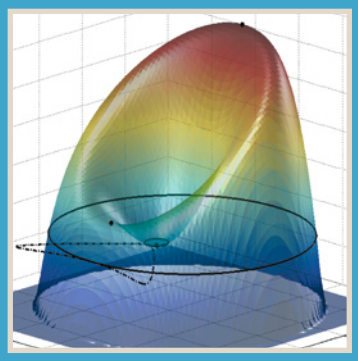
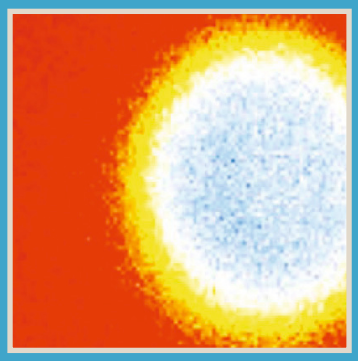
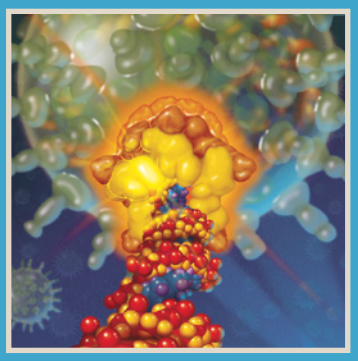
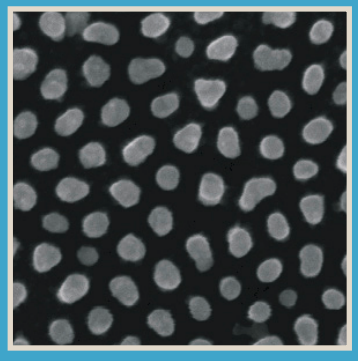
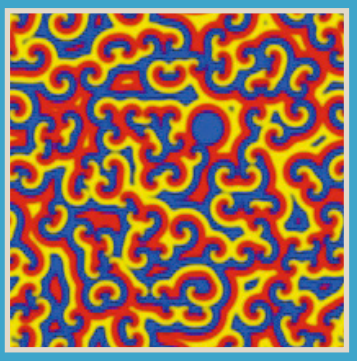
Center for NanoScience

Annual Report 2007



Center for NanoScience
Ludwig-Maximilians-Universität

Dear Members of CeNS, dear Friends and Mentors!
Looking back to the year 2007 is a real pleasure. CeNS increased its range of activities, grew in numbers, widened its partnerships, and most importantly, strengthened the synergies with the new structures created by the Excellence Initiative, particularly with the Nanosystems Initiative Munich (NIM) and the Center for Integrated Protein Science Munich (CIPSM).

Let me start with the most enjoyable part of my review - the awards. Patrick Cramer won the Philip Morris Prize, Uli Schubert two Invention Awards of the Dutch Polymer Institute, Matthias Schneider together with Advalytix and ibidi the Innovation Award for medical technologies of the BMBF, Jens Michaelis the Award from the Dr. Klaus Römer-Foundation for his habilitation and finally Heinrich Leonhardt and Ulrich Rothbauer were winners of the GO-Bio Competition of the BMBF. The Bavarian order of merit was awarded to Jörg Kotthaus, and Peter Hänggi was elected Ordinary Member of the Academia Europaea in the Physics, Astrophysics and Engineering Section. Peter also became Visiting Professor of Beijing Normal University and Ernst Wagner was elected honorary member of BUON (Balkan Union of Oncology). LMU*excellent* research professorships were granted to Patrick Cramer and Jochen Feldmann.

The numerous offers that our members received from other universities very convincingly reflect the world-wide recognition of the high scientific standards at CeNS. Thomas Klar declined several offers e.g. from Pittsburgh and the TU Delft and accepted the professorship at the TU Ilmenau. Irmgard Frank accepted a professorship from the Universität Hannover and Don Lamb turned down the offer from Greensburo, North Carolina, and accepted a LMU-professorship in the Chemistry department. Dieter Braun turned down an offer from the Universität Leipzig, accepted a LMU*innovativ* professorship and became an ordinary CeNS member. Alex Holleitner accepted the offer from the TU Munich and Thorsten Hugel turned down an offer from Frankfurt. Jens Michaelis received an offer from Frankfurt and Andrey Rogach declined the offer from the Nanyang University in Singapore. Uli Schubert turned down several offers amongst them from the Universities of Hamburg and Stuttgart and took over a directorship at the Friedrich-Schiller-Universität Jena. Fritz Simmel declined a LMU*innovativ* position and took over the professorship at the TU Munich. Enrique Solano became professor at the Universidad del País Vasco and Ikerbasque in Spain.

It is a pleasure to welcome several new CeNS-members. Lukas Schmidt-Mende and Philip Tinnefeld both took over professorships at the LMU and became ordinary members of CeNS. Ralf David, Ralf Metzler and Matthias Schneider joined us as extraordinary members, and of course numerous PhD and Diploma or Master students joined the network.

The CeNS Winterschool in Mauterndorf with the focus on „Nanosystems: From Quantum Devices to Biological Engines“ was again a central event in our efforts to train our students and junior researchers. It was supplemented by two additional workshops “Scientific Presentations in English” and “Patent Protection for Research in Natural Sciences”, the latter being organized together with the European Patent Office and the University of Augsburg. Particularly notable is the lecture series on Bayesian Data Analysis by Prof. Volker Dose, MPI Plasmaphysics, which was initiated and organized by CeNS PhD students.

As in the years before, CeNS has strengthened its position amongst the internationally leading centers for nanosciences which leads to an increasing number of cooperative projects

“CeNS is dedicated to further promote nanosciences and to sculpture the scientific landscape beyond the borders of our institutions.”

with other institutions. Together with the Elite Study Programme “Macromolecular Science” of the University of Bayreuth the International Doctorate Program NanoBioTechnology (IDK-NBT), hosted by CeNS, organized a workshop with the focus on “Macromolecular Systems”. Another notable event in the list of last year’s activities was the “Winter School on Nanotechnology Convergence” in Edmonton (Alberta), which CeNS co-organized with the National Institute for Nanotechnology of Canada. The participating PhD students from Germany and Canada had the chance to follow high-quality lectures from renowned speakers from Canada and the U.S. and to acquire instructive hands-on experience during various lab tutorials.

Despite the currently rather frosty business climate for startups, CeNS maintained its creative and supportive founder-environment in which two new companies were started: Neaspec GmbH by Rainer Hillenbrand, Fritz Keilmann and Nenad Ocelic, and NanoTemper Technologies by Philipp Baaske and Stefan Duhr. The latter were awarded the 3rd rank in the Munich Business Plan Contest where also the team of Ulrich Rothbauer with its Chromobodies Technology was successful. Our maturing ventures did very well, too: Nanion Technologies reached the final round of the “German Future Award”, the Federal President’s Award for Technology and Innovation, and Attocube Systems was selected finalist of the Innovation Award of the German Economy. CeNS still sees technology transfer as one of its prominent goals and therefore encourages its students by means of workshops like “CeNS meets industry” which found wide recognition and triggered many discussions that lasted far into the subsequent CeNS Summer Party.

Last but not least it should be mentioned that the continuous efforts of CeNS to improve the education of our PhD students was rewarded by the extension of the International Doctorate Program “NanoBioTechnology” financed by the Elite Network of Bavaria for another four years. Special credit should be given here to Joachim Rädler and Christoph Bräuchle for their sedulous commitment.

Since CeNS is a transient structure, the members had to decide in their general meeting on the continuation of CeNS. Unanimously they voted for an extension for another five years. The discussion on future goals was as refreshing as ever and showed that CeNS is willing and dedicated to further promote nanosciences and to sculpture the scientific landscape beyond the borders of our institutions. With all the efforts of our active members and the fabulous support from our management team CeNS will succeed.

The future looks bright!

Prof. Hermann E. Gaub
Spokesman CeNS, LMU Munich

New Members

Dr. Ralf David

LMU Munich

Ralf David studied biochemistry at the University of Leipzig. After receiving his diploma in 2002 he joined the group of Prof. Beck-Sickinger as PhD student, where his research was focused on the synthesis of chemically modified chemokines (2002-2006). He continued working in this lab for another year while teaching the lab course biochemistry at the University of Leipzig. Since April 2007 he is PostDoc at the chair of Prof. Gaub at the LMU. Here, his research is dedicated to the synthesis and modification of enzymes as well as DNA-protein conjugates and their characterization using AFM-methodology.

Website:
www.biophysik.physik.uni-muenchen.de/

Prof. Ralf Metzler

TU Munich

Ralf Metzler earned his PhD from the University of Ulm. He then went for his first PostDoc position to Tel Aviv University, where he worked with Prof. Joseph Klafter (1998-2000). After a period as visiting scientist with Prof. Peter Wolynes at the University of Illinois, Urbana-Champaign, Ralf Metzler joined the group of Prof. Mehran Kardar at the Massachusetts Institute of Technology as a PostDoc. In 2002, Ralf Metzler was appointed Assistant Professor at the Nordic Institute for Theoretical Physics (NORDITA) in Copenhagen. From 2006 he spent a year at the University of Ottawa as Associate Professor and Chairholder of the Canada Research Chair in Biological Physics. In 2007 he accepted a Professorship at the Technische Universität München. Ralf Metzler's scientific interests concern the behavior of biopolymers and their interactions, gene regulation, biological search processes, and stochastic processes in general.

Website:
http://users.physik.tu-muenchen.de/metz/

Dr. Matthias F. Schneider

University of Augsburg

After finishing his Diploma Thesis at the Max Planck Institute of Biophysical Chemistry (Prof. Thomas Heimburg) working on phase transitions in lipid membranes, Matthias Schneider expanded his experience in lipid membrane thermodynamics in the lab of Prof. E. Sackmann at the TU in Munich. His strong driving force towards the physics of medicine led to an extensive stay of 9 months at the lab of Prof. John Geibel in the department of Physiology at Yale (CT, USA). In 2003 he started his habilitation in the group of Prof. Wixforth at the University of Augsburg. Together with his colleagues from theoretical physics (Prof. Roland Netz, TUM) and his brother Stefan Schneider (Uni Münster) he discovered the phenomenon of "self organized blood clotting". His future goals are to understand the physics of mutants, conformational disease and the role of membrane thermodynamics in living cells in general.

Website:
www.physik.uni-augsburg.de/exp1/schneider/schneider.html

Prof. Lukas Schmidt-Mende

LMU Munich

Lukas Schmidt-Mende studied physics at the RWTH Aachen and the University of Heidelberg and earned his PhD from the University of Cambridge (UK) in the group of Sir Richard Friend. He then moved to Switzerland where he worked in the group of Prof. Michael Grätzel at the Ecole Polytechnique Fédérale de Lausanne in the field of dye-sensitized solar cells. In 2005 he returned to Cambridge where he became group leader at the Materials Science Institute as a Royal Society Fellow. In 2007 Lukas Schmidt-Mende joined the LMU as a professor for experimental physics with the main research focus on the studies of nanostructured solar cells.

Website:
www.functional-nanosystems.lmu.de/professorships/schmidt-mende/

Prof. Philip Tinnefeld

LMU Munich

Philip Tinnefeld studied chemistry in Münster, Montpellier, and Heidelberg. In 2002, he received his PhD at the University of Heidelberg in the group of Prof. J. Wolfrum. He carried out post-doctoral research with Prof. S. Weiss (UCLA) and with Prof. F. C. de Schryver (KU Leuven) on the development of new single-molecule fluorescence techniques for the investigation of molecular interactions and dynamics. After his habilitation in physics at Bielefeld University in 2006 he was appointed Professor for Biophysics at the LMU in 2007. His research interests are the development of new fluorescence microscopic techniques to investigate biomolecular processes on the level of single molecules.

Website:
www.biophysik.physik.uni-muenchen.de/

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CALLS

Dr. Dieter Braun declined a call as Associate Professor (W2) in Leipzig

and accepted a call to Munich as Associate Professor (W2) within the LMU*innovativ* project "Functional Nanosystems".

Dr. Irmgard Frank accepted a call from the Leibniz University Hannover for a Professorship (W2) in Theoretical Chemistry.

Jun.-Prof. Alexander Holleitner accepted a call from the Technical University Munich as Associate Professor (W2) for "Nanotechnology and nanomaterials".

Jun.-Prof. Thorsten Hugel declined a call for a Professorship (W2) at the Johann-Wolfgang Goethe University in Frankfurt.

Dr. Thomas Klar declined calls from Iowa State University, the University of Pittsburgh, the TU Delft, and Trinity College in Dublin and accepted a call from the Technical University Ilmenau as Associate Professor (W2) in Experimental Physics.

Dr. Don Lamb declined a call as Associate Professor (Tenured) from the University of North Carolina, Greensburo, USA, and accepted a call as Associate Professor (W2) at the Department of Chemistry and Biochemistry at the LMU Munich.

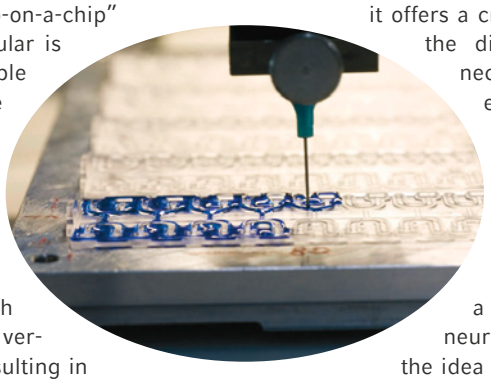
CeNS Spin-Off Nanion Finalist for the German Future Award

Nanion Technologies is one of the successful CeNS spin-off companies created in the last few years. Since its commercial start in 2002, the founding nanoscientists have demonstrated their scientific and entrepreneurial skills by the success story of their company. In 2007, Nanion reached the final round in the competition for the "Deutscher Zukunftspreis" (German Future Prize, Federal President's Award for Technology and Innovation) with its project "Small Holes – Big Effects: Cell Physiology in a Chip Format".

The outreach manager of NIM, Dr. Peter Sonntag, spoke with the CeNS member Dr. Niels Fertig, CEO of Nanion Technologies GmbH:

Dr. Fertig, your company was selected one out of four finalists for the German Future Prize 2007 awarded by the Federal President of Germany, Horst Köhler. In your opinion, what was the reason for the success of Nanion in this competition?

Our team succeeded in offering a real enabling technology with the development of the "patch-clamp-on-a-chip". This novel technique revolutionized the conventional "patch-clamp" method which requires a high level of virtuosity to act out the time-consuming, manual process. The introduction of the chip-based technology is a big step forward in the field of drug development research and leads to a high added-value for the patients by the discovery of innovative medicine. The invention of the "patch-clamp-on-a-chip" technology in particular is an excellent example for the complete cascade of a technological development: based on the scientific results of academic research, a spin-off company was founded which quickly developed a versatile technology, resulting in customer-oriented products successful on the international market which lead to the expansion of the company and the creation of high-value jobs. This development demonstrates the power of academic research in Germany and exemplifies comprehensively how pure basic research can breed technological innovation.



How Nanion was actually created? Why didn't you continue your academic career but decided to become an entrepreneur?

During my research as a Diploma and then PhD student, I worked on the development of a microstructured chip for the patch-clamp technique. The initial goal of the chip-technology was to improve the resolution of the measurement compared with the results obtainable with the common patch pipette. In the course of this research and by presenting the results at international conferences we soon became aware of the high potential for application of our investigations. Personally, I am highly attracted by the combination of scientific and entrepreneurial activities. Therefore, I realized quite early during my PhD that I wanted to found a company and make this technology accessible to others. Academic research attracts me a lot, but I really enjoy bringing scientific results to application and receiving the feedback of the customers. This kind of recognition is sometimes more difficult to obtain in the everyday life at university.

Which role did CeNS play in the foundation of Nanion?

The CeNS community was the ideal surrounding for my PhD work in many ways: On the one hand with respect to research it offers a cross-section through the disciplines and connects scientists who are experts in many different fields. On the other side, CeNS has created quite a number of spin-off companies and thereby developed a certain entrepreneurial culture. In fact, the idea of the chip emerged at a brainstorming meeting for a Collaborative Research Centre (SFB) in nanotechnology in relation with the foundation of CeNS. As it is typical for CeNS, a very diverse range of scientists came together at this meeting, amongst others Dr. Jan Behrends (medical scientist) and Dr. Robert Blick (physicist). Together, they then developed the idea of the chip.

What would you like to say to young scientists who think about founding a company on their own?

I deeply believe that there is a big entrepreneurial potential within the German universities and that there are many young scientists with excellent ideas who consider founding a spin-off company.

Needless to say, not every idea leads to an economically sustainable business model. But I would like to encourage everyone to give it a try. In any case, founding a company can be a lot of fun and if the first ideas fail to be realizable or marketable, you can still adapt everything and "stick to it". In my case, I can hardly imagine a profession more exciting than building up its own company and that's the reason why I am more than happy to discuss with potential founders about their plans and to share experiences at any time. ➤

Contact:

Nanion Technologies GmbH
Erzgiessereistr. 4
80335 Munich, Germany
www.nanion.de

New Start-Up Companies

Two new start-up companies have were founded by CeNS members in 2007: Neaspec GmbH and NanoTemper Technologies AG. A third business idea was awarded with substantial funding from the German Government.

Commercializing their novel optical microscopy technology, Dr. Fritz Keilmann, Dr. Rainer Hillenbrand and former PhD student Dr. Nenad Ocelic (all MPI of Biochemistry) founded **Neaspec GmbH**. Based in Martinsried, the start-up company develops and markets near-field microscopes with nanometric resolution, a novel photonic technology that excels in material-selective contrast provided by infrared light. Thereby, the Neaspec microscopes allow new analytical investigations by extending spectroscopic fingerprinting to nanometer-sized structures. http://www.neaspec.com/ ➤

Faster characterization of biomolecules is now possible thanks to the innovative technique developed by Dr. Stefan Duhr and PhD student Philipp Baaske (both LMU). Having been successful in the Munich Businessplan Competition (MBPW), the young researchers from the Braun lab at the Chair of Prof. Hermann Gaub founded the company **NanoTemper Technologies.** The young entrepreneurs will commercialize their technique which allows to speed up measurement times for the fast all-optical characterization of biomolecules by a factor of 10'000 compared to state of the art techniques. http://www.nanotemper.de➤

A second successful team in the Munich Business Competition lead by Dr. Ulrich Rothbauer at the Chair of Prof **Heinrich Leonhardt** plans to market its so-called **Chromobodies-Technology** for applications in biomedical research and diagnostics. Winning the GO-Bio competition of the Federal Ministry of Research and Education (BMBF), they receive 20 Million Euro to develop a marketable product from their innovative scientific idea.
http://sci.bio.lmu.de/epigenetics/ ➤

CALLS

Jun.-Prof. Jens Michaelis received a call for a Professorship (W2) at the Center of Excellence-Macromolecular Complexes at the Johann-Wolfgang Goethe University, Frankfurt.

Dr. Andrey Rogach declined a call as Associate Professor from Nanyang Technological University in Singapore.

Prof. Ulrich Schubert declined calls from the University of Hamburg (succession Prof. Kaminski) and University of Stuttgart (succession Prof. Oppermann) and accepted a call to the Chair of Organic Chemistry at the Friedrich-Schiller-Universität Jena.

Dr. Fritz Simmel declined an offer for an Associate Professorship (W2) in Experimental Physics at the LMU Munich and accepted an offer for a full professorship (W3) in Experimental Physics/Bioelectronics at the TU Munich.

Prof. Enrique Solano accepted a call to a permanent Professorship at Universidad del País Vasco and Ikerbasque (Basque Foundation for Science) in Bilbao, Spain.

Winterschool in Mauterndorf

For the 4th CeNS winterschool, more than 120 nanoscientists travelled to the small Austrian village Mauterndorf to follow stimulating lectures held by internationally renowned scientists from around the globe and from the CeNS community. The workshop entitled "Nanosystems: From Quantum Devices to Biological Engines" was held from February 12th to 18th in a medieval castle close to the skiing slopes "Großeck-Speiereck" in the Salzburg-region.

The traditional meeting organized biannually by CeNS brings together PhD and diploma students as well as postdoctoral and senior researchers from different disciplines dealing with nanosciences to broaden their scientific horizon by lectures on topics as diverse as artificial viruses and qubits. The junior researchers presented their scientific projects during two stimulating poster sessions where they had the chance to discuss with senior researchers and students from other groups and disciplines. This fruitful scientific exchange was further promoted by common skiing excursions in the beautiful mountains of Austria. ➤

CeNS Meets Industry & Summer Party

Once a year, CeNS invites representatives from industry to present their company and employment possibilities to the CeNS community. At the meeting in 2007, Dr. Ralf Schnell, President & CEO of Siemens Venture Capital and Dr. Gerhard Brehm, Executive Vice President & CTO of Siltronic accepted to talk about their company. To strengthen the links to CeNS alumni in industry, former PhD students of CeNS, now working as business consultants, patent attorneys and in the semiconductor industry, were invited to speak about their job duties and surrounding. At the following traditional summer party during a warm summer evening, about 140 CeNS members took the opportunity to discuss with the representatives from industry, with CeNS alumni and with each other. ➤

Patent Protection for Research in Natural Sciences

A useful insight into the business of patent law and intellectual property protection was given to interested PhD and diploma students of CeNS at the workshop "Patent protection for research in natural sciences". This one-day workshop was organized by students of the International Doctorate Program NanoBioTechnology (IDK-NBT) which is hosted by CeNS. In cooperation with the European Patent Office, competent speakers were invited to the workshop which was held at the University of Augsburg on February 23rd. The talks gave the students an overview about how to claim and protect their Intellectual Property effectively in case that they develop new and innovative ideas and devices. For this informative workshop, the organizers could win Roland Grenz (BayernPatent/ ZWW), Dr. Norbert Hansen (Maiwald Patentanwalts GmbH), Dr. Christian Kallinger (European Patent Office) and CeNS member Prof. Achim Wixforth (Spin-Off founder) to share their knowledge and experiences. These insights and practical tips will surely be very useful to the young researchers which might become successful entrepreneurs or inventors one day. ➤

Bayesian Data Analysis - Take a Close Look to your Data

Initiated and organized by two PhD students of the International Doctorate Program NanoBioTechnology (IDK-NBT), this lecture series on Bayesian Data Analysis was held by Prof. Volker Dose from the Max-Planck-Institute of Plasma Physics. In five morning sessions from September 24th to 28th, the students were introduced to information theory. The workshop focused on how to apply Bayesian theorems, a statistical method to maximize the amount of extracted information from measured data. This method takes into account prior knowledge about the system and provides a comprehensive method to incorporate any known source of measurement errors. Due to the generalized approach of this technique, Bayesian data analysis can be applied to various fields, including physics, chemistry and life science. ➤

Weekly Events at CeNS

During the semester, the CeNS team organizes a weekly colloquium where different speakers from all over Europe are invited to give a talk on a topic related to nanosciences. Starting with discussions accompanied by coffee and cookies, the colloquium takes place every Friday from 3 to 4:30 p.m. either on the LMU main campus or at the Chemistry department in Großhadern.

Preceding the CeNS colloquium from 2 to 3 p.m., the International Doctorate Program NanoBioTechnology offers a series of lectures on nanobiosciences which are held by researchers of CeNS.

National Research Council Canada
National Institute for Nanotechnology
Conseil national de recherches Canada
Institut national de nanotechnologie

Europäisches Patentamt
European Patent Office
Office européen des brevets

UNIVERSITÄT BAYREUTH

Elitenetzwerk Bayern

Joint Winterschool with the National Institute for Nanotechnology in Canada

Held on the Campus of the University of Alberta in Edmonton, the "Winterschool on Nanotechnology Convergence" brought together 30 PhD students from Germany and Canada to learn more on nanosciences and their possible applications. The workshop, jointly organized by CeNS and the Canadian National Institute for Nanotechnology (NINT) from March 14th to 21st, was financed on the German side by the International Office of the Federal Ministry of Education and Research (BMBF).

The unique concept of this winterschool was to combine introductory lectures on many different topics of nanosciences with lab tutorials teaching a broad range of new techniques to the participating doctoral students. The freshly acquired practical knowledge was extended by short presentations by the participants where they explained their experience to their pals. The scientific exchange between the Canadian and German students was stimulated by a joint poster session where all participants presented their ongoing PhD work. In an evening session, discussions about the implications of nanotechnology on environmental, ethical, social and legal aspects were initiated and moderated. During the weekend the German guests explored Canadian Wildlife by hiking through the snow at Elk Island National Park. ➤

Practicing Scientific Presentations in English

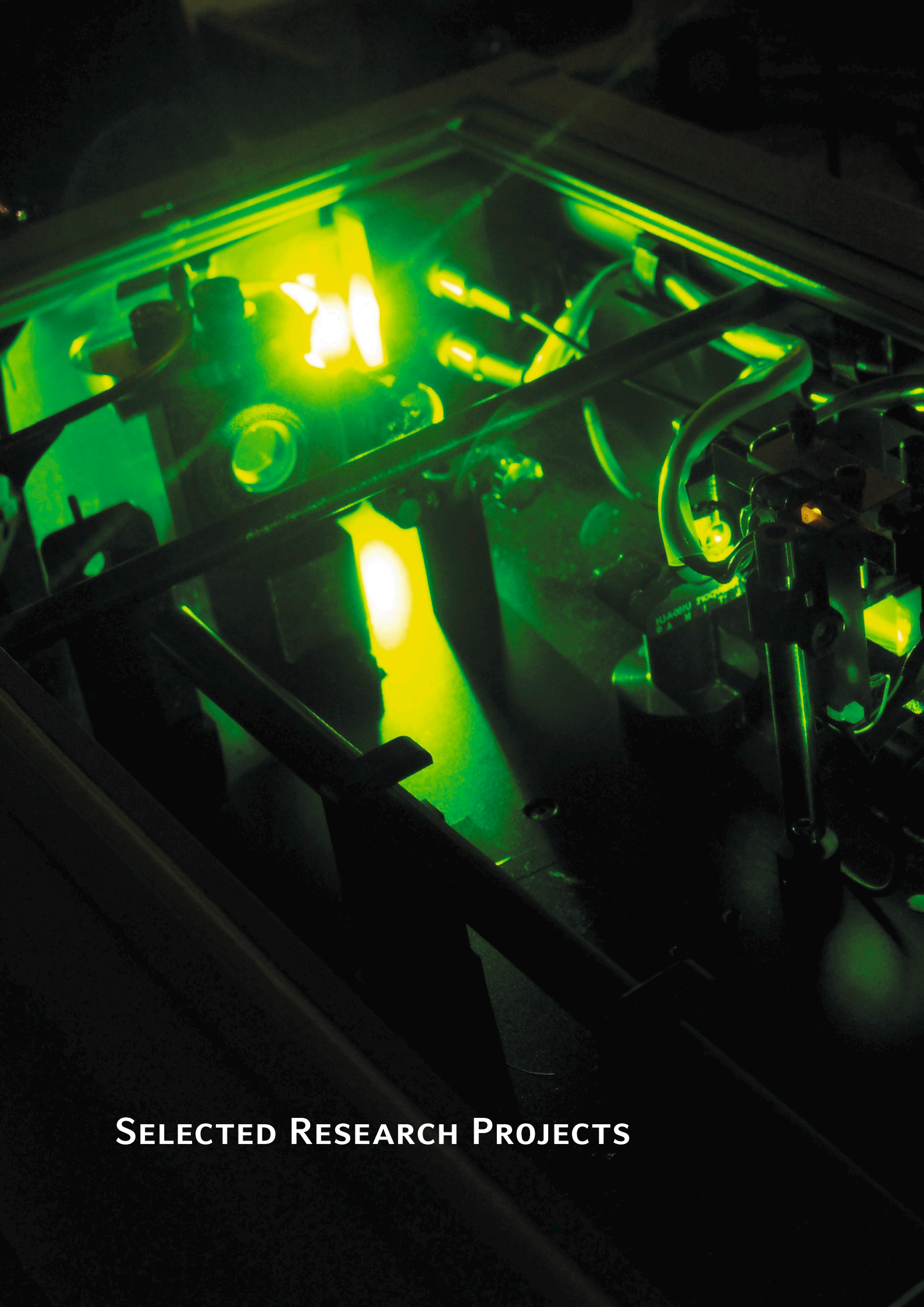
Most PhD students at CeNS are not native English speakers, but have to present their research at international conferences in English. Tom Sobey, an Australian graduate student at CeNS, decided to help his colleagues and set up a one-day hands-on workshop on August 8th. At this event, the participants practiced not only their English but also learned general presentation skills which Tom acquired previously at a workshop in Australia. ➤

Joint Workshop "Macromolecular Systems" with the University of Bayreuth

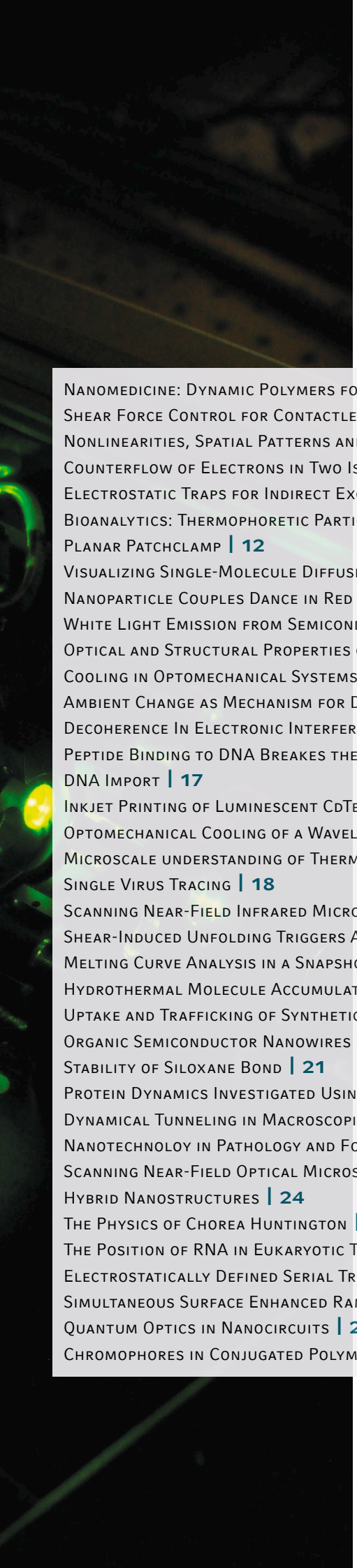
Putting together the International Doctorate Program NanoBioTechnology (IDK-NBT) hosted by CeNS and the Elite Study Programme "Marcomolecular Science" hosted by the University of Bayreuth (both financed by the Elite Network of Bavaria), the workshop "Macromolecular Systems for NanoScience - Chemistry, Physics and Engineering Aspects" offered 20 stimulating lectures to the participating PhD and Master students. Held at the former monastery at Irsee from September 6th to 9th, the program was composed of scientific talks by speakers invited from all continents and a poster session which was introduced by short presentations of the participants. The cosy atmosphere of the monastery offered many occasions for discussions and table tennis & billiard competitions between the young and senior researchers from Munich, Augsburg, Bayreuth and the invited guests. ➤

AWARDS

+++ The renowned research prize of the **Philip Morris Foundation** was granted to **Prof. Patrick Cramer** for his work on gene transcription of the RNA-Polymerase. He also received funding for a **Research Professorship** in the framework of LMU*excellent*. +++ **Prof. Jochen Feldmann** has been elected **Cluster Coordinator** of the "Nanosystems Initiative Munich" and received funding for a **Research Professorship** in the framework of LMU*excellent*. +++ **Beijing Normal University** in China has nominated **Prof. Peter Hänggi** Visiting Professor for 2007-2012. He has furthermore been elected Ordinary Member of the **Academia Europaea** for the Physics, Astrophysics and Engineering Section. +++ The **Elite Network of Bavaria** granted a second funding period of five years to the **International Doctorate Program "NanoBioTechnology"** chaired by Prof. Joachim Rädler. +++ Co-founder and board member of CeNS, **Prof. Jörg Kotthaus**, received the **Bayerischen Verdienstorden** (Bavarian order of merit) from the Bavarian Prime Minister. +++ The German Research Foundation (DFG) granted funding to **Dr. Florian Marquardt** for an independent Junior Research Group in the framework of the **Emmy-Noether-Programme**. He is now head of the "Maquardt Group" working on Condensed Matter Theory. +++ **Jun.-Prof. Jens Michaelis** received an award from the **Dr. Klaus Römer-Foundation** for his habilitation. +++ The Federal Ministry of Research and Education (BMBF) awarded 20 Mio Euro to the winners of the "GO-Bio" competition, **Dr. Ulrich Rothbauer** & **Prof. Heinrich Leonhardt**. With this funding, they will develop a marketable product from their innovative Chromobodies-Technology. +++ **Dr. Matthias Schneider**, together with the CeNS spin-off company **Advalytix**, received the **Innovation Award** for medical technologies of the Federal Ministry of Education and Research (BMBF). A further project partner was the CeNS spin-off company ibidi GmbH. With this governmental funding, the team plans to develop a lab-on-a-chip for the diagnostics of diseases based on blood clotting. +++ The Dutch Polymer Institute (DPI) awarded **Prof. Ulrich Schubert** with two **Invention Awards** for his participation in submitting two patents. +++ The Balkan Union of Oncology (BUON) elected **Prof. Ernst Wagner** **Honorary Member**. +++



Selected Research Projects



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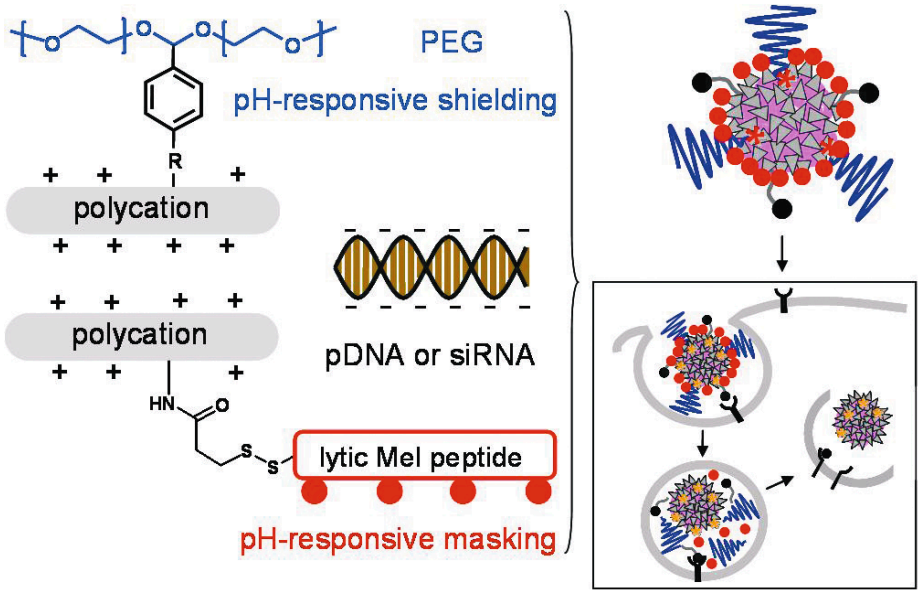
Nanomedicine: Dynamic Polymers for Tumor-Targeted Drug Nanoparticles

Prof. Thomas Bein (LMU Munich)
Prof. Christoph Bräuchle (LMU Munich)
Prof. Joachim Rädler (LMU Munich)
Prof. Ernst Wagner (LMU Munich)

A key aspect of nanomedicine addresses the development of nanoparticles for drug delivery to disease target sites. For a more specific delivery and more effective drug release, a timely operation of multiple delivery tasks is required. In the initial phase, drug nanodevices have to be shielded against unspecific interactions and degradation in the blood stream, in the second phase they have to specifically bind the target tissue and cells, and in the third phase they have to effectively release their drug payload in a bioactive form. Wagner and colleagues have developed dynamic nanoscaled polymer complexes for therapeutic nucleic acid delivery. These polyplexes are able to sense the different delivery phases and adopt their characteristics to most effectively cope with these different phases [1]. For this purpose dynamic polymers were developed that respond, for example, to the slightly acidic pH as present in intracellular endosomes or tumors. pH-sensitive polyethylene glycol conjugates, which stably shield nanoparticles in the blood circulation, are cleaved at endosomal pH [2]. Endosomal acidification was also exploited for a triggered activation of the lytic activity of melittin (Mel) in the intracellular compartment. Mel peptide masked with dimethylmaleic anhydride (DMMAn) has minimum lytic activity and toxicity. After endosomal acidification the DMMAn protecting groups are cleaved and lytic activity is restored within the target cell [3]. Nanoparticles containing such dynamic polymers displayed strongly enhanced efficiency in plasmid DNA and siRNA transfer. ➤



Dynamic pH-responsive polycation conjugates (left) for formation of plasmid DNA (pDNA) or siRNA nanoparticles (right, upper panel) and their targeted delivery into cells and pH-triggered endosomal release (right, lower panel).

Publications:
» [1] E. Wagner et al., Expert Opin. Biol. Ther. 7, 587-593 (2007)
» [2] V. Knorr et al., Bioconjug. Chem. 18, 1218-1225 (2007)
» [3] M. Meyer et al., J. Gene Med. 9, 797-805 (2007)

Research Websites:
» Bein: http://bein.cup.uni-muenchen.de/index.php
» Bräuchle: http://www.cup.uni-muenchen.de/pc/braeuchle/index.html
» Rädler: http://softmatter.physik.lmu.de/
» Wagner: http://www.cup.uni-muenchen.de/pb/aks/ewagner/

Shear Force Control for Contactless Sensing of Charge Carriers in Terahertz Nearfield Microscopy

Prof. Roland Kersting (LMU Munich)
Dipl. Ing. Stephan Manus (LMU Munich)

Terahertz (THz) time-domain techniques provide attractive tools for gaining insight into ultrafast carrier dynamics in semiconductors and quantum structures. In particular in the nanosciences, contactless THz microscopy may play an important role for the characterization of the intrinsic quantum dynamics. Additionally, the contactless determination of carrier relaxation times is a fundamental requirement for the design of future device concepts but may also find application in characterizing novel materials such as organic semiconductors.

In order to address an individual nanosystem, the THz radiation is condensed in the nearfield of the sampling probe to volumes with dimensions that are about 1000 times smaller than the wavelength of the THz field. The challenge in THz near-field optics is to maintain an accurate distance between probe and sample, which has been mastered by integrating shear-force control in the apertureless THz microscope. Shear-force technology (originally developed by CeNS member Prof. Khaled Karrai) now allows using THz microscopy for exciting nanosystems with a precision of a few nanometers. The achieved resolutions and the improved image contrast hold promise for future studies on charge carrier dynamics in nanosystems. ➤

Publication:
» F. Buersgens et al., Rev. Sci. Instr. 78, 13701 (2007)

Research Websites:
» Kersting: http://www.thz.physik.uni-muenchen.de/
» Manus: http://www.nano.physik.uni-muenchen.de/

Nonlinearities, Spatial Patterns and Stochastic Effects

Prof. Erwin Frey (LMU Munich)

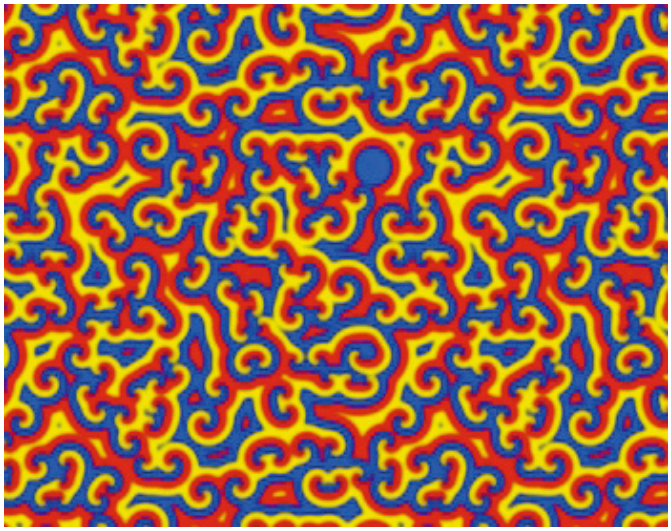
An astonishing biodiversity exists within the earth's ecosystems. While being of essential importance to the viability of ecological systems, conceptual explanations of such diversity pose major challenges. Indeed, in a naive understanding of Darwinian evolution, two interacting species would compete for resources until only the fitter one survives (competitive exclusion principle).

In their research, Tobias Reichenbach and Erwin Frey are aiming at an identification and characterization of mechanisms that allow for the long-term maintenance of biodiversity. Examples of such mechanisms include non-hierarchical competitions between species, in its simplest form described by the game "rock-paper-scissors", where rock crushes scissors, scissors cut paper, and paper wraps rock in turn. Both experimentally as well as theoretically, in combination with spatial dispersal of static populations, such dynamics have been shown to guarantee stable coexistence of species.

Mobility is an important factor in most ecosystems, from animals that migrate from place to place to bacteria that swim and tumble.

Using the rock-paper-scissors game to model interacting species, Tobias Reichenbach, Mauro Mobilia and Erwin Frey have investigated the influence of individuals' mobility and demonstrated that it critically affects biodiversity.

A threshold mobility exists such that above, some species become extinct, and only one survives. Below the threshold value, all species coexist in a stable manner by self-arranging into entangled, rotating spiral waves. ➤



Biodiversity of many interacting species is often maintained by self-organization of individuals into spatial patterns. The picture shows such spatial structures resulting from a computer simulation of three bacterial strains that interact according to the rock-paper-scissors game.

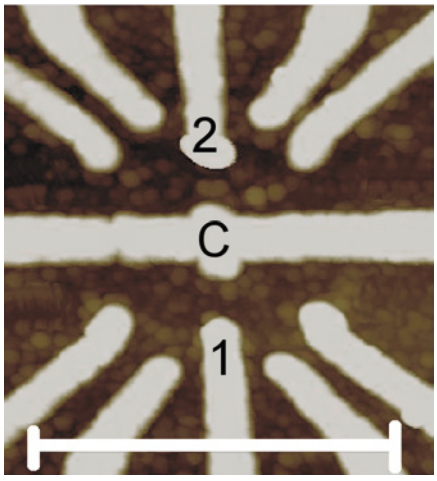
Publication:
» T. Reichenbach et al., Phys. Rev. Lett. 99, 238105 (2007)

Research Website:
» Frey: http://www.theorie.physik.uni-muenchen.de/lsfrey/

Counterflow of Electrons in Two Isolated Quantum Point Contacts

Prof. Jörg P. Kotthaus (LMU Munich)
Dr. Stefan Ludwig (LMU Munich)

In GaAs/AlGaAs-heterostructures that contain a two-dimensional electron system (2DES) mesoscopic devices can be electrostatically defined. Our heterostructure was grown by Werner Wegscheider at the University of Regensburg. In this project two short one-dimensional channels called quantum point contacts (QPCs) are electrostatically defined in the 2DES. Across one of them a voltage is externally applied causing a current flowing through the QPC. The other QPC is electrically isolated from the first one and no voltage is applied across it. Nevertheless, a small current flowing through the second QPC can be detected under certain conditions. This current is a consequence of an interaction between electrons being driven by an external force through the first QPC and electrons in the leads of the second unbiased QPC. For the geometry shown in the figure the detected current always flows in the opposite direction than the externally applied current. Our results strongly suggest an interaction mechanism between the two electrically isolated circuits where phonons are emitted in the externally driven circuit and absorbed by electrons in the second unbiased circuit.



Atomic force micrograph of gold-gates on the surface of the heterostructure. The gates marked by 1, 2, or C are negatively biased to define two QPCs. The gate C divides the 2DES into two electrically separate circuits. The scalebar (white) is one micrometer long.

Strongly biased QPCs are often used to detect the charge states of coupled quantum dots. Phonons emitted by such a charge detector can be reabsorbed by electrons inside the quantum dots and thereby destroy a coherent motion. This is an important implication of our research for possible applications in the field of quantum information processing. ➤

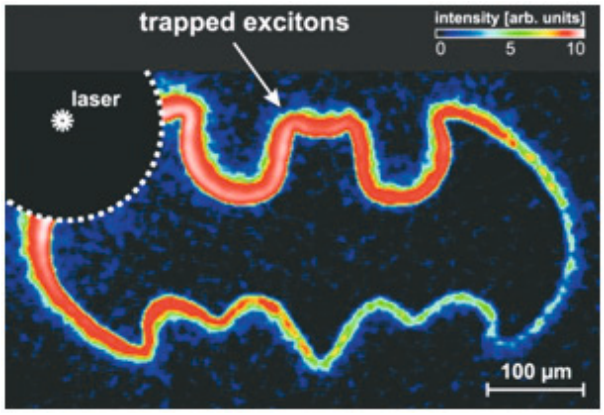
Publication:
» V. S. Khrapay et al., Phys. Rev. Lett. 99, 096803 (2007)

Research Websites:
» Kotthaus: http://www.nano.physik.uni-muenchen.de/
» Ludwig: http://www.nano.physik.uni-muenchen.de/group/people/Ludwig/index.html

Electrostatic Traps for Indirect Excitons in Coupled GaAs Quantum Wells

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

For detecting the Bose-Einstein condensation of excitons, it is a prerequisite to define controllable confinement potentials for excitons. Andreas Gärtner and co-workers realized an electrostatic trap for excitons that gives rise to a very steep harmonic trapping potential for indirect excitons in one dimension [1,2]. The trapping mechanism relies on a local electrostatic field enhancement in combination with the quantum confined Stark effect. The indirect excitons are trapped in GaAs double quantum wells just below the perimeter of SiO_2 layers, which are sandwiched between the surface of the GaAs heterostructure and a semitransparent metallic top gate. The researchers explain the exciton trapping via the electrostatic influence of surface states at the GaAs/SiO_2 interface and they find nearly harmonic trapping potentials with spring constants of ~10 keV/cm^2. The value exceeds previous results on coupled quantum wells by a factor of 300. Such electrostatic traps for indirect excitons may ultimately be exploited for hosting an excitonic Bose-Einstein condensate. ➤



Excitons captured and stored along the perimeter of a SiO_2 layer on top of a GaAs/AlGaAs heterostructure. The intensity of the resulting observed photoluminescence is color-coded.

Publications:
» [1] A. Gärtner et al., Phys. Rev. B 76, 085304 (2007).
» [2] A. Gärtner et al., Physica E (2007), DOI:10.1016/j.physe.2007.10.042

Research Websites:
» Holleitner: http://www.nano.physik.uni-muenchen.de/nanoptronics/
» Kotthaus: http://www.nano.physik.uni-muenchen.de/

Bioanalytics: Thermophoretic Particle Sizing

Prof. Dieter Braun (LMU Munich)
Prof. Wolfgang Parak (University of Marburg)

In this collaboration, the size of nanoparticles were measured with various techniques. The contribution of the Braun group in this extensive work led by Ralf Sperling of the Parak group was to use thermophoresis for measuring nanoparticles. The researchers from the Braun group could show that thermophoresis provides a straight forward and simple measurement method with error bars comparable with those of the other methods. Notably thermophoresis provides much faster results in much less volume. In this work, the size of inorganic colloidal nanoparticles coated with organic layers of different thickness has been measured with different techniques, including transmission electron microscopy, gel electrophoresis, size exclusion chromatography, fluorescence correlation spectroscopy, and thermophoresis. The results are critically compared, and the advantages and disadvantages of the respective methods are discussed. ➤

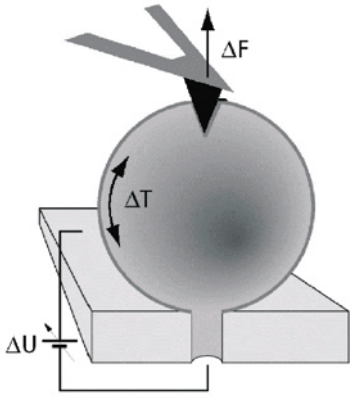
Publications:
» R. A. Sperling et al., J. Phys. Chem. C 111, 11552-11559 (2007)

Research Websites:
» Braun: http://www.functional-nanosystems.lmu.de/professorships/braun/
» Parak: http://www.physik.uni-marburg.de/de/forschung/biophotonik/

Planar Patchclamp

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

In this project a new combination of the patch-clamp technique with the atomic force microscope (AFM) was created. A planar patch-clamp chip, invented by Nanion Technologies, microstructured from borosilicate glass turned out to be ideally suited as a support for mechanical probing of living cells. The setup not only allows for immobilizing even a non-adherent cell for measurements of its mechanical properties, but also for simultaneously measuring the electrophysiological properties of that cell. As a proof of principle experiment we measured the voltage-induced membrane movement of HEK293 and Jurkat cells in the whole-cell voltage clamp configuration. The results of these measurements are in good agreement with measurements by others. Using the planar patch-clamp chip for immobilization, the AFM not only can image non-adhering cells, but also easily gets access to an electrophysiologically controlled cellular probe at low vibrational noise. This work was performed in collaboration with Evren Pamir and Michael George. ➤



Cell on the planar patch-clamp setup in voltage clamp whole-cell configuration. An externally applied change in transmembrane voltage changes the mechanical membrane tension that is monitored by the induced deflection of the cantilever.

Publication:
» E .Pamir et al., Ultramicroscopy, 108 (6):552-7 (2008), published online on 14.9.2007

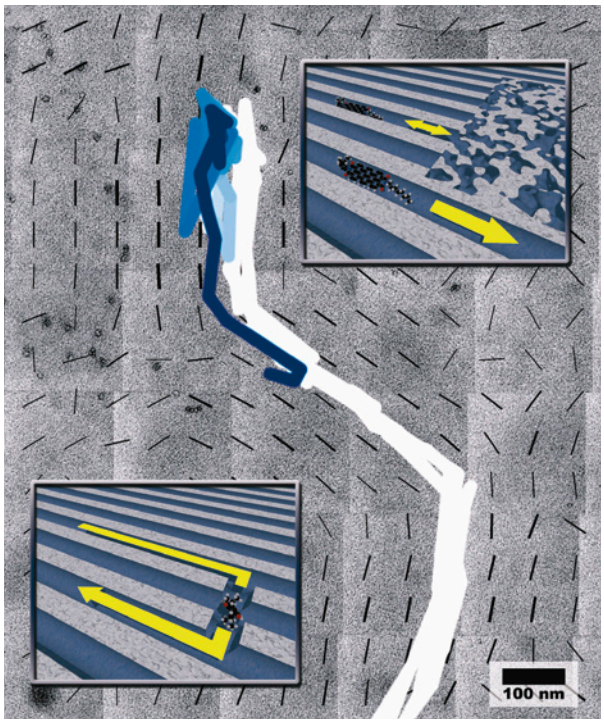
Websites:
» Benoit: http://www.biophysik.physik.uni-muenchen.de/
» Fertig: http://www.nanion.de/

Visualizing Single-Molecule Diffusion in Mesoporous Materials

Prof. Thomas Bein (LMU Munich)
Prof. Christoph Bräuchle (LMU Munich)

In this collaborative project the groups of Thomas Bein and Christoph Bräuchle study the translational and rotational dynamics of single molecules in mesoporous silica hosts [1,2]. Periodic mesoporous materials made through the cooperative self-assembly of surfactants and framework building blocks are attractive for numerous applications due to a remarkable flexibility in tuning the structural order, pore size, pore topology and the composition of the mesoporous framework. As molecular movements in the pore system are the most important and defining feature of porous materials, it is of great interest to learn about this behavior as a function of local structure. However, optical microscopy methods using single molecules are limited to about half the wavelength of visible light and can therefore not directly image the nanoporous structure of the host system in which the individual molecules diffuse.

The two groups have recently developed a unique combination of electron microscopic mapping and optical single molecule tracking experiments that provides a detailed picture of the real mesoporous defect structure and its effects on the dynamic behavior of dye molecules at the nanometer scale [3]. They can directly correlate the porous structures not visible in optical microscopy with the diffusion dynamics of single molecules that cannot be detected in transmission electron microscopy (TEM). With this approach they can uncover, in unprecedented detail, how a single luminescent dye molecule travels through linear or strongly curved sections of the hexagonal channel system in a thin film of mesoporous silica, how it varies speed in the channel structure, and how it bounces off a domain boundary having a different channel orientation. They also show how lateral motions between 'leaky' channels allow a molecule to explore different parallel channels within an otherwise well-ordered periodic structure. The inner landscape of porous nanostructures probed with this method is of fundamental importance in the context of numerous applications involving molecular transport, including separations, catalysis or the controlled release of bioactive molecules. ➤



Trajectory of a single molecule exploring the pore system of mesoporous silica – two types of defects are shown in the insets.

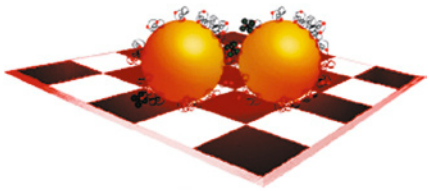
Publications:
» [1] J. Kirstein et al., Nature Materials 6, 303 (2007)
» [2] C. Jung et al., J. Am. Chem. Soc. 129, 5570 (2007)
» [3] A. Zürner et al., Nature 450, 705 (2007)
» [4] C. Jung et al., Adv. Mater. 19, 956 (2007)

Research Websites:
» Bein: http://bein.cup.uni-muenchen.de/index.php
» Bräuchle: http://www.cup.uni-muenchen.de/pc/braeuchle/index.html

Nanoparticle Couples Dance in Red Light

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

Raman scattering has high potential as a tool for the specific detection of biomolecules and other chemicals. However, it is usually very weak and thus a large number of molecules is needed to obtain a detectable signal. Therefore, it is important to understand how Raman scattering is enhanced on nanostructured metal surfaces such as clusters of gold nanoparticles. In the long-standing cooperation of the Photonics and Optoelectronics Group of the LMU with Roche Diagnostics, protein-ligand interactions were used to assemble gold nanoparticle dimers, which have a well-defined Surface-enhanced Raman scattering (SERS) hot spot in the inter-particle gap. SERS spectra from these dimers were measured, while at the same time the dimer geometry was monitored through Rayleigh scattering spectroscopy of the coupled particle plasmon. This allowed the graduate students Moritz Ringler and Alexander Schwemer to find out that the Raman-active molecule acts back on the hot spot by pushing the gold nanoparticles apart or pulling them together. In this sense, the couples of gold nanoparticles "dance" in red laser light until they get out of resonance with the laser frequency. This finding can explain some of the fluctuations of the SERS spectra and the bleaching of Raman activity that have so far hindered the use of surface enhanced Raman scattering. ➤



Two gold nanoparticles are coupled together via biotin - streptavidin binding. Upon excitation with laser light, they start to "dance" on the substrate's dance floor.

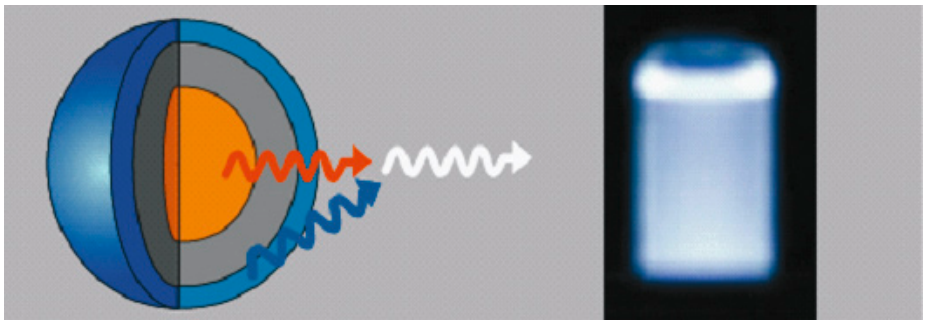
Publication:
» M. Ringler et al., Nano Lett. 7, 2753 (2007)

Research Websites:
» Feldmann: http://www.phog.physik.uni-muenchen.de/
» Klar: http://tu-ilmenau.de/fakmn/Forschung.7609.0.html?&L=0

White Light Emission from Semiconductor Nanocrystals

Prof. Jochen Feldmann (LMU Munich)
Prof. Thomas Klar (TU Ilmenau)
Dr. Andrey Rogach (LMU Munich)

Solid state white light emitting devices have a great potential to reduce the global electricity consumption. Luminescent semiconductor nanocrystals (NCs) are potentially useful candidates for applications in white light emitting displays. Researchers at the Photonics and Optoelectronics Group of the LMU developed two bright white light emitting semiconductor nanocrystal based systems. CdS nanocrystals emit white light due to the presence of surface states over the entire range of the visible spectrum, while onion like CdSe/ZnS/CdSe/ZnS core-shell-shell-shell NCs are designed to emit white light as a result of the combination of blue and orange emissions from the CdSe shell and the CdSe core, respectively. The latter system shows high emission quantum efficiencies of 30 %, a record for white light emission from nanocrystals up to date. ➤



White light emission from core-shell-shell semiconductor nanocrystals.

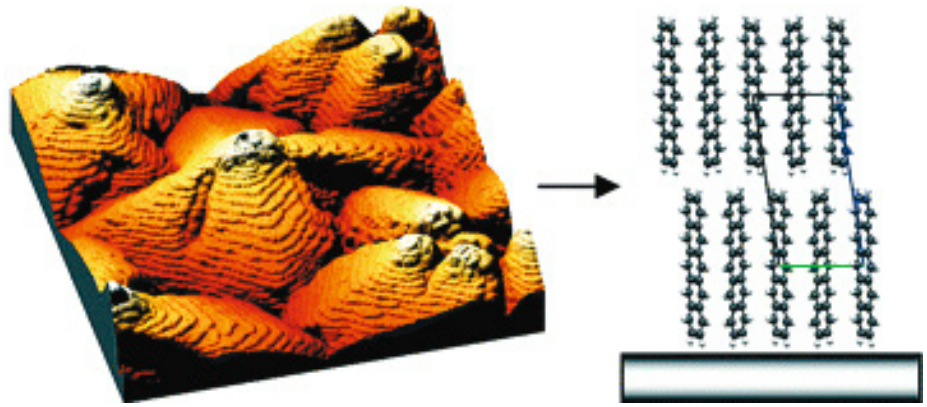
Publication:
» S. Sapra et al., Adv. Mater. 19, 568 (2007)

Research Websites:
» Feldmann: http://www.phog.physik.uni-muenchen.de/
» Klar: http://tu-ilmenau.de/fakmn/Forschung.7609.0.html?&L=0
» Rogach: http://www.phog.physik.uni-muenchen.de/people/rogach_andrey/

Optical and Structural Properties of Pentacene Thin Films

Dr. Bert Nickel (LMU Munich)
Prof. Jörg P. Kotthaus (LMU Munich)

It is widely recognized that the intrinsic charge transport properties in organic thin-film transistors (OTFT) depend strongly on the crystal structure of the organic semiconductor layer. Pentacene, showing one of the highest charge carrier mobilities among organic semiconductors, is known to crystallize in at least four polymorphs, which can be distinguished by their layer periodicity d(001). The substrate-induced 15.4 Å polymorph is the most relevant for OTFT applications; however, its crystal structure has remained incomplete. We have extended the crystal truncation rod X-ray scattering technique to resolve the complete structure of this polymorph grown on technologically relevant substrates (see figure). We found that the molecular arrangement within the unit cell is substrate dependent, which may lead to a controlled fine-tuning of intrinsic charge transport properties [1]. Beyond those structural aspects, we have also studied the dynamics of exciton generation in pentacene thin films using pump-and-probe techniques [2]. We found that the emission from photoexcited Frenkel excitons decays within 70 fs due to the ultrafast formation of an excitonic species with a strongly reduced transition dipole to the ground state and an absorption dipole in the plane of the film. Such experiments contribute to develop a molecular understanding of the opto-electronical properties of organic thin films. ➤



Molecular structure of pentacene thin films. (Left) An AFM micrograph reveals a stepped surface with terraces of molecular height and a grain size of several microns. (Right) The dimension of the unit cell and the molecular arrangements was determined for the first time from x-ray diffraction experiments in a surface sensitive geometry.

Publications:
» [1] S. Schiefer et al., J. Am. Chem. Soc. 129 (33) 10316 (2007)
» [2] H. Marciniak et al., Physical Review Letters 99 176402 (2007)

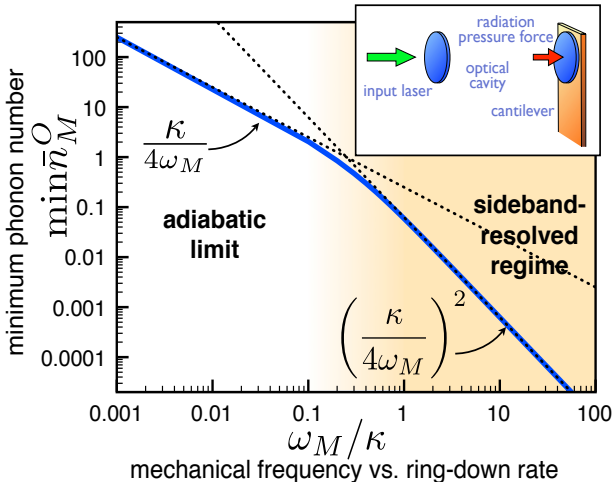
Research Websites:
» Nickel: http://softmatter.physik.lmu.de/tiki-index.php?page=GroupNickelHome
» Kotthaus: http://www.nano.physik.uni-muenchen.de/

Cooling in Optomechanical Systems

Jun.-Prof. Florian Marquardt (LMU Munich)

Nano- and micromechanical systems are a topic of considerable current interest. An interesting and versatile way of manipulating these systems is via optical means. The paradigmatic setup is an optical cavity, where the light intensity (of an incoming laser beam) is resonantly enhanced. If one of the end-mirrors is movable, the radiation pressure force will act on it, thereby inducing a coupled dynamics of light and mechanical degree of freedom. It has been known for some time that this effect can be used to cool down mechanical systems, due to the viscous light-induced force. A seminal work was conducted in 2004 by Constanze Metzger and Khaled Karrai at the LMU.

In the meantime, many experimental groups worldwide are studying a variety of systems which all can be described by the same theoretical modelling. These include cantilevers and beams carrying mirrors for an optical cavity, but also nanobeams coupled capacitively to a driven LC circuit, a driven superconducting microwave transmission line, or a superconducting single electron transistor. The current interest in the field focusses on cooling a big mechanical system (made up of billions of atoms), thereby bringing one of its mechanical degrees of freedom into the ground state. A fully quantum-mechanical theory of optomechanical cooling, however, was still missing. Such a theory was developed recently in a collaboration between Florian Marquardt (LMU), S. M. Girvin (Yale), J. P. Chen, and A. A. Clerk (McGill). The publication in Physical Review Letters predicted the quantum limits for the achievable phonon number, pointed out that ground-state cooling is only possible in the regime of a high optical finesse („resolved sideband limit"), and discussed the peculiar features at strong laser input power. Simultaneously and independently a theory was developed by I. Wilson-Rae, N. Nooshi, W. Zwerger and T. Kippenberg, that arrived at some of the same conclusions from a different perspective. Right now experiments worldwide are at the threshold of entering the quantum regime in these devices. ➤



The minimum achievable phonon number as a function of mechanical cantilever frequency and optical cavity ring-down rate. Ground-state cooling is only possible in the resolved sideband limit.

Publication:
» F. Marquardt et al., Phys. Rev. Lett. 99, 093902 (2007)

Research Website:
» Marquardt: http://homepages.physik.uni-muenchen.de/~Florian.Marquardt/

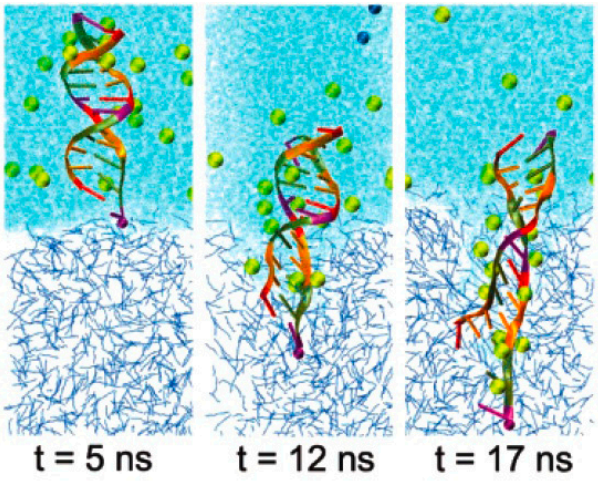
Ambient Change as Mechanism for DNA Unwinding

Prof. Hermann E. Gaub (LMU Munich)

DNA displays a richness of biologically relevant supramolecular structures, which depend on both sequence and ambient conditions. The effect of ambient changes on the structure of double-stranded DNA (dsDNA) e.g. when dragged from water into poor solvent structure is still unclear. Here, we employed single molecule techniques based on atomic force microscopy in combination with molecular dynamics (MD) simulations to investigate the change in structure and mechanics of DNA during this ambient change. We found that the two strands are split apart when the dsDNA is pulled at one strand from water into a poor solvent. dsDNA is denatured into single-stranded DNA (ssDNA) in organic poor solvents where the solvophobic effect is absent. The interpretation of the measured data is confirmed by a freely rotating chain model fitting, a direct comparison with ssDNA experimental data, and by MD simulations that drag dsDNA from water to poor solvent, revealing details of the strand separation at the water/poor solvent interface. Because the structure of DNA is of high polarity, all poor solvents show a relatively low polarity. We speculate that the principle of spontaneous unwinding/splitting of dsDNA by providing a low-polarity (in other words, hydrophobic) micro-environment is exploited as one of the catalysis mechanisms of helicases. ➤

Publication:
» S. Cui et al., J. Am. Chem. Soc. 129, 14710 (2007)

Research Website:
» Gaub: http://www.biophysik.physik.uni-muenchen.de/



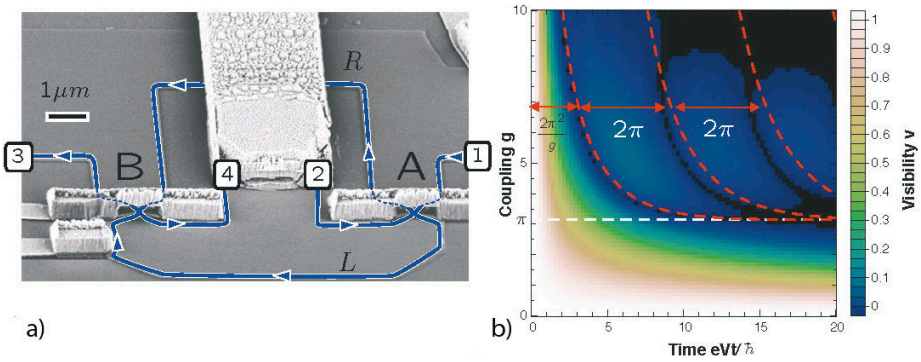
DNA in aqueous ambient (ions are indicated as yellow balls) is pulled into the poor solvent below. Initial snapshot of the MD-simulation.

Decoherence In Electronic Interferometers

Jun.-Prof. Florian Marquardt (LMU Munich)

The study of quantum interference effects in nanostructures is important both for fundamental physics (the quantum to classical transition, the measurement process) as well as potential applications (sensitive detection, quantum information processing etc.). As those structures become smaller, they are likely to couple strongly to the noise of a few individual fluctuators. When the statistics of fluctuations are not Gaussian-distributed, remarkable qualitative deviations from the usual paradigmatic picture may arise.

In a recent joint work with the group of Moty Heiblum at the Weizmann Institute, Florian Marquardt (LMU) studied these effects in an electronic which-path interferometer. In the Weizmann experiment, the arm of an electronic Mach-Zehnder interferometer was capacitively coupled to a nearby electron channel that served to detect the presence or absence of an interferometer electron. In this case, the unavoidable decoherence (connected with any measurement process) was generated by the electronic shot noise of the detector electrons. When the loss of interference contrast was measured, it displayed surprising unexpected features. The corresponding theory showed that this is because the shot noise is due to discrete electrons. Therefore, the fluctuations are not Gaussian, and consequently, beyond a certain coupling strength, the interference contrast starts to oscillate as a function of detector bias voltage and other parameters. This experiment was the first controlled which-way experiment in which sufficiently strong coupling was generated to detect these effects. ➤



(a) An electronic Mach-Zehnder interferometer in the Quantum Hall Effect regime, as used in the experiments (courtesy I. Neder and M. Heiblum). (b) The theoretically expected interference contrast, or „visibility", as a function of detector bias voltage (or interaction time) [horizontal axis], and coupling strength [vertical axis]. Beyond a certain coupling strength, oscillations appear, being a genuine feature of non-Gaussian noise.

Publications:

» I. Neder et al., Nature Physics 3, 534 (2007)
» I. Neder et al., New J. Phys. 9, 112 (2007)

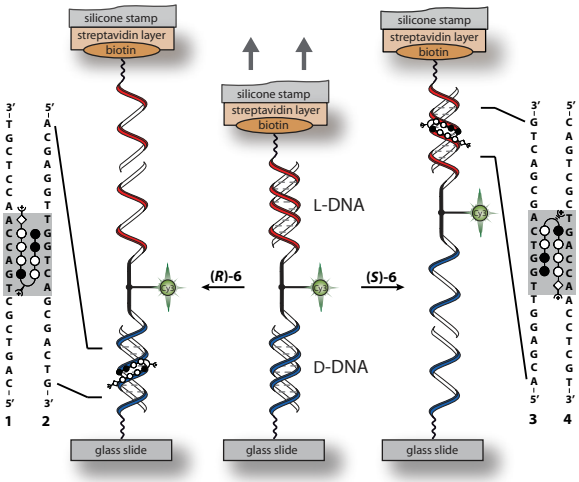
Research Website:

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

Peptide Binding to DNA Breakes the Symmetry of the Molecular Force Balance

Prof. Hermann E. Gaub (LMU Munich)

Pyrrole-imidazole polyamides are synthetic oligomers with affinities and specificities for DNA comparable to naturally occurring DNA-binding proteins. The molecular recognition of the minor groove of DNA by polyamides arises from interactions of pairs of the aromatic amino acids N-methylpyrrole, N-methylimidazole, and N-methylhydroxypyrrole with the edges of Watson–Crick DNA base pairs. Introduction of an amino group in the R configuration to the g-turn unit of hairpin polyamide oligomers confers a chiral substituent and increases the DNA-binding affinity, whereas S-configured molecules provide lower affinities relative to unsubstituted hairpins. l-DNA is the "mirror-image" of the natural occurring d conformation and has been applied in nucleic acid chemistry for developing anti-HIV agents, in the study of aptamers, transcription factors, mechanisms of antitumor drugs, and as microarray platforms. Herein we report that mirror-image hairpin polyamides can distinguish l-DNA in presence of natural DNA. To detect this specificity we introduce a symmetric molecular force balance to simultaneously measure rupture forces of diastereomeric DNA–ligand complexes. We show that the chirality of polyamides is suitable to enhance the sensitivity of the measurement to determine effects of subtle structural changes in a single experiment. ➤



Due to chiral discrimination peptides bind to only one side of the molecular DNA balance causing an asymmetry of the transfer of the label upon separation of slide and stamp.

Publications:

» C. Dose et al., Angew. Chem. Int. Ed. Engl. 46(44):8384-7 (2007)
» G. Neuert et al., Biophys J. 93(4):1215-23 (2007)

Research Website:

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

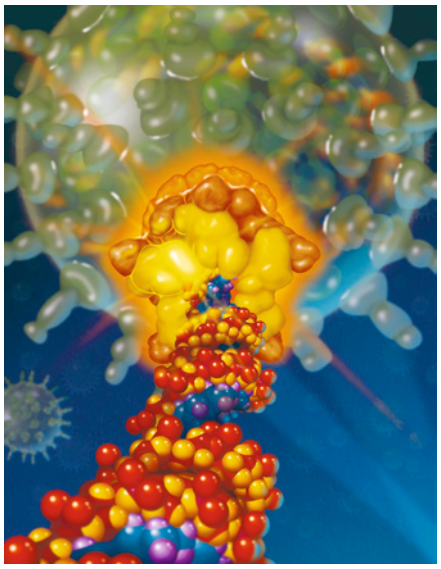
DNA Import

Jun.-Prof. Thorsten Hugel (TU Munich)
Jun.-Prof. Jens Michaelis (LMU Munich)

Many viruses compact their genome into a previously formed protein capsid during replication. This is done with specialised and highly efficient molecular motors. New Single Molecule techniques allow for the direct observation of the motor mechanics in real time and under physiological conditions. The available in vitro system of the bacteriophage phi29 allowed to put several mechanical models for DNA import into this virus under test. Putative connector rotation was investigated by combining the methods of single-molecule force spectroscopy with polarization sensitive single-molecule fluorescence. In our experiment, we observed motor function in several packaging complexes in parallel using video microscopy of bead position in a magnetic trap. At the same time, we followed the orientation of single fluorophores attached to the portal motor connector. From our data, we can exclude connector rotation with greater than 99% probability and therefore answer a long-standing mechanistic question. Our results allow us to propose a new model for the mechano-chemical coupling of the free energy released during ATPhydrolysis to a translocation of the DNA packaging motor. ➤

Publication:
» T. Hugel, J. Michaelis et al., PLOS Biology 5, 558-567 (2007)

Research Websites:
» Hugel: http://cell.e22.physik.tu-muenchen.de/Hugel/home.html
» Michaelis: http://www.cup.uni-muenchen.de/pc/michaelis/



The bacteriophage phi29 DNA packaging machine. Double-stranded DNA is driven into the preformed capsid shell by a complex and powerful molecular motor. [Image by Precision Graphics (Champaign, Illinois), K. Aathavan and Y. Chemla (UCB)]

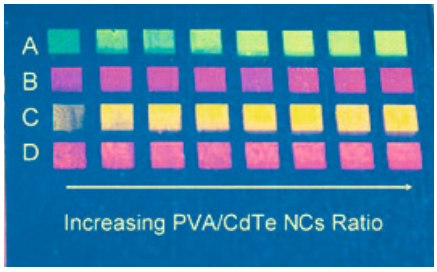
Inkjet Printing of Luminescent CdTe Nanocrystal-Polymer Composites

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

Inkjet printing is an attractive technology for microscale patterning since it can eject tiny droplets (with diameters in the range 50–100 µm) which are composed of either solutions or dispersions of functional materials. The drop-on-demand techniques allows accurate placement of individual drops and micrometer structures; in addition films can be fabricated by this technique. A promising approach targets in this respect on the fabrication of micrometer size, combinatorial library systems, that allow the systematic alteration of film formulations.

In a collaboration of the Laboratory of Macromolecular Chemistry and Nanoscience in Eindhoven, Netherlands (Prof. U. S. Schubert) and the Photonics and Optoelectronics group at LMU (Prof. J. Feldmann, Dr. A. Rogach) a thin film library consisting of well-defined patterns of dots (with diameters of approx. 120 µm) composed of luminescent CdTe nanocrystals (NCs) embedded within a poly(vinylalcohol) (PVA) matrix were printed.

These combinatorial libraries of CdTe nanocrystals embedded into PVA films were investigated concerning their luminescent properties by high-throughput characterization techniques. The systematic variation of the size of the nanocrystals integrated into the polymer films resulted in an energy transfer from green-light emitting to red-light emitting and tuning of the emission colors of the printed films could be achieved by a variation of the PVA content. The use of inkjet printing as a prototyping fabrication process and the systematic investigation of the film properties allows for the rapid screening of materials and demonstrates the large flexibility of properties that can be generated by nanocrystal/polymer hybrid systems. ➤



Photograph of an inkjet-printed combinatorial library of different size CdTe NCs emitting at different wavelengths, including systematic variation of PVA content in the solution used for printing: from 0 to 1.4 wt% with an increment step of 0.2 wt% Corresponding molar ratios of PVA/CdTe NCs in the films in each row vary from 0 (0/1.6 × 10−8) to 21.9 with an increment step of 3.12.

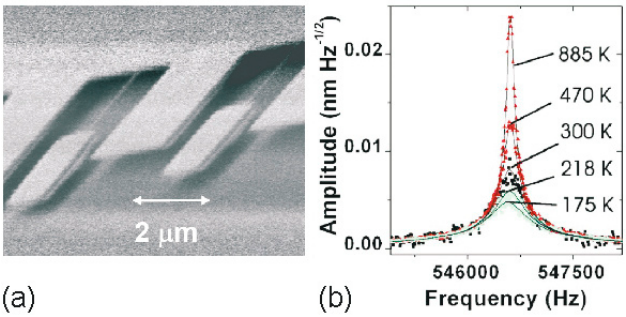
Publications:
» E. Tekin et al., Adv. Funct. Mater. 17, 277 (2007)
» E. Tekin et al., Adv. Funct. Mater. 17, 23 (2007)
» A. M. J. van den Berg et al., J. Mater. Chem. 17, 677 (2007)
» A. M. J. van den Berg et al., Soft Matter 3, 238 (2007)
» B. J. de Gans et al., J. Mater. Chem. 17, 3045 (2007)

Research Websites
» Feldmann: http://www.phog.physik.uni-muenchen.de/
» Rogach: http://www.phog.physik.uni-muenchen.de/people/rogach_andrey/
» Schubert: http://www.schubert-group.com/

Optomechanical Cooling of a Wavelength-Size Micromirror

Prof. Khaled Karrai (LMU Munich & Attocube Systems)
Prof. Jörg P. Kotthaus (LMU Munich)
Dr. Heribert Lorenz (LMU Munich)
Dr. Eva-Maria Weig (LMU Munich)

Taking advantage of the optomechanical coupling of a movable mirror of a Fabry-Pérot cavity, its vibrational fluctuations can be optically cooled to temperatures that are expected to approach the limit of very few quanta of oscillations. The quest for the quantum limit requires a diminishing mirror mass, thus calling for a miniaturization of the mirrors. On the other hand, the mirror needs to have an area larger than the diffraction limit of the light mode in the cavity and must be thick enough to reduce cavity losses by transmission. A micromirror attached to a cantilever with dimensions approaching the diffraction limit and a mass of only 11.3 pg has been fabricated using integrated circuit technology. Optical cooling of the Brownian motion of the micromirror has been accomplished which represents the tiniest mirror optically cooled so far. Furthermore, the reciprocal effect of cooling has been investigated and opens the way to the optical excitation of megahertz vibrational modes under continuous wave laser illumination. ➤



(a) Scanning electron micrograph of the paddle micromirrors. (b) Brownian motion amplitude spectra of the micromirror at low laser power (squares labelled 300 K) and at higher laser powers for both negative (circles labeled 218 and 175 K) and positive (triangles labeled 470 and 885 K) detuning showing optical cooling and optical excitation, respectively.

Publication:
» I. Favero et al., Appl. Phys. Lett. 90, 104101 (2007)

Research Websites:
» Karrai: http://www.attocube.com/ & http://www.nano.physik.uni-muenchen.de/~karrai/people.html
» Kotthaus: http://www.nano.physik.uni-muenchen.de/
» Lorenz: http://www.nano.physik.uni-muenchen.de/
» Weig: http://www.nano.physik.uni-muenchen.de/nanomech/

Microscale understanding of Thermophoresis

Prof. Dieter Braun (LMU Munich)

At this time, there is an extensive debate on how to understand thermophoresis. We have provided our own solution in the past (PNAS from last year) and have confirmed the result with detailed experiments. This year we grouped with the highly respected colloidal theoretician Jan Dhont which has discussed the concentration dependence of thermophoresis in the past. Essentially, we come to the same equation for particles which are larger than the Debye length (as is in our case), however Jan Dhont extended the regime for smaller particles. Such theory is important since we plan to do more extensive measurement in this regime in the future.

In the work, an expression for the single particle thermal diffusion coefficient of a charged colloidal sphere is derived on the basis of force balance on the Brownian time scale in combination with thermodynamics. It is shown that the single particle thermal diffusion coefficient is related to the temperature dependence of the reversible work necessary to build the colloidal particle, including the core, the solvation layer and the electrical double layer. From this general expression, an explicit expression for the contribution of the electrical double layer to the single particle thermal diffusion coefficient is derived in terms of the surface charge density of the colloidal sphere, the electrostatic screening length and its core-radius, to within the Debye-Hückel approximation. This result is shown to explain experimental data, both for thin and thick double layers. In addition, a comparison with other theories is made. ➤

Publication:
» Jan K. G. Dhont et al., Langmuir 23, 1674-1683 (2007)

Research Website:
» Braun: http://www.functional-nanosystems.lmu.de/professorships/braun/

Single Virus Tracing

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

Human immunodeficiency virus (HIV) delivers its genome to a host cell through fusion of the viral envelope with a cellular membrane. Single virus tracing (SVT) provides the unique opportunity to visualize viral particles in real time allowing direct observation of the dynamics of this stochastic process. For this purpose, a double-coloured HIV derivative was developed carrying a green fluorescent label attached to the viral matrix protein. It was combined with a red label fused to the viral Vpr protein. This allowed distinguishing between complete virions and subviral particles after membrane fusion. ➤

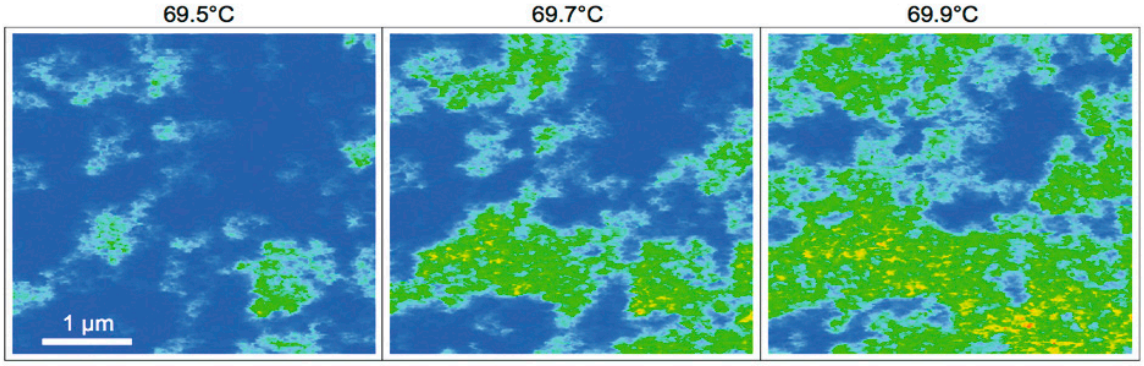
Publications:
» M. Lampe et al., Virology 360, 92 (2007)
» D. C. Lamb and C. Bräuchle, Physik Journal 6(12), 39 (2007)

Research Websites:
» Bräuchle: http://www.cup.uni-muenchen.de/pc/braeuchle/index.html
» Lamb: http://www.cup.uni-muenchen.de/pc/lamb/index.html

Scanning Near-Field Infrared Microscopy

Dr. Rainer Hillenbrand (MPI of Biochemistry, Martinsried)
Dr. Fritz Keilmann (MPI of Biochemistry, Martinsried)

Scanning force microscope is operated with the additional channel of infrared near-field scattering, to achieve the simultaneous imaging of topography and of local infrared response. This scattering near-field microscope (s-SNOM) routinely achieves 30 nm spatial resolution on both channels.



Infrared-nanoscope images (λ = 10.6 µm) taken in the critical temperature range of the Mott phase transition of VO_2. The transition from insulator to metal clearly proceeds by temperature-induced growth and coalescence of initially separate nanoscopic metal puddles.

State-of-the-art transistors were inspected in a cooperation with Infineon GmbH, in order to verify fixed-wavelength-infrared nano-imaging in a comparison to Scanning Electron Microscope (SEM), and to explore new opportunities. The results are very encouraging [1]. Not only can all materials constituting the transistor be recognized by their specific, complex-valued (i.e. amplitude and phase) responses. In addition, free carrier density can be recognized and, beyond the SEM's capability, even quantitatively determined.

Furthermore, the evolution of metallic nanostructures was recorded, in a cooperation with the University of California San Diego, as the crystal of vanadium dioxide (VO_2) is taken through its insulator-to-metal phase transition. The metal phase was observed to appear in form of spontaneously forming metal puddles of < 30 nm size which continuously grow and percolate with increasing temperature. Very surprisingly, the optical constants of the metal forming puddles is distinctly different from that of the high-temperature metal phase, whence we discover the existence of a highly correlated metal with pseudo-gap and heavy electron mass just in the transition region [2]. ➤

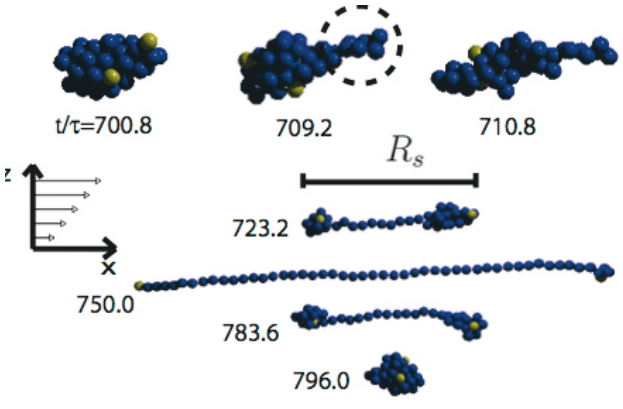
Publications:
» [1] A. J. Huber et al., Adv. Mater. 19, 2209-2212 (2007)
» [2] M. M. Qazilbash et al., Science 318, 1750-1753 (2007)

Research Websites:
» Hillenbrand: http://www.biochem.mpg.de/hillenbrand/
» Keilmann: http://www.biochem.mpg.de/en/rd/baumeister/

Shear-Induced Unfolding Triggers Adhesion of von-Willebrand Factor Fibers

Prof. Roland R. Netz (TU Munich)
Dr. Matthias F. Schneider (University of Augsburg)
Prof. Achim Wixforth (University of Augsburg)

The behavior of a single globular protein under shear flow was examined using experiments with a surface-acoustic-wave driven circulatory fluid system as well as theoretical methods. Using hydrodynamic simulations and scaling arguments it is found that below a threshold shear rate $\dot{\gamma}^*$ the chain remains collapsed and only deforms slightly, while above $\dot{\gamma}^*$ the globule exhibits unfolding/refolding cycles. Hydrodynamics are crucial: in the free draining case $\dot{\gamma}$ scales with the globule radius R as $\dot{\gamma} \sim 1/R$, while in the presence of hydrodynamic interactions $\dot{\gamma} \sim R$. Experiments on the globular von-Willebrand protein confirm the presence of an unfolding transition at a well-defined critical shear rate. These findings explain the function of the von-Willebrand factor, a protein present in our circulatory system, to stop bleeding under high shear-stress conditions as found in small blood vessels. ➤



Snapshots of the simulations of a collapsed polymer in shear flow. The upper row shows the formation of a protrusion (encircled beads), followed by a stretch-fold event displayed below.

Publications:
» S. W. Schneider et al., PNAS 104, 7899 (2007)
» A. Alexander-Katz and Roland R. Netz, Europhysics Letters 80, 18001 (2007)

Research Websites:
» Netz: http://www.ph.tum.de/lehrstuehle/T37/Welcome.html
» Schneider: http://www.physik.uni-augsburg.de/exp1/schneider/schneider.html
» Wixforth: http://www.physik.uni-augsburg.de/exp1/wixforth/wixforth.html

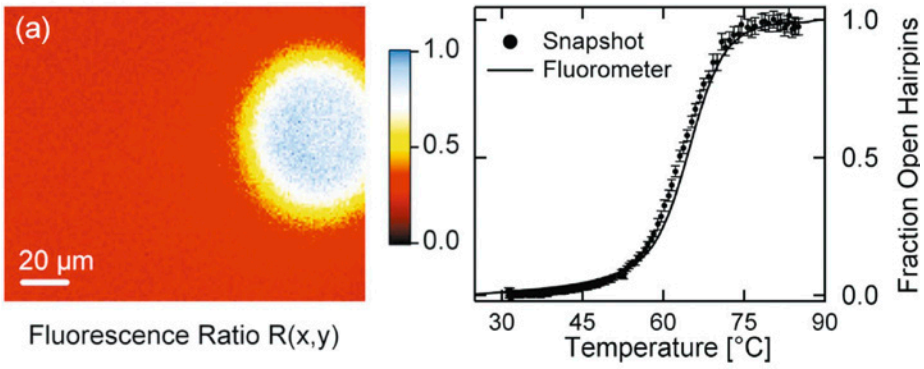
Melting Curve Analysis in a Snapshot

Prof. Dieter Braun (LMU Munich)
Dr. Stefan Duhr & Philipp Baaske (LMU Munich & NanoTemper Technologies)

The thermal denaturation of molecules is an essential method in biochemistry and diagnostics, including the measurement of single nucleotide polymorphisms and the binding analysis of proteins. We present a method for the all-optical high speed measurement of melting curves. A thin sheet of water is locally heated with an infrared laser to obtain a spatial temperature distribution between 20°C and 100°C. Using microscope fluorescence imaging a melting curve is recorded within 50ms. This is about 10000-times faster than state of the art fluorometry and yields the same results for the validation example of a DNA hairpin. This application of microthermal fields is one of the techniques offered by the new spin-off company "Nanotemper Technologies" by Stefan Duhr and Philipp Baaske. ➤

Publication:
» P. Baaske et al., Appl. Phys. Lett. 91, 133901 (2007)

Research Websites:
» Braun: http://www.functional-nanosystems.lmu.de/professorships/braun/
» NanoTemper: www.nanotemper.de/



Snapshot Melting Curves. Melting curves are measured within 50 milliseconds using the concurrent imaging of temperature and probe fluorescence. The approach speeds up the melting curve analysis from hours to milliseconds. Snapshot melting is one of the bioanalytics approaches which are commercialized by the spin-off Nanotemper Technologies. For details see Baaske, Duhr and Braun, APL 91, 133901 (2007).

Hydrothermal Molecule Accumulation

Prof. Dieter Braun (LMU Munich)

Thermophoresis can be combined with convection. Both driven by the same temperature gradient, we found that single nucleotides can be accumulated in elongated geometries. Connecting to experts in geology, we found that hydrothermal vents provide the necessary temperature gradients to drive such strong accumulation. To understand the molecular evolution of the initial molecules of biology, most probably RNA, a non equilibrium mechanism has to be found which can hold and accumulate the molecules against the highly diluted background of the ocean seafloor. We showed a compelling solution by convection and thermophoresis. The publication made it on the cover of PNAS.

We simulate molecular transport in elongated hydrothermal pore systems influenced by a thermal gradient. We find extreme accumulation of molecules in a wide variety of plugged pores. The mechanism is able to provide highly concentrated single nucleotides, suitable for operations of an RNA world at the origin of life. It is driven solely by the thermal gradient across a pore. On the one hand the fluid is shuttled by thermal convection along the pore, whereas on the other hand, the molecules drift across the pore, driven by thermodiffusion. As a result, millimeter-sized pores accumulate even single nucleotides more than 108-fold into micrometer-sized regions. The enhanced concentration of molecules is found in the bulk water near the closed bottom end of the pore. Since the accumulation depends exponentially on the pore length and temperature difference, it is considerably robust with respect to changes in the cleft geometry and the molecular dimensions. While thin pores can concentrate only long polynucleotides, thicker pores accumulate short and long polynucleotides equally well and allow various molecular compositions. This setting also provides a temperature oscillation, shown previously to exponentially replicate DNA in the protein-assisted Polymerase Chain Reaction (PCR). Our results indicate that for life to evolve, complicated active membrane transport is not required for the initial steps. We find that interlinked mineral pores in a thermal gradient provide a compelling high-concentration starting point for the molecular evolution of life. ➤

Publication:
» P. Baaske et al., PNAS 104, 9346–9351 (2007)

Research Website:
» Braun: http://www.functional-nanosystems.lmu.de/professorships/braun/

Uptake and Trafficking of Synthetic Viruses

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

Synthetic viruses enable safe and targeted delivery of transgenes into cells and are therefore an important tool in gene therapy. Wagner and Bräuchle analyzed the uptake and pathway of polyplexes (polyethlyenimine/DNA) into HUH7 cancer cells by single particle tracking. The epidermal growth factor EGF was used for targeting since the cancer cells overexpress strongly the EGF receptor. The results show that EGFR targeting leads to a faster and much more efficient internalization of these nanoparticles compared to untargeted synthetic viruses. Furthermore, the mechanistic details of the uptake and trafficking of such synthetic viruses in living cells were revealed. ➤

Publication:
» K. de Bruin et al., Mol. Therapy 15(7), 1297 (2007)

Research Websites:
» Bräuchle: http://www.cup.uni-muenchen.de/pc/braeuchle/index.html
» Wagner: http://www.cup.uni-muenchen.de/pb/aks/ewagner/

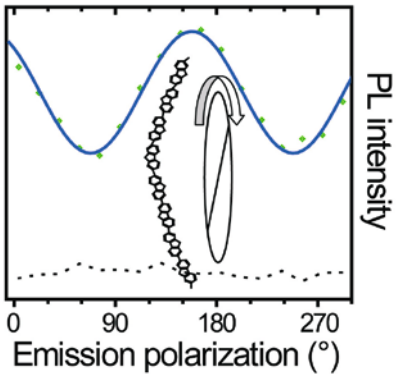
Organic Semiconductor Nanowires Under Strain

Dr. Enrico Da Como (LMU Munich)
Prof. Jochen Feldmann (LMU Munich)
Prof. John M. Lupton (University of Utah)

Conjugated polymers have potential to create new types of flexible, cheap and light-weight semiconductor devices. However, the performances are not yet comparable with the established silicon-based technology. Coiled or collapsed polymer chains are commonly identified as the origin for the poor semiconductor properties, because of breakings in the conjugation length. E. Da Como and J. Feldmann (LMU) in collaboration with J. M. Lupton (Univ. of Utah) demonstrated how single polymer chains can be bent in space without losing their semiconductor properties. In contrast to the commonly accepted picture, the bending in polyfluorene nanowires does not lead to disruption of the π-conjugation, as demonstrated by the only weakly polarized photoluminescence emission from a single chromophore. The degree of strain causing this non-stretched geometry controls directly the linewidth of the photoluminescence spectrum, providing a unique correlation between the single molecule conformation and the optical properties. The work illustrates a structure-property correlation at the nanoscale and highlights the potential of these materials for implementation in single-molecule based optoelectronic devices. ➤

Publication:
» E. Da Como et al., Nano Lett. 7, 2993 (2007)

Research Websites:
» De Como: http://www.phog.physik.uni-muenchen.de/people/da_como_enrico/
» Feldmann: http://www.phog.physik.uni-muenchen.de/index.html
» Lupton: http://www.physics.utah.edu/~lupton/



Weakly polarized photoluminescence anisotropy trace of a bent chromophore, recorded during the polarizer rotation. The zero intensity level is displayed as a dotted line.

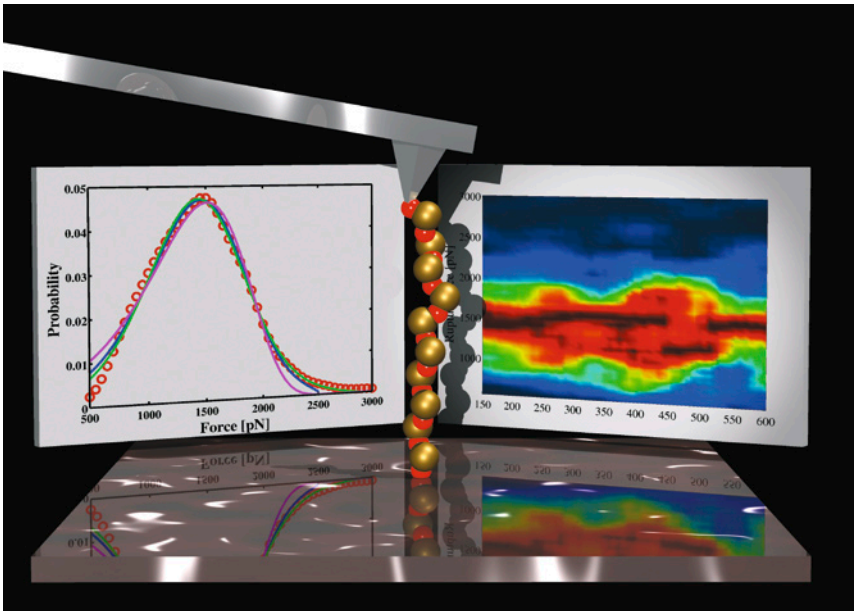
Stability of Siloxane Bond

Prof. Christoph Bräuchle (LMU Munich)
Prof. Irmgard Frank (University of Hannover)
Jun.-Prof. Jens Michaelis (LMU Munich)

Polydimethylsiloxane molecules are widely used by the chemical industry due to their tunable molecular properties. However, current applications are sometimes limited by the mechanical stability of the silicone elastomer. Bräuchle and Michaelis, both in cooperation with the Wacker Chemistry Company, therefore sought after the molecular reason for bond failure in siloxane materials. Performing single-molecule force spectroscopy on siloxane polymers, covalently attached to an Atomic Force Microscope (AFM) cantilever and an oxidized silicon wafer, they determined the forces at which the Si-O bond ruptures. Moreover, using single-molecule force spectroscopy they could also map details of the underlying potential energy surface and found that bond ruptures occur already at small fractions of the energies of the covalent bonds. ➤

Publications:
» P. Schwader et al., Langmuir published online: DOI: 10.1021/la702352x
» E. M. Lupton et al., Phys. Rev. B 76, 125420-1 (2007)

Research Websites:
» Bräuchle: http://www.cup.uni-muenchen.de/pc/braeuchle/index.html
» Frank: http://www.theochem.uni-hannover.de/
» Michaelis: http://www.cup.uni-muenchen.de/pc/michaelis/

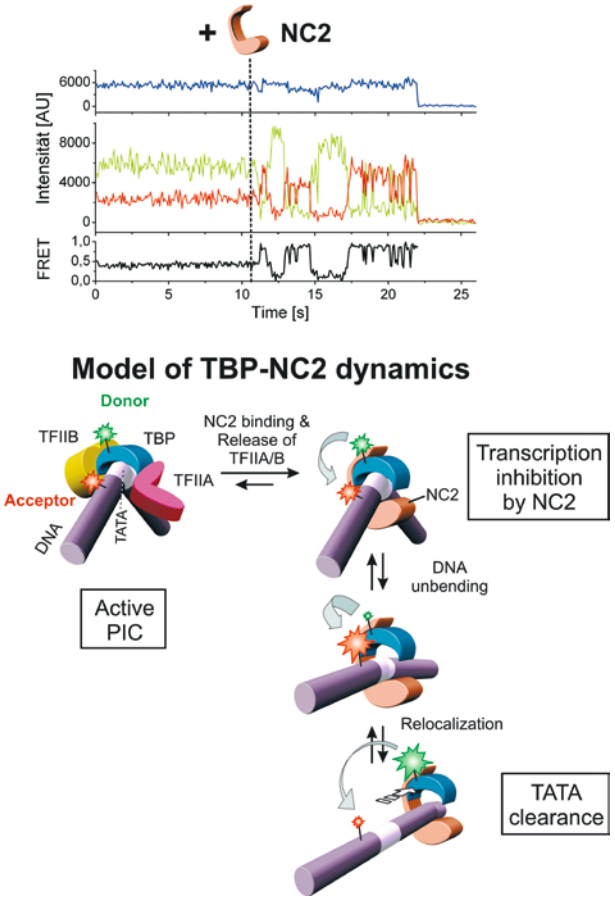


Single-molecule force spectroscopy of siloxane polymers. Using an AFM cantilever individual polymers are stretched and ruptured. The observed rupture force histograms reveal details of the underlying potential. [Graphic: Peter Schwaderer]

Protein Dynamics Investigated Using Single-Pair Förster Resonance Energy Transfer

Prof. Don C. Lamb (LMU Munich)

In the research group of Prof. Lamb, ultrasenstive fluorescence methodologies are developed and used to investigate, among other things, the dynamics of proteins. Proteins are the nanomachines designed by nature which perform the everyday tasks of life. One of the first steps in the biosynthesis of new proteins is binding of the TATA-Box-Binding Protein (TBP) to the TATA box region signifying a promoter site on the DNA. The TBP-DNA complex then recruits other cofactors necessary for transcription of the DNA sequence into mRNA. This early step in transcription is a primary target for gene regulation and control. One protein known to suppress gene transcription is Negative Cofactor 2 (NC2). Using single-pair Förster Resonance Energy Transfer (spFRET), the conformation of TBP and DNA could be followed on individual complexes. In the absence of NC2, TBP forms a stable interaction with the DNA resulting in a steady FRET signal detected from the complex. Upon addition of NC2, TBP- DNA undergoes a drastic change in behavior, observable via the rapid fluctuations in the FRET signal between different FRET subpopulations. This dynamics signifies a conformation change in the DNA and an eventual movement of TBP away from the TATA box region of the DNA (see accompanying figure). These results have lead to an entirely new perspective to the mechanistic understanding of gene repression. As it is not possible to synchronize this behavior, it could only be observed using single molecule techniques. ➤



Upper panel: The total intensity (blue), donor intensity (green), acceptor intensity (red) and FRET signal (black) shown for a single TPB-DNA complex during the addition of NC2. The FRET signal switches from being steady at approximately 0.4 to rapid fluctuations between different subpopulations (0.8, 0.4, 0.2) upon binding of NC2. Lower panel: A schematic model of the interaction of NC2 with TBP-DNA complexes. In the preinitiation complex (PIC), transcription factors TFIIA and TFIIB are bound to TBP-DNA. Upon NC2 binding, TFIIA and TFIIB dissociation and the TBP-NC2-DNA complex undergoes conformational changes. The TBP-NC2 complex can also move along the DNA, clearing the TBP from the promoter site.

Publication:
» P. Schlüsche et al., Nature Structural and Molecular Biology 14, 1196 (2007)

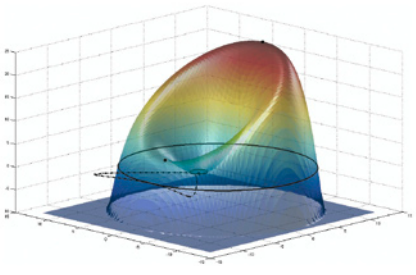
Research Website:
» Lamb: http://www.cup.uni-muenchen.de/pc/lamb/index.html

Dynamical Tunneling in Macroscopic System - Tunneling Between a Tremble and a Swing

Dr. Frank Wilhelm (University of Waterloo)

New research from Canada and Germany is challenging the notion that quantum mechanics is the science of the small and the static. Research published in the Physical Review Letters suggests that quantum tunneling, one of several phenomena associated exclusively with the quantum level, may also occur with larger and dynamic systems.

In quantum physics, quantum tunneling draws on micro and nanoscopic phenomenon in order to allow a particle to pass through a barrier that is too high to overcome by classical physical events. It has been widely assumed that the larger a macroscopic system becomes, the less likely it is for the quantum physics effects, such as tunneling, to occur. They suggest that tunneling can occur not only between two places, but between two patterns of motion. In particular, it may be possible for a nanomechanical clapper to generate both a pendulum swing and a tiny tremor at the same time. The discovery will advance the development of detectors to be used in quantum computing. ➤



Phase space portrait of a Duffing oscillator. It can dynamically tunnel from a trembling (minimum) to a swinging (maximum) state.

Publication:
» I. Serban, and F. K. Wilhelm, Phys. Rev. Lett. 99, 137001 (2007)

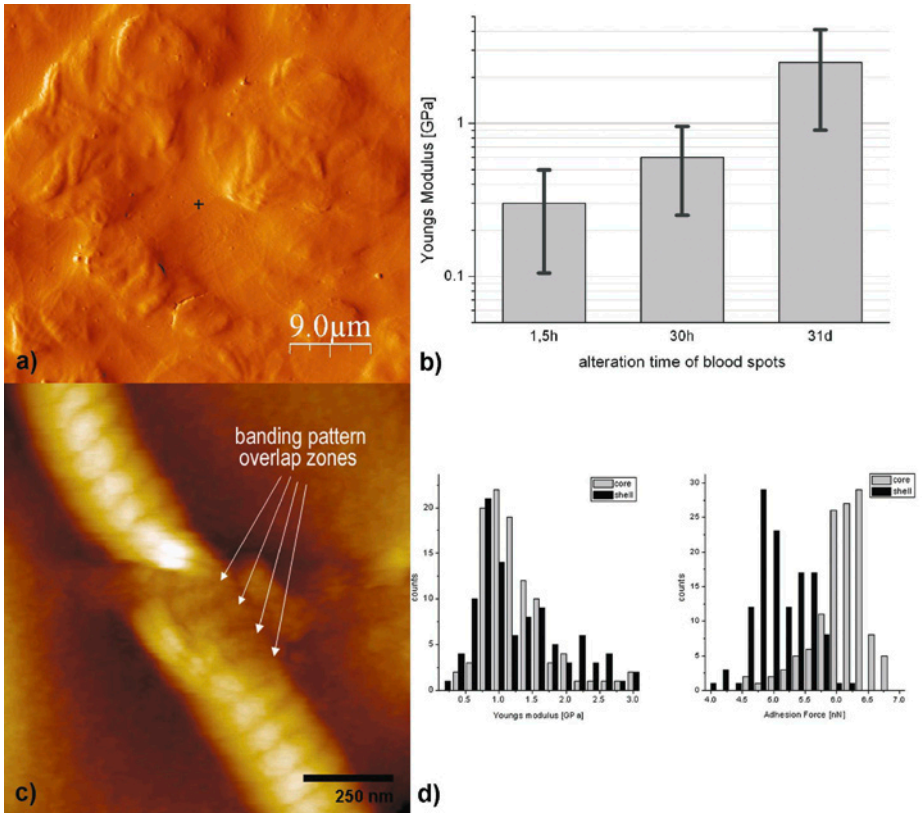
Research Website:
» Wilhelm: http://www.iqc.ca/people/person.php?id=23

Nanotechnology in Pathology and Forensics

Dr. Stefan Thalhammer (Helmholtz-Zentrum & LMU Munich)
Prof. Achim Wixforth (University of Augsburg)
Dr. Albert Zink (EURAC Research, Bolzano)

Blood analysis including blood cell measurement is one of the most basic items of hematological testing which is indispensable in health examination, disease diagnosis and treatment. There exists a lot of reliable methods for the detection and identification of blood spots. For the evaluation of suspected bloodstains solutions such as phenolphthalein, tetramethylbenzidine can be used, as they change color when they come into contact with peroxidase or hemoglobin in the blood. However, the determination of the age of a blood spot remains an unsolved problem in forensic routine work. In our approach, an Atomic Force Microscope (AFM) was used as a nanoindentor to monitor age-related changes of the elasticity of bloodstains under standardized conditions. To investigate the alteration of the elasticity of blood samples with the AFM by force spectroscopy, force distance curves were applied to the blood spot. It is a promising approach to establish a tool, which can be used for the age determination of dried blood spots in forensic routine applications.

The mechanical properties of collagen rich tissues, e.g. tendons, are largely determined by the collagen structure. Native collagen fibrils were formed by self-assembly in vitro characterized with the AFM. To confirm the inner assembly of the collagen fibrils, the AFM was used as a microdissection tool. Native collagen type I fibrils were dissected and the inner core uncovered. To determine the elastic properties of collagen fibrils the tip of the AFM was used as a nano-indentor by recording force displacement curves. ➤



a) AFM image of a typical area for recording force distance curves on the blood spot. As an example, one of these measuring spots is marked on the AFM image (cross); b) Elasticity change versus alteration time: the evaluation of the Young's moduli indicates an elasticity change depending on the alteration time. The bloodstain was measured after 1.5 hours, after 30 hours and after 31 days; c) AFM image of a microdissected collagen fibril: The core of the collagen fibril is revealed and the banding pattern can be recognized inside the fibril. The arrows indicates the overlap zones of the collagen molecules that arise during the self assembly process of the collagen fibril; d) Elasticity measurement of a single collagen fibril. Force distance curves were recorded on the shell and the exposed core.

Publication:
» S. Strasser et al., Forensic Sci Int. 170, 8 (2007)
» S. Strasser et al., Biochem. and Biophys. Research Communications 354(1), 27 (2007)

Research Websites:
» Thalhammer: http://www.helmholtz-muenchen.de/iss/nanoanalytik/index.html
» Wixforth: http://www.physik.uni-augsburg.de/exp1/wixforth/wixforth.html
» Zink: http://www.eurac.edu/org/geneticMedicine/iceman/index.htm

Scanning Near-Field Optical Microscopy (SNOM) in Fluorescence

Prof. Reinhard Guckenberger (MPI of Biochemistry, Martinsried)

Compared to the confocal laser scanning microscope, scanning near-field optical microscopy (SNOM) achieves a higher resolution and allows to acquire a topographical signal simultaneously with the optical signal which facilitates interpretation of the images. Model calculations showed a way how to concentrate light at the very end of a sharp metal tip, in a setup which minimizes exposure of the sample to light. This minimization is important in biological applications exploiting fluorescence, in order to reduce bleaching of fluorophores. Experiments corroborated the theoretical findings but optimal and reproducible realization of this new type of SNOM probe turned out to be difficult. Further model calculations clarified the interplay between SNOM tip and the fluorophore. ➤

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» N. A. Issa and R. Guckenberger et al., Plasmonics 2, 31 (2007)
» N. A. Issa and R. Guckenberger et al., Optics Express 15, 12131 (2007)

Research Website:
» Guckenberger: http://www.biochem.mpg.de/en/rd/baumeister/

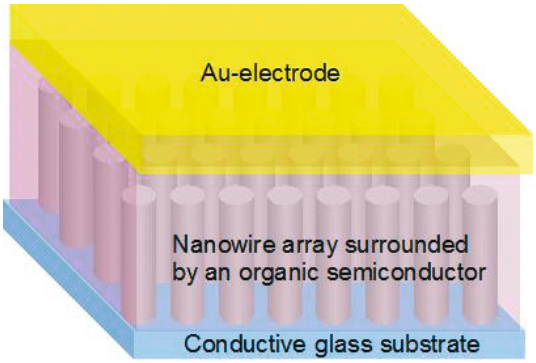
Hybrid Nanostructures

Prof. Lukas Schmidt-Mende (LMU Munich)

The group of Lukas Schmidt-Mende investigates hybrid nanostructures and their applications, where organic materials (such as small molecules or polymers) and an inorganic metal-oxide are combined to a functional device. A key issue of the research is the fabrication of nanostructured arrays of nanowires and their physical characterization and applications.

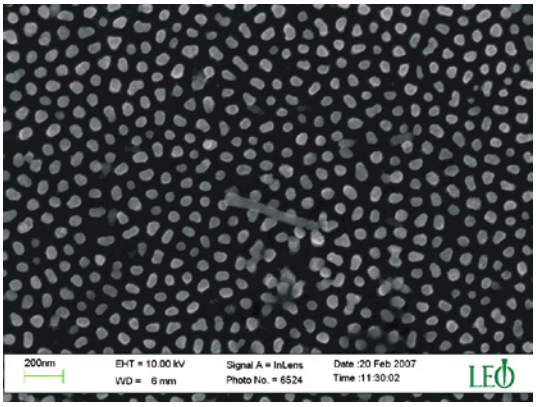
One important application is the use of these ordered nanowires as electrode material in hybrid solar cells. The ordered structure of the metal-oxide serves as electrode materials as well as nanostructured template for the organic counter-material. Organic materials are filled in the nanowire arrays. This way the distance and interface between the organic/inorganic material can be controlled. This helps to ensure exciton separation and charge collection in the solar cell. Recombination of charges can be minimized in this nanostructure devices and higher solar efficiencies are expected.

The group has experience in the fabrication of organic, dye-sensitized and hybrid solar cells, as well as in the fabrication of nanowire arrays. ➤



Top image: Schematic of a nanostructured solar cell.

Bottom image: Large area nanowire array on a conducting glass substrate (ITO).



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» H. J. Snaith and L. Schmidt-Mende, Adv. Mater. 19 (2007), 3187-3200
» L. Schmidt-Mende and J. L. MacManus-Driscoll, Materials Today 10, 40 (2007)

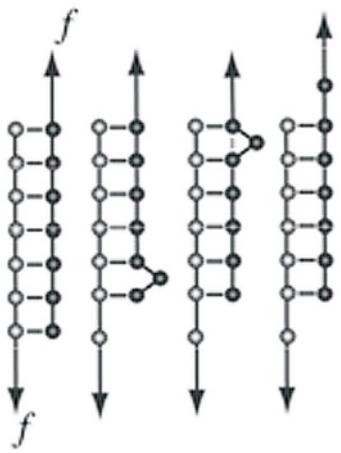
Research Website:

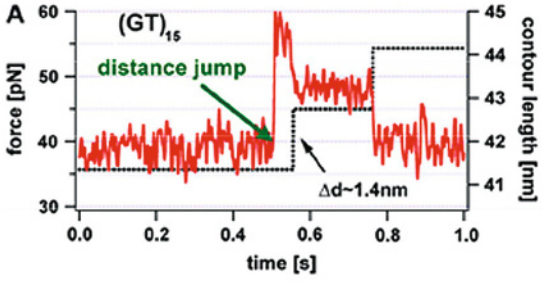
» Schmidt-Mende: http://www.functional-nanosystems.lmu.de/professorships/schmidt-mende/

The Physics of Chorea Huntington

Prof. Hermann E. Gaub (LMU Munich)
Prof. Ulrich Gerland (University of Cologne)

DNA containing repetitive sequences displays richer dynamics than heterogeneous sequences. In the genome the number of repeat units of repetitive sequences, known as microsatellites, may vary during replication by DNA slippage and their expansion gives rise to serious disorders. We studied the mechanical properties of repetitive DNA using dynamic force spectroscopy and found striking differences compared with ordinary heterogeneous sequences. Repetitive sequences dissociate at lower forces and elongate above a certain threshold force. This yield force was found to be rate dependent. Following the rapid stretching of the DNA duplex, the applied force relaxes by stepwise elongation of this duplex. Conversely, contraction of the DNA duplex can be observed at low forces. The stepwise elongation and shortening is initiated by single slippage events, and single-molecule experiments might help to explain the molecular mechanisms of microsatellite formation. In addition to the biological importance, the remarkable properties of repetitive DNA can be useful for different nanomechanical applications. ➤





Bulge loop propagation is discussed as leading mechanism for DNA microsatellite formation. Shown here is the force relaxation of DNA strands with repetitive sequences on jumps in the contour length.

Publications:

» F. Kühner et al., Biophysical Journal 92, 2491-2497 (2007)
» J. Morfill et al., Biophysical Journal 93, 7, 2400-2409 (2007)

Research Websites:

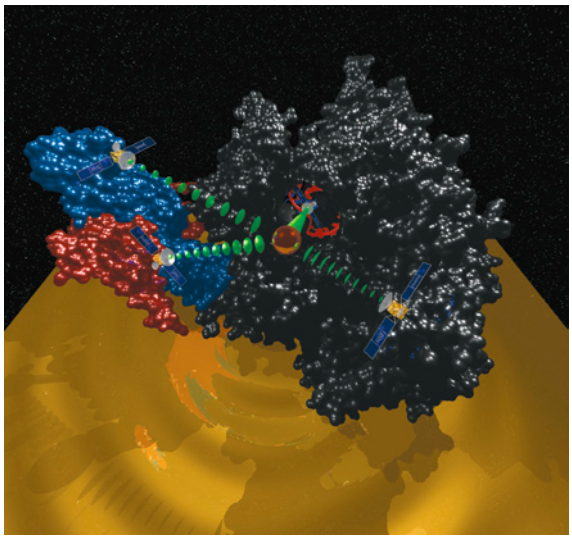
» Gaub: http://www.biophysik.physik.uni-muenchen.de/
» Gerland: https://wiki.uni-koeln.de/biologicalphysics/

The Position of RNA in Eukaryotic Transcription Elongation Complexes

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

Structural biology has in the past been extremely successful in determining high resolution models for macro-molecular complexes. One current limitation of the structural biology tools is that the position of highly flexible domains cannot be determined using the ensemble methods due to averaging effects.

Cramer, Michaelis and co-workers have now shown that by using single molecule fluorescence one can overcome these limitations. They have attached pairs of dye molecules to different well defined positions within transcription elongation complexes. By measuring the fluorescence resonance energy transfer between these pairs of molecules, they could determine intra-molecular distances. By measuring more than one distance and performing triangulation they were able to follow the path that the nascent RNA takes when leaving the elongation complex. Due to the similarities to the Global Positioning System (GPS) they termed their method Nano Positioning System (NPS). ➤



Nano Positioning System (NPS). Single-molecule fluorescence resonance energy transfer can be used for position measurements within macro-molecular complexes. In analogy to GPS, dye molecules at defined positions act as 'nano-satellites.' [Graphic: Peter Schwaderer]

Publication:
» J. Andrecka et al., PNAS, published online: DOI /10.1073/pnas.0703815105

Research Websites:
» Cramer: http://www.lmb.uni-muenchen.de/cramer/
» Michaelis: http://www.cup.uni-muenchen.de/pc/michaelis/

Electrostatically Defined Serial Triple Quantum Dot Charged with Few Electrons

Prof. Jörg P. Kotthaus (LMU Munich)
Dr. Stefan Ludwig (LMU Munich)

We have created three tunnel coupled quantum dots in a serial configuration. The quantum dots are defined laterally in a two-dimensional electron gas by applying negative voltages to Ti/Au gate electrodes on the surface of a GaAs/AlGaAs heterostructure (Fig. 1). Each quantum dot is occupied with a well-defined number of electrons that can be changed down to zero by varying gate voltages V_α, V_β and V_γ. Three nearby quantum point contacts (QPCs, see arrows in Fig. 1) allow to monitor changes of the electronic configuration and can be used to map charge stability diagrams of the triple quantum dot (TQD) (Fig. 2). Quantum mechanical ground and excited states can be investigated by driving current through the TQD. The rich set of observed features includes peculiar TQD properties like quadruple points, where four configurations are degenerate allowing resonant transport of electrons through the TQD, combined charge reconfigurations of multiple quantum dots (quantum cellular automata processes), and a bistable region of the stability diagram. ➤

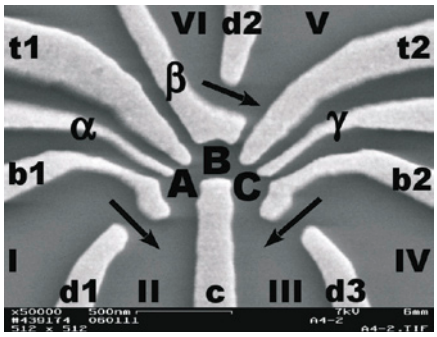


Fig. 1 : SEM micrograph of the sample structure. Gate electrodes (bright color) are used to electrostatically define a TQD and three QPCs. The approximate positions of the QDs are depicted by black circles. Arrows mark possible tunneling current paths through QPCs or the TQD. The blue arrow marks the current path through the QPC used as a charge detector for Fig. 2.

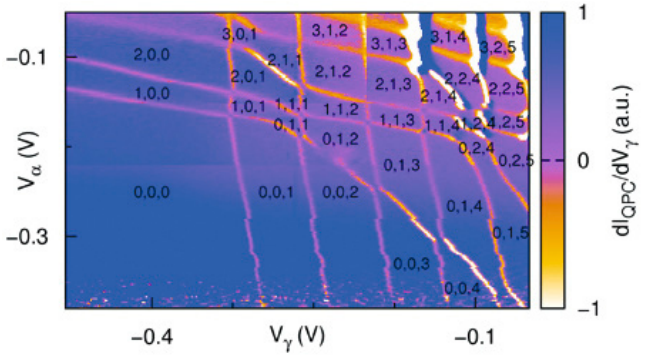


Fig. 2: Charge stability diagram of the TQD detected by use of a QPC (blue arrow in Fig. 1). Bright lines of almost horizontal, diagonal and vertical slope depict changes of the electron number on quantum dots A, B and C respectively. Triples of numbers NA,NB,NC denote the number of electrons on each dot in areas of stable charge configuration. In the lower left area, the TQD is uncharged.

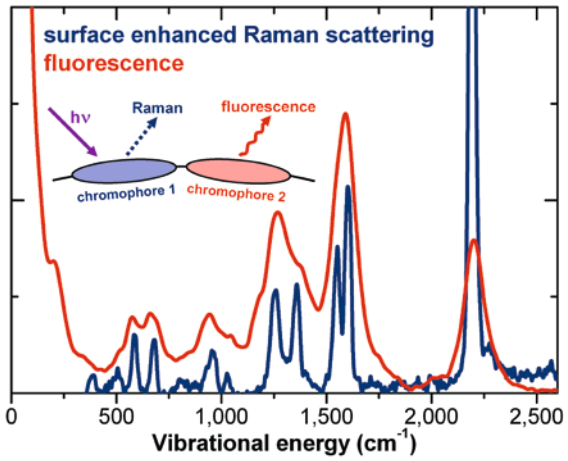
Publication:
» D. Schröer et al., Phys. Rev. B 76, 075306 (2007)

Research Websites:
» Kotthaus: http://www.nano.physik.uni-muenchen.de/
» Ludwig: http://www.nano.physik.uni-muenchen.de/group/people/Ludwig/

Simultaneous Surface Enhanced Raman and Fluorescence Spectroscopy of Single Conjugated Polymer Chains

Prof. Jochen Feldmann (LMU Munich)
Prof. John M. Lupton (University of Utah)

Molecular scale engineering of material characteristics, which is often considered a main advantage of organic electronics, requires powerful nanoscopic characterization techniques. Two powerful means - single molecule fluorescence spectroscopy and single molecule surface enhanced resonance Raman spectroscopy – were combined into a new spectroscopic tool for organic semiconductors to study excited state relaxation mechanisms, such as excitation energy transfer and exciton self-trapping. While resonance Raman spectra probe the vibrational modes of the absorbing chromophore on the polymer chain, fluorescence spectra display the respective modes of the emitting one. Comparing both simultaneously acquired spectra from a single chain made it possible to determine whether or not an energy transfer process occurred as different chromophores on the polymer show slightly shifted vibronic fingerprints. Further discrimination between chromophores arises from correlating temporal changes in the Raman scattering intensity, which results from the absorbing chromophore, and the fluorescence spectral position, which acts as a probe for the emitting unit. ➤



Raman bands (blue) probe the absorbing chromophore while fluorescence (red) comes from the emitting chromophore. The comparison of the energetic positions of the bands and the correlation of their temporal characteristics allows insight into exited state relaxation mechanisms within conjugated polymer molecules.

Publication:
» M. J. Walter et al., Phys. Rev. Lett. 98, 137401 (2007)

Research Websites:
» Feldmann: http://www.phog.physik.uni-muenchen.de/
» Lupton: http://www.physics.utah.edu/~lupton/

Chromophores in Conjugated Polymers

Prof. Irmgard Frank (Univ. of Hannover)
Jun.-Prof. Jens Michaelis (LMU Munich)

Conjugated polymers have received a broad attention due to their applications for displays, organic light-emitting diodes (OLEDs) or photo-voltaic cells. A fundamental understanding of the molecular properties of conjugated polymers is therefore of utmost importance.

Using quantum chemical calculations in combination with molecular dynamics simulation Frank, Michaelis and co-workers addressed the question what limits the size of a chromophore in a conjugated polymer. They could show that in polyphenylene vinylene molecules at normal operating temperatures the thermal motion provides enough mechanical energy to deform the molecule and as a result cause a localization of chromophores to only fractions of its length. Therefore in addition to static defects, the conformation of the polymer in the device will have an important role on its optical properties. ➤

Publication:
» S. Grimm et al., J. Phys. Chem. B 111, 12053-12058 (2007)

Research Websites:
» Frank: http://www.theochem.uni-hannover.de/
» Michaelis: http://www.cup.uni-muenchen.de/pc/michaelis/

Quantum Optics in Nanocircuits

Jun.-Prof. Florian Marquardt (LMU Munich)
Prof. Enrique Solano (Universidad del País Vasco)
Dr. Frank Wilhelm (University of Waterloo)

The groups of CeNS members Enrique Solano, Florian Marquardt, and Frank Wilhelm team up with physicists at the Max-Planck-Institute for Quantum Optics and the Walter Meissner Institute for Low Temperature Research to study the realization of quantum optics in superconducting nanosystems. It has been established how to realize the basic building blocks - artificial atoms and coherent waveguides (quantum cables) for this setup. We have developed schemes and setups how to use them for generating nonclassical states of the field in the cable - single photons, Schroedinger Cats. We have also proposed new means of detection and characterization of these states - dual cavities, microwave beamsplitters, state tomography. These systems can double as an ultimate, quantum-limited tool for characterizing nanodevices and as building blocks for quantum communication inside a superconducting quantum processor. ➤

Publication:
» F. K. Wilhelm and E. Solano, Photon lab in a circuit, Nature 445, 500 (2007)

Research Websites:
» Marquardt: http://homepages.physik.uni-muenchen.de/~Florian.Marquardt/
» Solano: http://homepages.physik.uni-muenchen.de/~Enrique.Solano/
» Wilhelm: http://www.iqc.ca/people/person.php?id=23

Selected Publications

A. Alexander-Katz and R. R. Netz: *Surface-enhanced unfolding of collapsed polymers in shear flow;* Europhysics Letters 80, 18001 (2007)

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F. F. Buersgens, G. Acuna, and R. Kersting: *Acoustic phase imaging with terahertz radiation;* Optics Express 15 (8), 4427 (2007)

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K. de Bruin, N. Ruthardt, K. von Gersdorff, R. Bausinger, E. Wagner, M. Ogris, and C. Bräuchle: *Cellular dynamics of EGF receptor-targeted synthetic viruses;* Mol. Ther. 15, 1297-1305 (2007)

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T. Hugel*, J. Michaelis*, C. Hetherington, P. J. Jardine, S. Grimes, J. M. Walter, W. Falk, D. L. Anderson, and C. Bustamante (*equal contribution): *Experimental Test of the Connector Rotation during DNA Packaging into the Bacteriophage phi29 Capsids;* PLOS Biology 5, 558-567 (2007)

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D. C. Lamb and C. Bräuchle: *Dem Molekül auf der Spur;* Physik Journal 6, 39 (2007)

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HABILITATIONS

Dr. Dieter Braun:
Thermischer Transport von DNA.
(Prof. Hermann E. Gaub)

Dr. Thomas Klar:
Nanooptische Funktionen hybrider Nanopartikelsysteme.
(Prof. Jochen Feldmann)

Dr. Don C. Lamb:
The Development of Ultrasensitive Fluorescence Methods and their Application to Biological Systems.
(Prof. Christoph Bräuchle)

Dr. Robert W. Stark:
Nanoscale fabrication, characterization and manipulation by atomic force microscopy.
(Prof. Wolfgang Heckl)

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Maximilian Baumann: *Aufbau und Test eines Multifrequenz- Rasterkraftmikroskops* (LMU, PD Dr. Robert W. Stark and Prof. Wolfgang M. Heckl); **Julia Blechinger:** *Funktionalisierung von mesoporösen Systemen als hochselektive Methode zur Kontrolle der Einzelmoleküldiffusion* (LMU, Prof. Christoph Bräuchle); **Thomas Einert:** *RNA: Secondary Structures with Explicit Loops in Polynomial Time* (TUM, Prof. Roland Netz); **Thomas Faßbender:** *Manipulation der Adsorption und Desorption von Polymeren an elektrische Felder* (LMU, Prof. Hermann E. Gaub); **Dimitra Georgiadou:** *Mesoporous Nanoscale Titania for Photovoltaic Systems* (LMU, Prof. Thomas Bein); **Markus Hallermann:** *The Electrochemical Solar Cell – Semiconductor Nanocrystals in Mesoporous Hosts* (LMU, Prof. Thomas Bein); **Georg Heinrich:** *Full counting statistics of rough superconducting tunnel junctions* (LMU, Prof. Frank K. Wilhelm and Prof. Jan von Delft); **Oliver Helmreich:** *Kolloidsonden: Nanotribologische Charakterisierung mittels Rauschanalyse* (LMU, PD Dr. Robert W. Stark and Prof Wolfgang M. Heckl); **Martin Herz:** *Elektronentransport durch freitragende Nanostrukturen in GaAs* (LMU, Dr. Stefan Ludwig and Prof. Jörg P. Kotthaus); **José Horas Aznar:** *Investigation on unconventional aspects in the quantum Hall regime on narrow gate defined channels* (LMU, Dr. Stefan Ludwig and Prof. Jörg P. Kotthaus); **Calin Hrelescu:** *Optothermisches DNA-Schmelzen in Gold-Nanopartikel-Aggregaten* (LMU, Prof. Jochen Feldmann); **Florian Huth:** *Single molecule fluorescence studies of protein complexes* (LMU/MPI, Dr. Reinhard Guckenberger and Prof. Hermann E. Gaub); **Marek Janko:** *Force spectroscopy on heterogeneous biomaterials* (LMU, Dr. Stefan Thalhammer); **Reiner Jansen:** *Erzeugung von Hotspots durch AFM-Manipulation* (LMU, Prof. Jochen Feldmann); **Barbara Körner:** *Synthesis of Nanosized Zeolites and their Application as Hosts in Laser Flash Photolysis* (LMU, Prof. Thomas Bein); **Alexander Ohlinger:** *Photovoltaischer Effekt in hybriden Fulleren-/Nanokristall-Systemen* (LMU, Prof. Jochen Feldmann); **Leo Prechtel:** *Zeitaufgelöste Photostrommessungen an Wellenleiterschaltkreisen* (LMU, Prof. Alex W. Holleitner); **Patrick Rebentrost:** *Optimal control of solid state qubits in presence of leakage and decoherence* (LMU, Prof. Frank K. Wilhelm and Prof. Jan von Delft); **Anna Sauer:** *Lokalisiation und Dynamik von magnetischen Gentransferkomplexen* (LMU, Prof. Christoph Bräuchle); **Georg Schinner:** *Heiße Elektronen- und Phononenspektroskopie in zweidimensionalen Strukturen* (LMU, Dr. Stefan Ludwig and Prof. Jörg P. Kotthaus); **Jörg Schuster:** *Highly Ordered Mesoporous Phenolic Resins made by an Organic-Organic EISA Process as Films and in Anodic Alumina Membranes* (LMU, Prof. Thomas Bein); **Julia Sedlmair:** *Kraftspektroskopie an doppelsträngiger DNA* (LMU, Prof. Hermann E. Gaub); **Daniel Soujon:** *Kontrolle der Fluoreszenzraten einzelner kolloidaler Nanostäbchen* (LMU, Prof. Jochen Feldmann); **Verena Stockhausen:** *Creation and Analysis of an electrochemical switch system based on conducting polymers and transition metal nanoparticles* (LMU, Prof. Christoph Bräuchle); **Johann Szeifert:** *Titania nanostructured materials for photovoltaic applications* (LMU, Prof. Thomas Bein); **Hugo Abdiel Vieyra Villegas:** *Optoelectronic Transport Properties of Hybrid Systems made of Single-Walled Carbon Nanotubes and Nanocrystals* (LMU, Prof. Alex W. Holleitner and Prof. Thomas Bein); **Kathrina Weiß:** *Kohärente Laserspektroskopie an einzelnen ladungsdurchstimmbaren Quantenpunkten* (LMU, Prof. Khaled Karrai and Prof. Alex W. Holleitner); **Christoph Wienken:** *Thermophoresis on the Nanoscale: Electric and Nanoscale Methods* (LMU, Prof. Dieter Braun) ➤

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