoßzahlansatz". It states that the motion of molecules after a collision is statistically independent of their motion before the collision, allowing a statistical description of macroscopic properties independent of microscopic details. One result of the present work, however, is that this hypothesis is only partially valid for thin granular fibers. Although the motion is not deterministically predictable, it is not entirely random. Instead, the fibers travel along a straight line over many hundred collisions, changing their orientation only very slowly. As a result, microscopic details are amplified and become visible in the macroscopic zigzag motion. ➤



The spacious zigzag motion extends over many multiples of the fiber length. It is easily seen in subsequent snapshots of one fiber in the simulated minimal model. Color encodes the longitudinal velocity (green: slow, red/blue: fast).

Felix Höfling, Erwin Frey, and Thomas Franosch; Phys. Rev. Lett. 101, 120605 (2008)

Franosch: *www.theorie.physik.uni-muenchen.de/lsfrey/members/group_leaders/thomas_franosch/*

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

THE ROLE OF CHAPERON PROTEINS IN PROTEIN FOLDING

Prof. Don C. Lamb (LMU Munich)

Proteins are naturally occurring nanomachines that perform the everyday tasks of life. The last step in protein biosynthesis is folding of these newly synthesized polypeptides into their three-dimensional functional conformation. Many proteins require the assistance of molecular chaperones to fold rapidly and efficiently. Chaperone proteins are believed to aid protein folding by isolating the nascent polypeptide chain from deleterious interactions within the cell. We have used single pair and ensemble FRET to investigate the pathway of chaperon assisted protein folding. The conformation of a protein substrate was monitored with FRET at different time points during the folding cycle of the chaperonin GroEL. As a substrate, we used the maltose binding protein (MBP). Several mutants of MBP were specifically labeled at well defined locations with fluorescent donor and acceptor molecules. Our investigations reveal the existence of a bimodal FRET distribution upon binding of the substrate to GroEL with a fraction of the substrate being stretched into an extended conformation. Upon ATP binding to GroEL, which induces a conformation change in the chaperonin, the bimodal distribution disappears and a transient stretching of the substrate is observed along with the controlled release of the substrate into the chaperonin cavity. These results reveal a much more active role of chaperones in the folding process than was previously believed. ➤

S. Sharma, K. Chakraborty, Barbara K. Müller, N. Astola, Y.-C. Tang, Don C. Lamb, M. Hayer-Hartl, F. U. Hartl; Cell 133, 142 (2008)

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

SINGLE-MOLECULE CUT AND PASTE

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

Self-assembly guided by molecular recognition has been employed to assemble nanoparticle superstructures like hypercrystals or nanoparticle molecules in the past. An alternative approach is the direct molecule-by-molecule assembly of nanoscale superstructures (bottom-up). This project is a hybrid technique where first a pattern of binding sites is assembled one-by-one at a surface and then different nanoparticles are allowed to attach by self-assembly.

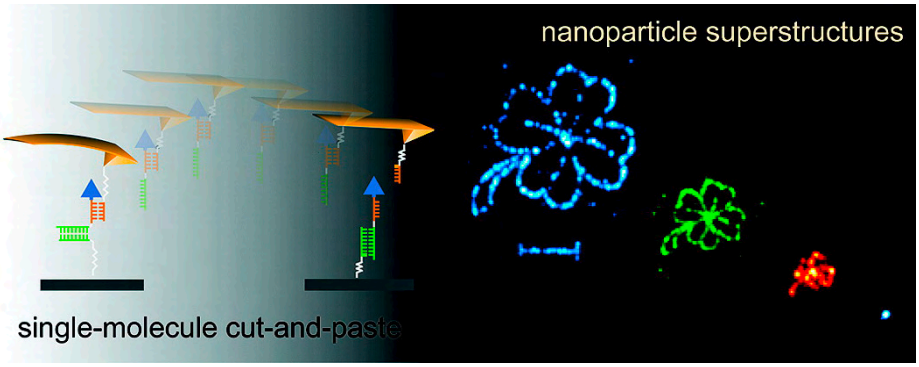


Image of fluorescent nano-particles self-assembled on a surface nano-structured by single molecule cut and paste (scalebar =5µm).

With the precision of the atomic force microscope (AFM) and the selectivity of DNA hybridization, the following routine was performed to generate a nanostructure: Functional units (e.g. Biotin) coupled to DNA oligomers were picked up from a depot area by means of a complementary DNA strand bound to an AFM tip. These units were transferred to and deposited on a target area by hybridization to create basic geometrical structures, assembled from units with different functions. Fluorescent semiconductor nanoparticles conjugated with streptavidin can assemble on this scaffold and form a final nanoparticle superstructure. Each of these cut-and-paste events was characterized by single-molecule force spectroscopy and single-molecule fluorescence microscopy. Transport and deposition of more than 5000 units was achieved, with less than 10% loss in transfer efficiency. A combination of this single-molecule cut-and-paste technique with total internal reflection fluorescence microscopy and atomic force microscopy can not only be used to deposit individual fluorophores in well-defined nanoscale patterns but also to monitor the process in real time with nanometer precision. Although the size of the 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 labeled biomolecules can be arranged at will for specific functions, such as coupled fluorophore systems or tailored enzyme cascades, and monitored with nanoscale precision. ➤

Stefan K. Kufer, Elias M. Puchner, Hermann Gumpp, Tim Liedl, Hermann E. Gaub; Science 319, 594 (2008)

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

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

CONTROL OF SINGLE-MOLECULE BLINKING FOR SUPERRESOLUTION MICROSCOPY

Prof. Philip Tinnefeld (LMU Munich)

Revolutionary developments in fluorescence microscopy are partly slowed down by blinking and photobleaching of the fluorescent probes used. By rapidly depopulating transient dark states of the fluorescent dyes, uncontrolled blinking is significantly reduced and the photostability is increased. The new concept employs a reducing and an oxidizing agent to rapidly depopulate triplet as well as radical ion states of the fluorescent dyes using photoinduced electron transfer reactions (Figure 1). This scheme is applicable to a wide range of fluorophores and especially enables single-molecule and super-resolution applications. Based on the understanding of the factors that are responsible for the dark states, i.e. radical ion states, a super-resolution microscopy method was developed that reconstructs fluorescence images from subsequently localized single molecules (Figure 2). Therefore blinking was induced by preparing most molecules in a dark state by photoinduced electron transfer and reading out the positions of the remaining molecules. Figure 2 shows a conventional total internal reflection fluorescence microscopy image of actin filaments on cover slides with the corresponding super-resolved 'blink-microscopy' image that provides ~ 50 nm resolution. ➤

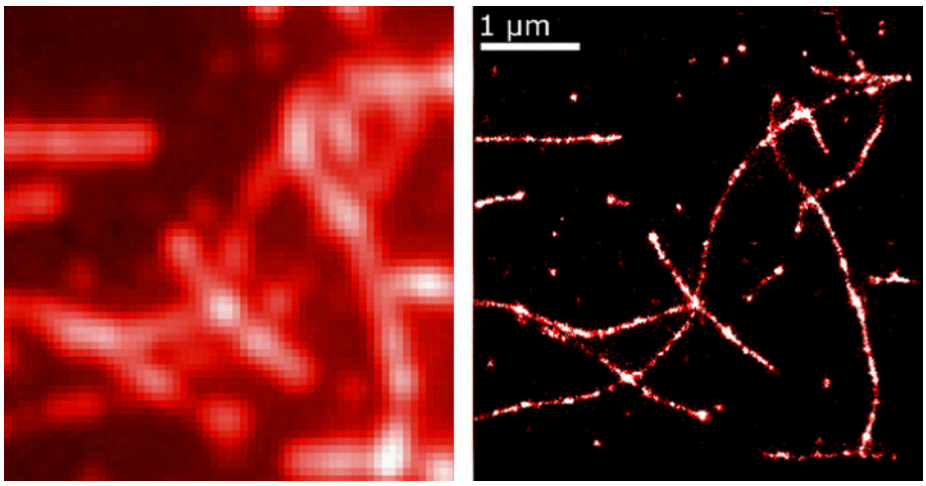


Fig. 2: Conventional widefield fluorescence (left) and "Blink Microscopy" (right) images of actin filaments labeled with Alexa647.

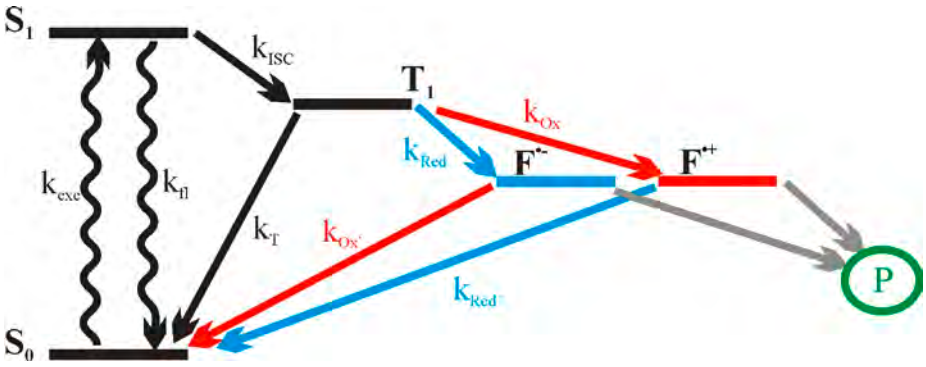


Fig 1: After excitation to the first excited singlet state (S1), fluorescence is emitted. Intersystem crossing leads to the infrequent formation of triplet states T1. With the reducing and oxidizing system (ROXS), the triplet state is rapidly depleted via electron transfer; either through oxidation forming a radical cation F^+ or through reduction yielding a radical anion F^-. The two possible radical ions are rapidly recovered to singlet ground state fluorophores by the complementary redox reaction.

Christian Steinhauer, Carsten Forthmann, Jan Vogelsang, Philip Tinnefeld; J. Am. Chem. Soc. 130, 16840 (2008)

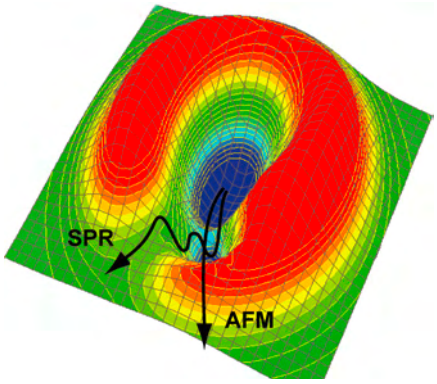
Tinnefeld: *http://www.biophysik.physik.uni-muenchen.de/lsgaubstaff/philiptinnefeld*

MULTI-DIMENSIONAL FORCE PROBE

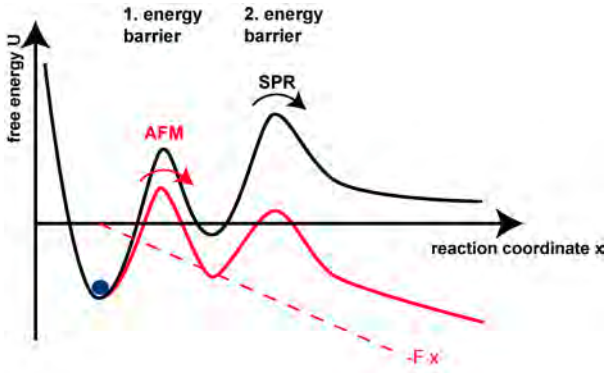
Prof. Hermann E. Gaub (LMU Munich)
Dr. Kay Gottschalk (LMU Munich)

Inter-molecular interactions play an important role in life. Force spectroscopy reveals unique and complementary information on molecular interactions that can be correlated with classical methods and additionally provide access to the geometry of the binding potential. The complexity of the potential landscape is visualized and confined by molecular dynamic simulations.

Such multidimensional energy landscapes describe intrinsic properties of proteins and define their dynamic behavior as well as their response to external stimuli. In order to explore the energy landscape and its implications on the dynamic function of proteins, dynamic force spectroscopy and steered molecular dynamics (SMD) simulations have proved to be important tools. In this study, these techniques have been employed to analyze the influence of the direction of the probing forces on the complex of an antibody fragment with its peptide antigen. Using an atomic force microscope, experiments were performed where the attachment points of a 12 amino acid long peptide antigen were varied. These measurements yielded clearly distinguishable basal dissociation rates and potential widths, proving that the direction of the applied force determines the unbinding pathway. Complementary atomistic SMD simulations were performed, which also show that the unbinding pathways of the system are dependent on the pulling direction. However, the main barrier to be crossed was independent of the pulling direction and is represented by a backbone hydrogen bond between Gly(H)-H40 of the antibody fragment and Glu(Oepsilon)-6(peptide) of the peptide. For each pulling direction, the observed barriers can be correlated with the rupture of specific interactions, which stabilize the bound complex. Furthermore, although the SMD simulations were performed at loading rates exceeding the experimental rates by orders of magnitude due to computational limitations, a detailed comparison of the barriers that were overcome in the SMD simulations with the data obtained from the atomic force microscope unbinding experiments show excellent agreement. ➤



Three-dimensional representation of the energy landscape.



Two-dimensional projection of the unbinding pathway, including two energy barriers, in a defined direction.

Julia Morfill, Jan Neumann, Kerstin Blank, Uta Steinbach, Elias M. Puchner, Kay E. Gottschalk, Hermann E. Gaub; J. Mol. Biol. 381, 1253 (2008)

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

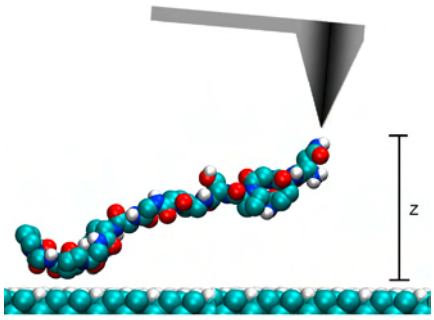
Gottschalk: *http://www.biophysik.physik.uni-muenchen.de/lsgaubstaff/kaygottschalk*

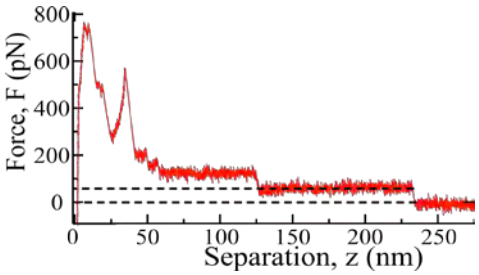
HYDROPHOBIC EFFECT

Prof. Thorsten Hugel (TU Munich)
Prof. Roland Netz (TU Munich)

The hydrophobic effect, i.e., the poor solvation of nonpolar parts of molecules, plays a key role in protein folding and more generally for molecular self-assembly and aggregation in aqueous media.

The perturbation of the water structure accounts for many aspects of protein hydrophobicity. However, to what extent the dispersion interaction between molecular entities themselves contributes has remained unclear. This is so because in peptide folding interactions and structural changes occur on all length scales and make disentangling various contributions impossible. We address this issue both experimentally and theoretically by looking at the force necessary to peel a mildly hydrophobic single peptide molecule from a flat hydrophobic diamond surface in the presence of water.





The mean desorption force of a single spider-silk molecule is determined by atomic force spectroscopy and molecular dynamics simulations.

This setup avoids problems caused by bubble adsorption, cavitation, and slow equilibration that complicate the much-studied geometry with two macroscopic surfaces. Using atomic-force spectroscopy, we determine the mean desorption force of a single spider-silk peptide chain as F = 58 pN, which corresponds to a desorption free energy of 5 k_BT per amino acid. Our all-atomistic molecular dynamics simulation including explicit water correspondingly yields the desorption force F = 54 pN. This observation demonstrates that standard nonpolarizable force fields used in classical simulations are capable of resolving the fine details of the hydrophobic attraction of peptides. The analysis of the involved energetics shows that water-structure effects and dispersive interactions give contributions of comparable magnitude that largely cancel out. It follows that the correct modeling of peptide hydrophobicity must take the intimate coupling of solvation and dispersive effects into account. ➤

Dominik Horinek, Andreas Serr, Michael Geisler, Tobias Pirzer, U. Slotta, S. Q. Lud, J. A. Garrido, T. Scheibel, Thorsten Hugel, Roland R. Netz;
PNAS 105, 2842 (2008)

Hugel: *http://www.e27.physik.tu-muenchen.de/Hugel/*

Netz: *http://www.ph.tum.de/lehrstuehle/T37/*

THEORETICAL AND EXPERIMENTAL INVESTIGATIONS OF COULOMB BLOCKADE IN COUPLED QUANTUM DOT SYSTEMS

Prof. Peter Hänggi (University of Augsburg)
Prof. Achim Wixforth (University of Augsburg)

The groups of Prof. Hänggi and Prof. Wixforth have studied theoretically and experimentally a system of strongly coupled quantum dots with the aim of inducing pump currents by surface acoustic waves. Figure 1 shows a scanning electron micrograph of the sample. Black areas are wet-etched and, thus, non-conducting. The depletion of the left channel is controlled by the left in-plane gate. This allows one to constrict the channel by applying a negative gate voltage which eventually can even force out all electrons from the channel. In the experiment, we operate the system such that transport occurs through only the left channel.

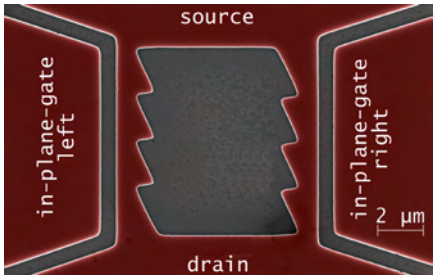


Figure 1: (a) Scanning electron micrograph of the sample. Red (darker) areas correspond to a 2DEG, grey (brighter) areas are wet-etched and, thus, non-conducting. The right channel is closed by a large negative gate voltage (-4.5V), while the gate voltage at the left channel is controlled to adjust the energy levels that support the electron transport.

In order to later capture pumping effects with a relatively simple and, thus, analytically treatable model, the authors have performed conductance measurements at the undriven model and observed a Coulomb-diamond structure for the current as a function of the gate and the bias voltage. Comparison with theoretical results for a two-level model revealed that this model is already sufficient to capture the main physics.

Figure 2 depicts the measured differential conductance (a) and the corresponding theoretical results (b). Blue color corresponds to large values indicating significant changes of the conductance. These changes occur whenever the gate or the bias voltage is modified such that an energy level enters or leaves the voltage window. The clear asymmetry in the experimental data with respect to the gate voltage indicate the absence of particle-hole symmetry due to strong Coulomb repulsion between an electron in the one dot and an electron in the other dot. This leads to the conclusion that the system is well-described by a two-level system that can be occupied with at most one electron. ➤

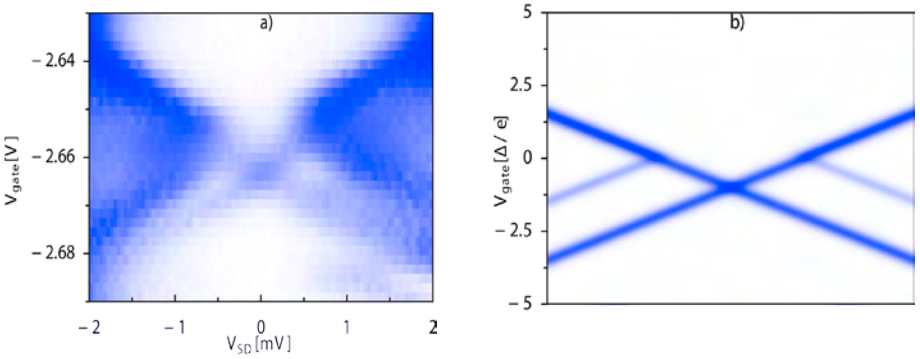


Figure 2: (a) Measured differential conductance dI / dV_{SD} as a function of source-drain voltage and gate voltage. Bright regions correspond to low conductance and blue regions to high conductance. (b) Corresponding theoretical prediction for a double quantum dot modelled by a two-level system with strong Coulomb repulsion.

Franz J. Kaiser, S. Kohler, Peter Hänggi, M. Malecha, Jens Ebbecke, Achim Wixforth, H. W. Schumacher, B. Kästner, D. Reuter, and A. D. Wieck;
J. Phys. - Condensed Matter 20, 374108 (2008)

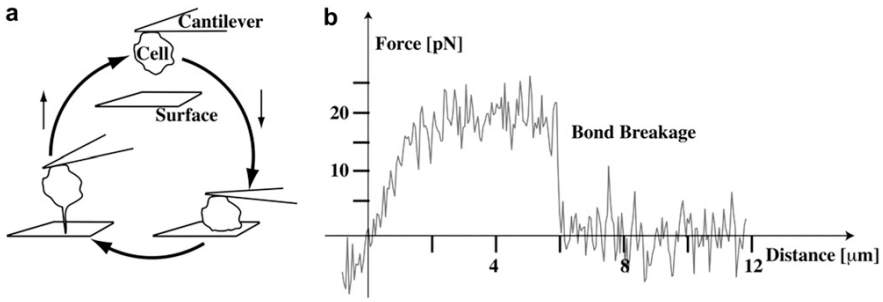
Hänggi: *http://www.physik.uni-augsburg.de/theo1/hanggi/*

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

PLANAR PATCH-CLAMP FORCE SPECTROSCOPY

Dr. Martin Benoit (LMU Munich)
Dr. Niels Fertig (Nanion Technologies)
Dr. Kay Gottschalk (LMU Munich)

To extend single molecule force spectroscopy measurements to cell adhesion molecules, many approaches have been developed. The planar patch-clamp technique recently developed by nan]i[on was successfully integrated into an AFM force spectroscopy setup. This combination allows for universal immobilization of cells in the aperture of the planar patch-clamp chip. Individual cell adhesion molecules can be accessed in their natural environment. Cell adhesion mechanically couples cells to surfaces. The durability of individual bonds between the adhesive receptors and their ligands in the presence of forces determines the cellular adhesion strength. For adhesive receptors such as integrins, it is a common paradigm that the cell regulates its adhesion strength by altering the affinity state of the receptors. However, the probability distribution of rupture forces depends not only on the affinity of individual receptor-ligand bonds but also on the mechanical compliance of the cellular anchorage of the receptor. Hence, by altering the anchorage, the cell can regulate its adhesion strength without changing the affinity of the receptor. In this project the anchorage of the integrin VLA-4 with its ligand VCAM-1 was analyzed based on the model of a Kelvin body. The measured force curves give valuable insight into the mechanics of the cellular anchorage of the receptor, which is described by the tether stiffness, the membrane rigidity, and the membrane viscosity. Based on our model, we postulate that anchorage-related effects are common regulating mechanisms for cellular adhesion beyond affinity regulation. ➤



A typical force curve of a Jurkat cell immobilized on the cantilever retracted from a VCAM-1 coated surface after 100ms contact at an indentation force of 50pN.

Julia Schmitz, Martin Benoit, Kay E. Gottschalk; Biophys J. 95, 1448 (2008)

Benoit: *http://www.biophysik.physik.uni-muenchen.de/groups/cell-biophysics*

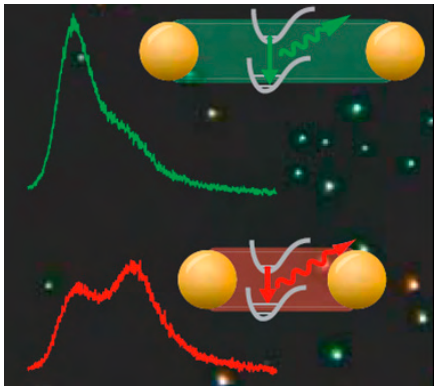
Fertig: *http://www.nanion.de/*

Gottschalk: *http://www.biophysik.physik.uni-muenchen.de/lsgaubstaff/kaygottschalk*

PLASMONIC NANORESONATORS

Prof. Thomas A. Klar (TU Ilmenau)
Prof. Jochen Feldmann (LMU Munich)

A pair of gold nanoparticles influences the shape of the fluorescence spectrum of dye molecules located between the nanoparticles. This effect, commonly known as Purcell effect, has hitherto been demonstrated with resonators of the size of half of the wavelength of the emitted light. Ringler et al. have now shown that similar effects work with nanoscopic resonators. In cooperation with Roche Diagnostics, Penzberg, they arranged pairs of gold nanoparticles using antigen-antibody recognition. In addition, dye molecules have been connected to these pairs of gold nanoparticles. Subsequently, Ringler et al. performed dark field scattering spectroscopy and fluorescence spectroscopy on single pairs of gold nanoparticles. Scattering spectroscopy allows for the exact determination of the surface to surface distance of the two nanoparticles of a dimer. Ringler et al. managed to measure these distances with an accuracy of 1 Angstrom only, although they used a pure far field setup. The "secret" of redeeming such a good accuracy lies in the spectroscopic information of the scattering spectrum. A 1 Angstrom change of surface to surface distance results in an easily measurable shift in the scattering spectrum. After they had determined the surface to surface distance, Ringler et al. switched to fluorescence spectroscopy of dye molecules attached to the previously characterized nanoparticle dimer. It turned out that among the spectrum of vibronic sidebands of the molecular emission, the one in resonance with the coupled nanoparticle plasmon is the most prominent one. Hence, it was shown that a pair of gold nanoparticles can serve as a resonator for molecular fluorescence emission. This is an important step towards a subwavelength sized laser. Usually, the size of a laser resonator needs to be at least half of the wavelength. So far, this hampered the design of photonic logic circuits from seriously competing with electronic circuits: The building blocks of the latter reach sizes of some tens of nanometres squared, while photonic building blocks cover areas which are 100 times larger. The gold nanoparticle resonators described in this work may now be used as resonators for a nanoscopic light source in a truly nanoscopic all-optical logic device. ➤



A pair of gold nanoparticles can tune the emission colour of a dye molecule sandwiched in between.

Moritz Ringler, Alexander Schwemer, M. Wunderlich, A. Nichtl, K. Kürzinger, Thomas A. Klar, Jochen Feldmann; Phys. Rev. Lett. 100, 203002 (2008)

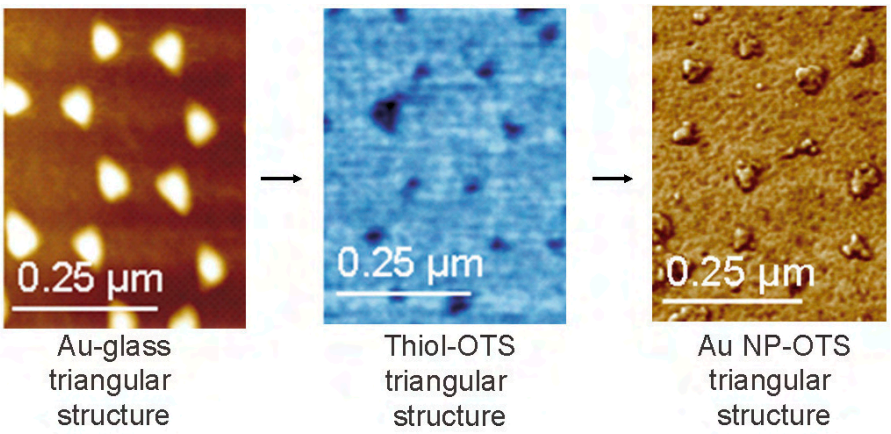
Feldmann: *http://www.phog.physik.uni-muenchen.de/*

Klar: *http://tu-ilmenau.de/fakmn/Experimentalphysik-I.975.0.html*

CHEMICAL NANOSTRUCTURES OF MULTIFUNCTIONAL SELF-ASSEMBLED MONOLAYERS

Prof. Jochen Feldmann (LMU Munich)
Prof. Andrey L. Rogach (LMU Munich)
Prof. Ulrich S. Schubert (Friedrich-Schiller-Universität Jena & Eindhoven University of Technology)

Chemical surface nanostructures consist of separate areas that expose different chemically reactive groups. They provide templates for the spatially defined fabrication of a plethora of different functionalities by the attachment of biomolecules, supramolecular complexes, or other organic or inorganic nanoparticles with nanometer precision. It still remains a challenge to fabricate chemical nanostructures that consist of functional self-assembled monolayers with nanometer resolution on large surface areas. A new concept for the fabrication of chemical nanostructures of multifunctional self-assembled monolayers (NanoMuSe) based on metal structures was introduced to fabricate replaceable barrier nanostructures to guide sequential self-assembly processes. *n*-Octadecyltrichlorosilane (OTS)/thiol patterns, providing well-defined structures with dimensions < 30 nm, were fabricated in a proof-of-concept study by employing latex bead projection patterning. The experiment was designed to demonstrate the versatility of the approach and to show the capabilities in terms of stability and resolution of the resulting NanoMuSes, consisting of bifunctional surface patterns. 6 nm gold nanoparticles, synthesized by Dr. Andrey Rogach in the group of Prof. Jochen Feldmann, were used to prove the chemical integrity of the NanoMuSe. The approach is compatible with other well-established high-resolution lithographic techniques to form barrier nanostructures of arbitrary shape for the fabrication of nanostructures. Moreover, the chemical modification of the employed monolayers allows for a tailor-made chemical functionalization that opens up a large variety of applications of this patterning approach, e.g., for the binding of nanoparticles, fluorescent dyes, polymer brushes, biomolecules (i.e., peptides) to build biochips, protein nanoarrays, and components for sensor applications. ➤



AFM investigation of the fabrication process of bifunctional OTS/thiol NanoMuSes with sub-30 nm resolution. Left: Gold barrier structures fabricated by latex bead projection patterning. Middle: Structure after filling of the non-covered silicon areas with OTS and removal of the gold barrier structures, which appear as holes within the OTS monolayer. Right: Site-selective assembly of 6 nm gold nanoparticles after the self-assembly and chemical conversion of functional molecules within the holes.

Nicole Herzer, Stephanie Hoeppener, Ulrich S. Schubert, Harald Fuchs, Ulrich C. Fischer; Adv. Mater. 20, 346 (2008)

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

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

EQUILIBRATION IN QUANTUM MANY-BODY SYSTEMS

Prof. Stefan Kehrein (LMU Munich)

Landau Fermi liquid theory is a paradigmatic description for moderately correlated fermions in equilibrium and has been applied to systems like 3He, nuclear matter or the electron gas of metals. Based on the prerequisite of adiabatic continuity, Landau developed the celebrated one-to-one correspondence between the eigenstates of noninteracting fermions and quasiparticles of an interacting model.

Challenging this adiabaticity requirement, Moeckel and Kehrein studied the Schrödinger dynamics of the Hubbard model within its Fermi liquid phase following a weak interaction quench, i.e. the sudden switching-on of a weak two-particle interaction. The system shows a rapid initial build-up of a quasiparticle picture, and then a long lasting transient prethermalized nonequilibrium state. This prethermalized state exhibits freezing of the momentum distribution originating from Pauli blocking of scattering processes at low temperatures, which is lifted on a longer time scale with a final approach towards a thermal state with an effective temperature. The delayed thermalization of the momentum distribution suggests that nonequilibrium phenomena of Fermi liquids may be observable within a time window after a quench and before heating washes out their signatures. This general scenario is suggested to be generic for thermalization in interacting many-body systems and was here for the first time derived from the underlying quantum dynamics. ➤

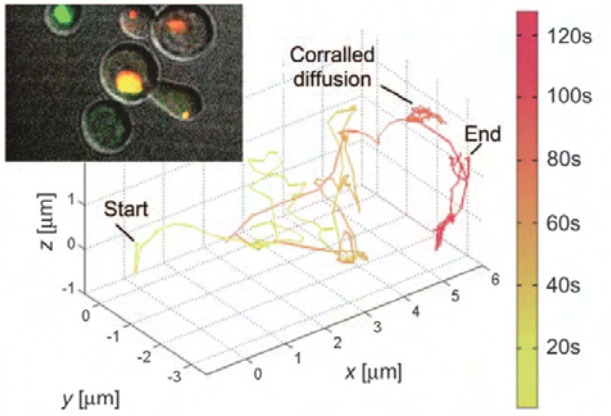
Michael Moeckel and Stefan Kehrein; Phys. Rev. Lett. 100, 175702 (2008)

Kehrein: *http://homepages.physik.uni-muenchen.de/~stefan.kehrein/*

DO DIFFERENT LOCALIZED mRNA SPECIES USE A "BUS" TOGETHER OR DO THEY USE INDIVIDUAL "TAXIS" FOR THEIR TRANSPORT IN LIVING YEAST CELLS?

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

Intracellular mRNA localization is a common mechanism to achieve asymmetric distributions of proteins. Previous studies have revealed that in a number of cell types, different mRNA species are localized by the same transport machinery. However, it has been unclear if these individual mRNA species are specifically sorted into separate or common ribonucleoprotein (RNP) particles before or during transport. Using budding yeast as a model system, we analyzed the intracellular movement of individual pairs of localized mRNA in live cells. Yeast cells localize more than 20 different mRNAs to the bud with the help of the Myo4p/ She3p/ She2p protein complex. For live cell imaging, mRNA pairs were tagged with tandem repeats of either bacteriophage MS2 or lambda boxB RNA sequences and fluorescently labeled by fusion protein constructs that bind to the RNA tag sequences. Using three-dimensional, single-particle tracking with dual-color detection, we have tracked the transport of two different localized mRNA species in real time. Our observations show that different localized mRNAs are coassembled into common RNP particles and cotransported in a directional manner to the target site. Nonlocalized mRNAs or mutant mRNAs that lack functional localization signals form separate particles that are not transported to the bud. This study reveals a high degree of co-ordination of mRNA trafficking in budding yeast. ➤



Coordinated transport of ASH1 mRNA and IST2 mRNA. The three-dimensional trajectory of a localizing RNP particle containing both boxB-ASH1 and IST2-MS2 mRNAs. Z-stacks were collected at a time resolution of ~ 300 msecond/stack. The trajectory is color coded according to the elapsed time from bright green to dark red.

S. Lange, Yoshihiko Katayama, M. Schmid, Ondrej Burkacky, Christoph Bräuchle, Don C. Lamb, R.-P. Jansen; Traffic 9, 1256 (2008)

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

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

OPTICAL DETECTION OF SINGLE-ELECTRON SPIN RESONANCE IN A QUANTUM DOT

Prof. Alexander Holleitner (TU Munich)
Prof. Khaled Karrai (attocube systems & LMU Munich)

We demonstrate optically detected spin resonance of a single electron confined to a self-assembled quantum dot. The dot is rendered dark by resonant optical pumping of the spin with a coherent laser as shown in the scheme of Fig. 1 (a). The contrast is restored by applying a radio frequency (rf) magnetic field at the spin resonance. The scheme is sensitive even to rf-fields of just a few µT that can be applied to the quantum dot by a simple loop antenna as depicted in Fig. 1 (b). The narrow electron-spin resonance line shown in Fig. 1 (c) makes the determination of the electron spin splitting - given by the electron g-Factor a crucial prerequisite for the experiment. We developed a two-laser resonant spectroscopy scheme to optically determine directly the electron Zeeman splitting with high precision as depicted in Fig. 1 (a). ➤

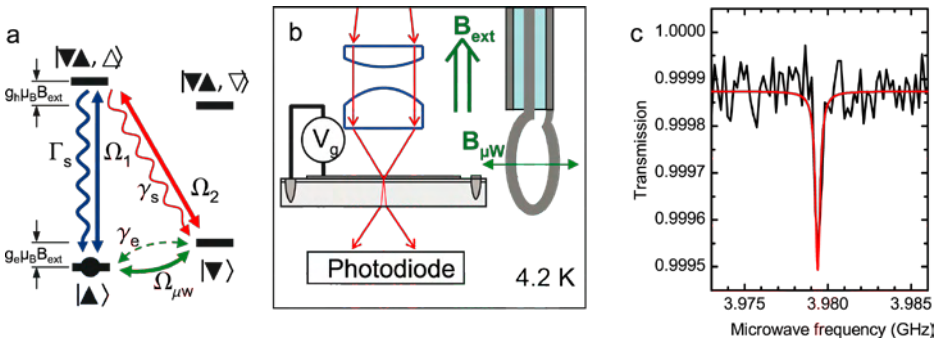


Fig. 1: (a) Level-scheme of the negatively charged exciton in a magnetic field. The ground and excited states are split by the Zeeman energy of the electron and hole respectively. A resonant laser (blue arrow) pumps the electron spin via a Raman transition (red curved arrow) into to the spin-down ground state. A resonant microwave field (green arrow) restores the equal population of the ground states and thereby allows again the absorption of the pump laser (blue arrow). A second laser (red arrow) is used to probe the Raman transition allowing a direct measurement of the Zeeman splitting of the electron ground state. (b) Schematic drawing of the confocal microscope objective to illuminate the sample. The photodiode measures the transmitted laser light. The microwave field is provided by a single loop antenna generating an oscillating magnetic field perpendicular to the external magnetic field. The whole setup is immersed in a bath cryostat and operates at 4.2 K. (c) Transmission signal of the pump laser (blue arrow in (a)) as a function of the microwave frequency. The absorption of the laser is re-established in case of resonance leading to a narrow dip in the transmission spectrum.

Martin Kroner, Kathrina M. Weiss, Benjamin Biedermann, Stefan Seidl, Stephan Manus, Alexander W. Holleitner, A. Badolato, P. M. Petroff, B. D. Gerardot, Richard J. Warburton, and Khaled Karrai; Phys. Rev. Lett. 100, 156803 (2008)

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

Karrai: *http://www.nano.physik.uni-muenchen.de/~karrai/*

OPTOMECHANICS: QUANTUM DYNAMICS AND FOCK-STATE MEASUREMENT

Dr. Florian Marquardt (LMU Munich)

The interaction of light and mechanical motion in so-called optomechanical systems is receiving strong attention recently, both on the theoretical and the experimental level. The typical system studied in this field consists of an optical cavity with a movable end-mirror. The mirror can be deflected by the incoming radiation pressure, and in turn this will affect the circulating light-intensity, giving rise to an interplay of radiation dynamics and mechanical motion. Thus, one extends the ideas of laser cooling and trapping for atoms to the domain of 'macroscopic objects', namely mirrors comprising about 10^{14} atoms. In the quantum regime, this could pave the way towards generating and observing 'macroscopic superposition states', and eventually test quantum mechanics in a new regime.

One consequence of this light-mechanics interaction is nonlinear dynamics, which had already been studied in the Marquardt group for the classical case. These studies have now been extended into the quantum regime, which several groups hope to reach soon via optomechanical cooling. The theory for the quantum regime [M. Ludwig et al. (2008), New Journal of Physics 10, 095013] shows interesting effects of quantum fluctuations, and it might be tested in optomechanical setups with cold atoms, where a single photon has a large effect on the mechanical motion of the atomic cloud. Another important issue in the quantum regime is how to detect the number of mechanical vibration quanta (phonons) stored in the mirror. If this could be achieved in a time-resolved way, without absorbing the quanta, then it would be possible to observe in real-time the quantum jumps between different vibrational states of a macroscopic object (the mirror). This feat is impossible in the standard optomechanical setup, where only the displacement of the mirror but not its phonon number may be measured. However, a modified setup with a membrane in the middle of a fixed optical cavity might allow this goal to be realized in the future. This setup has now been realized in the lab of Jack Harris at Yale, with theoretical input from the Marquardt group [J. D. Thompson et al. (2008), Nature 452, 72 and A. M. Jayich et al. (2008), New Journal of Physics 10, 095008]. Further improvements are still necessary to actually perform phonon detection. ➤

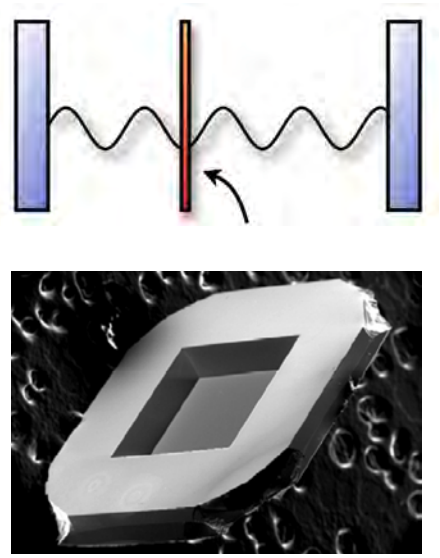


Fig. 1: An optical cavity containg a membrane placed between two fixed end-mirrors (experimental picture of membrane: courtesy Jack Harris, Yale).

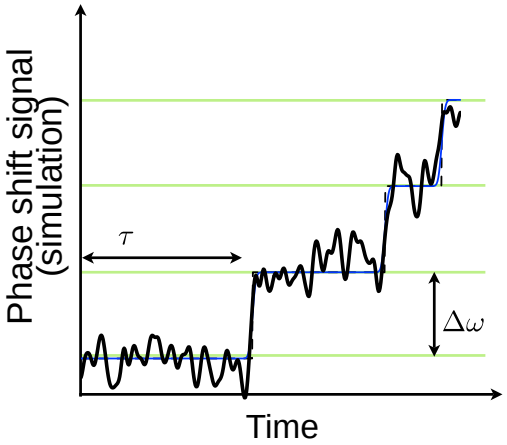


Fig. 2: Theoretical simulation for the phase shift of light reflected from such a cavity, which could in principle yield a direct "quantum-non-demolition" measurement of the vibrational quantum number for the mechanical motion of the membrane, given the right conditions. This would allow one to observe quantum jumps of mechanical motion for a macroscopic object.

J. D. Thompson, B. M. Zwickl, A. M. Jayich, Florian Marquardt, S. M. Girvin, and J. G. E. Harris;
Nature 452, 72 (2008)

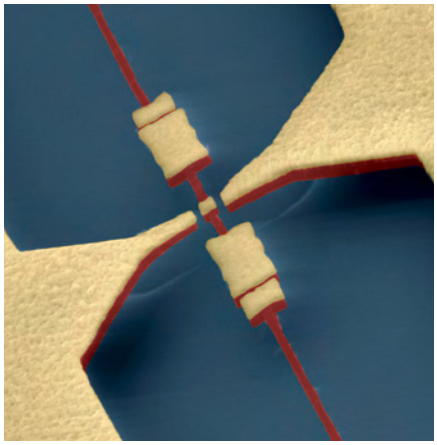
Marquardt: *http://homepages.physik.uni-muenchen.de/~Florian.Marquardt/*

NANO-MECHANICAL SINGLE-ELECTRON SHUTTLE

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

The transport and detection of single electrons with extraordinary precision has been a long sought goal since its potential impact on metrology was recognized in the 80s. For example, the one-by-one electron transfer with a well defined frequency may ultimately lead to the realisation of a quantum standard for the electrical current unit ampere – like the ones already implemented for voltage and resistance based on the Josephson and Quantum Hall effect, respectively. One possible approach to this goal is the mechanical transfer of single electrons.

For this purpose, Daniel Koenig developed a mechanical single electron shuttle which consists of a gold island situated in the center of a doubly clamped freely suspended nanoresonator (see picture). The resonator is 14 micrometers long and has been fabricated from silicon nitride under high tensile stress. A source and a drain electrode is placed to either side of the island, so that the gold island can shuttle electrons from one contact to the other once the system is mechanically excited. The highly parallel system integration of up to several hundred devices, each having an individual eigenfrequency, allows the measurement of a large number of individual devices in a short period of time. The samples are mechanically excited by ultrasonic waves and placed within a Faraday cage to shield it from undesired electromagnetic fields. In this configuration, electrically undisturbed mechanical electron transport at temperatures as low as 20 Kelvin was demonstrated. In this high temperature limit, excellent agreement between the measured data and theoretical calculations was observed. ➤



Single electron shuttle, consisting of a gold (yellow) island, which is placed in the center of a doubly clamped and 14 micrometer long silicon nitride (red) string under high tensile stress (clamping points not shown). Once the string is mechanically excited to sufficiently large amplitudes by ultrasonic waves, the island can mechanically shuttle electrons between the two electrodes depicted on either side of the island. Typical operation frequencies of devices are in the range between 1 and 10 MHz.

Daniel R. Koenig, Eva M. Weig, and Jorg P. Kotthaus;
Nature Nanotechnology 3, 482 (2008)

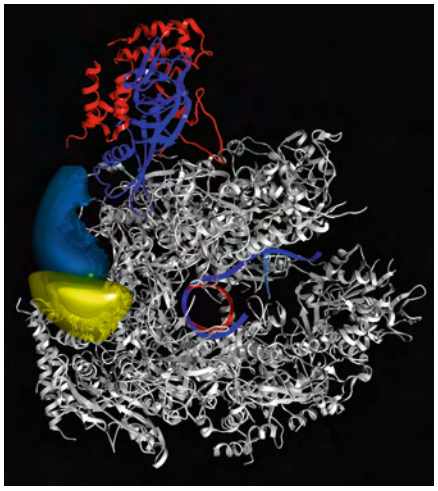
Kotthaus: *http://www.nano.physik.uni-muenchen.de/*

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

NANO POSITIONING SYSTEM

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

One hallmark of macro-molecular complexes that have evolved to perform specialised tasks inside of the cell is that biological activity of these complexes is oftentimes regulated by the binding and unbinding of other protein co-factors. In the case of eukaryotic transcription, several transcription factors regulate the action of the machine responsible for the production of the nascent RNA, the RNA polymerase. In a collaboration between the structural biology group of Patrick Cramer and the biophysical group of Jens Michaelis the conformation of the yeast RNA polymerase II was investigated on the single-molecule level. By developing a novel method, the nano-positioning system (NPS), it was found that the nascent RNA changes its position in the presence of transcription initiation factor TFIIB. The position of the RNA interferes with the binding site of TFIIB and therefore the presence of TFIIB pushes the RNA to a different position, another binding site. This binding site had been observed previously in biochemical experiments and taken together the results suggest that transcription initiation and elongation are coupled stronger than previously expected.



Yeast RNA Polymerase II elongation complex showing the position of the exiting RNA in absence (yellow) and presence (blue) of transcription factor TFIIB. The position of the RNA was determined using single molecule Fluorescence Resonance Energy Transfer measurements and the newly developed Nano Positioning System (NPS).

In order to obtain these results, the researchers needed to develop a quantitative analysis of the recorded FRET data. They measured the fluorescence resonance energy transfer (FRET) on the single molecule level between molecules attached to different known positions within Pol II elongation complexes and an unknown position, the end of the newly transcribed RNA molecule. Using the information from x-ray crystallographic data and a statistical analysis approach based on Bayesian parameter estimation they could relate the measured FRET data to the three dimensional probability density for the unknown position. Included in the analysis were uncertainties in the determination of the characteristic parameter for the FRET measurements, the so called Förster radius, as well as uncertainties due to the geometry of flexible linker molecules and FRET errors. While oftentimes FRET had been termed as a molecular ruler, truly quantitative information about distances and positions was previously hard to achieve. The new analysis method provides an elegant solution to this problem and will therefore have a large impact on future structural studies of macromolecules using FRET. ➤

Adam Muschielok, Joanna Andrecka, Florian Brückner, Anass Jawhari, Patrick Cramer and Jens Michaelis; Nature Methods 5, 965 (2008)

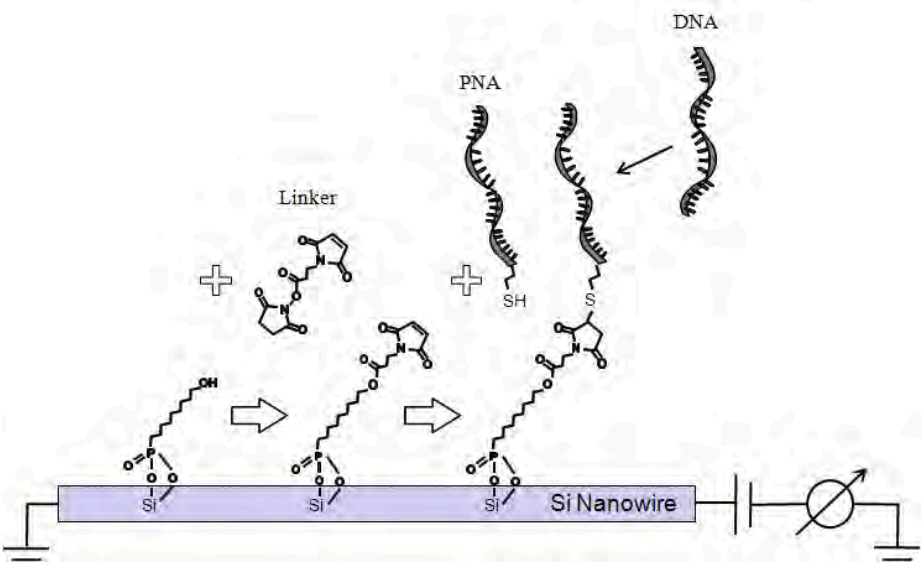
Cramer: *http://www.lmb.uni-muenchen.de/cramer/*

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

ORGANOPHOSPHONATE-BASED PNA FUNCTIONALIZATION OF SILICON NANOWIRES FOR LABEL-FREE DNA DETECTION

Priv.-Doz. Bert Nickel (LMU Munich)
Prof. Marc Tornow (Technical University Braunschweig)

In close collaboration with partners from TUM (Anna Cattani-Scholz, Daniel Pedone, Stefan Neppl, Peter Feulner, Gerhard Abstreiter) and Princeton University (Manish Dubey, Jeffrey Schwartz) hydroxyalkylphosphonate self-assembled monolayers were investigated as novel interface systems for the biofunctionalization of silicon nanowire sensor devices. The consortium performed a detailed study of organic thin film properties on planar Si substrates: AFM and ellipsometric analysis indicated the presence of a dense monolayer on the native oxide. This monolayer was comprised of alkylphosphonate molecules that are, on average, tilted by about 54° from the surface normal. This finding was further confirmed by x-ray reflection measurements done in aqueous media, which revealed a dense hydrophobic region of about 8 Å thickness (corresponding to a tilt angle 52°) that was separated from an additional layer of enhanced density suggesting co-adsorption of ions on top of the SAM. The monolayer effectively passivated the Si surface against electrochemical leakage current into the electrolyte solution. Functionalization of the phosphonate monolayer with a heterobifunctional maleimido compound, as well as the subsequent derivatization with peptidic nucleic acid (PNA) oligonucleotides, was verified by XPS. Contact angle measurements and fluorescence spectroscopy following hybridization with dye-labeled DNA supported these findings. The functionalization protocol was translated to 100 nm wide Si nanowire field effect devices fabricated from Silicon-on-Insulator, which allowed for the label-free detection of DNA hybridization: A decrease in wire resistance equivalent to a surface potential change of ~1.5 mV was measured upon injection of 1 µM DNA electrolyte buffer solution. Future work will focus on reduction of non-specific DNA adsorption effects and monolithic integration of these sensor structures into microfluidic systems. ➤

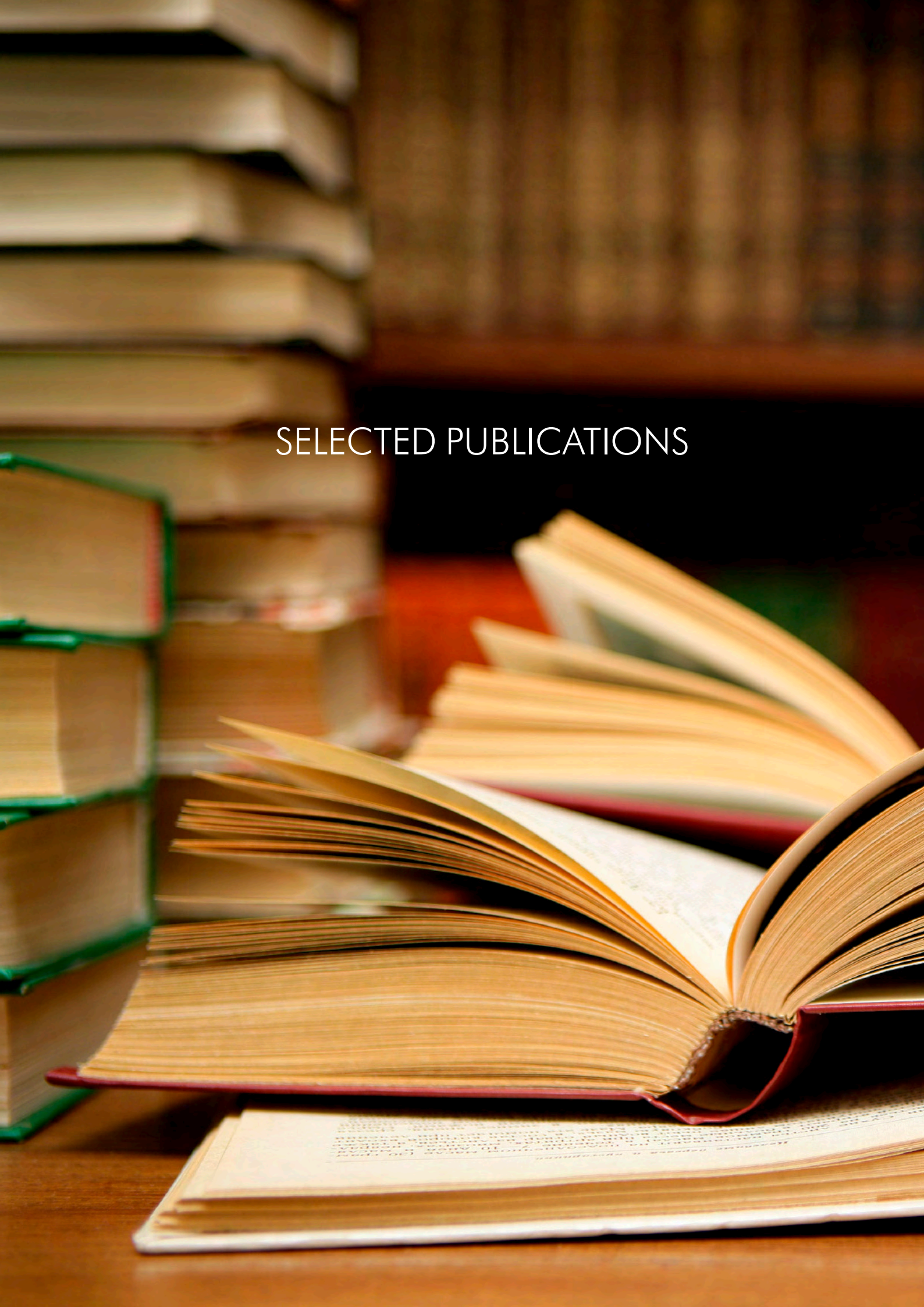


Schematic illustration of the step-wise biofunctionalization of silicon nanowire field effect devices based on hydroxyalkylphosphonate self-assembled monolayers. Coupling of PNA to the monolayer is achieved using a maleimido heterobifunctional linker.

A. Cattani-Scholz, D. Pedone, M. Dubey, S. Neppl, Bert Nickel, P. Feulner, J. Schwartz, G. Abstreiter, Marc Tornow; ACS Nano 2, 1653 (2008)

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

Tornow: *http://www.iht.tu-bs.de/EN/bn_group.html*



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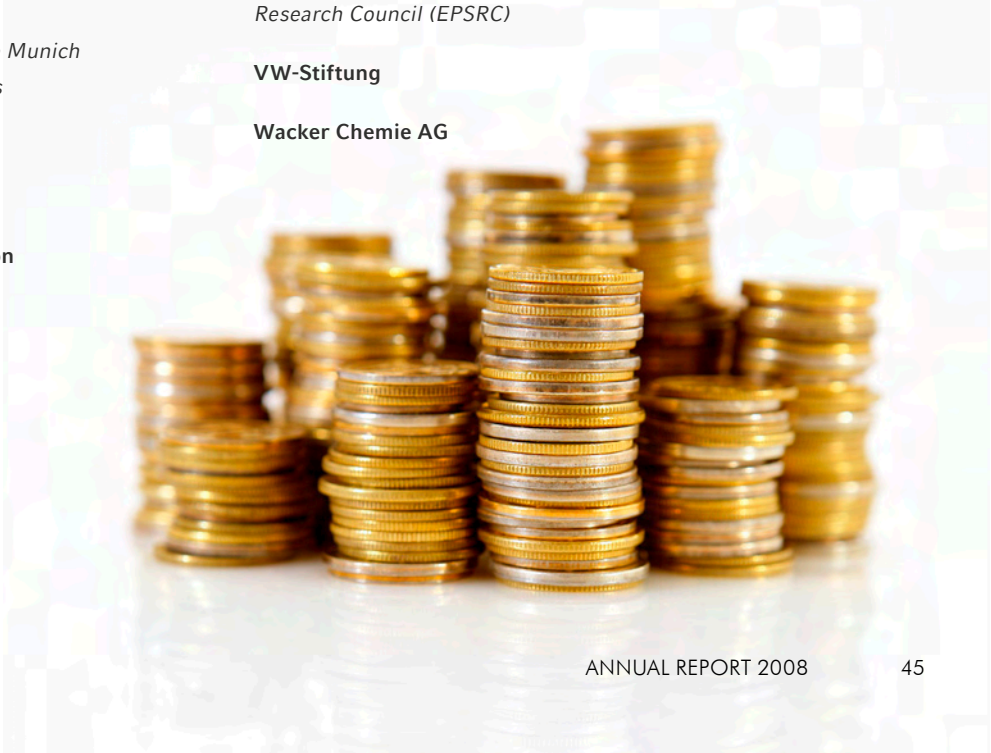

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