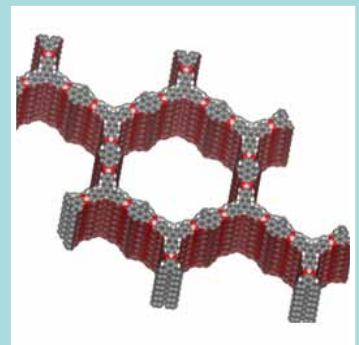
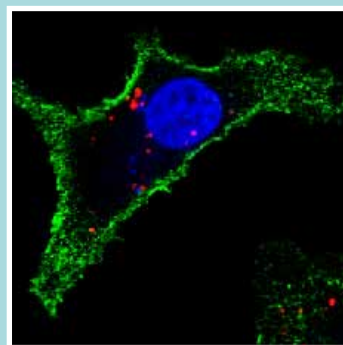
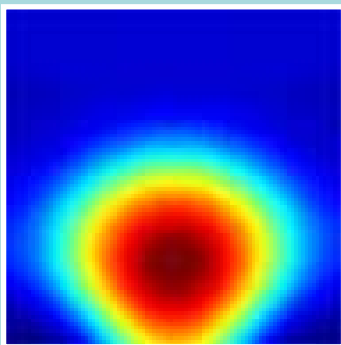
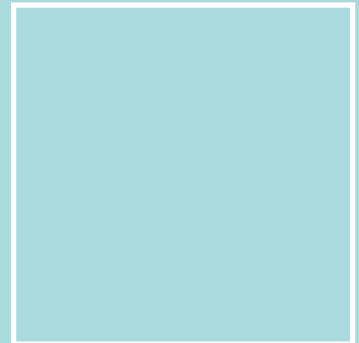
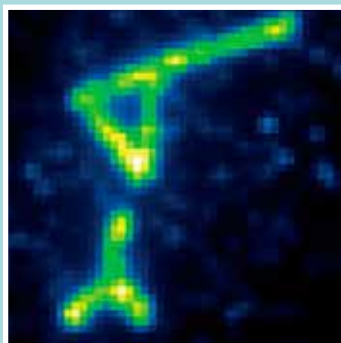


ANNUAL REPORT 2011





WELCOME

The demand for an active network in Nanoscience that promotes interdisciplinary collaborations and active sharing of knowledge in the field of physics, chemistry, biology, medicine and pharmacy is still undiminished. There are many open questions to solve in the coming years, and being embedded in such a network helps to address them efficiently.

CeNS continues to be a success story as you will see when browsing through this annual report. Numerous CeNS researchers have received national and international grants and awards, received attractive offers from renowned universities and published in highly ranked international journals, as nicely demonstrated in the list of the CeNS publication awards. We congratulate all of them and hope that those who left Munich will stay in contact as active CeNS alumni. Also our spin-off companies are doing extremely well and received prestigious business prizes in 2011.

Most of these achievements would not be possible without a lively network between young scientists and established academics. This is what CeNS strives to be, for example through organizing workshops and lecture series. The exciting atmosphere on the island of San Servolo in Venice and in St. Christoph/Arlberg together with a stimulating program and internationally renowned speakers made the CeNS workshop and the NIM/CeNS winter school more than successful. Speaking to graduate students after their participation shows that these events enable what we are hoping for, they provide broad information in the field of nanoscience, create a platform for scientific discussion, help to trigger new research activities and remove barriers to interact with established and leading scientists.

Our graduate students are the key to keep CeNS a living and active network within the coming decade. As such it is important to provide a sound knowledge in the interdisciplinary field of nanoscience and also to train their soft skills by dedicated workshops. As most of us might have experienced, fruitful scientific cooperations are often related to personal relationships and many of us have projects with colleagues from the time of their doctoral studies. As such the networking between the graduate students is very important too and I am glad to learn that Science Rocks! and the Network Lunches are getting more and more popular.

All these activities are supported by the CeNS management team, which did a great job in 2011 although personal changes occurred. In the summer of 2011 Marie-Christine Blüm took up a position at the University of Zurich and at the end of 2011 Evelyn Morgenroth moved to the administration of the LMU physics department. Both helped tremendously to establish CeNS as one of the most renowned centers for interdisciplinary nanotechnology research during the last years and we wish them all the best for their future. We welcome the new managing director of CeNS, Susanne Hennig, and the new team assistant Claudia Kleylein. Together with our program manager Marilena Pinto they form the new management team and we look forward to continuing the CeNS success story in the coming years.

I hope that you enjoy reading the annual report 2011 and that you will participate in the CeNS activities in 2012!

Prof. Christina Scheu
Advisory Member of the Scientific Board of CeNS

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MEMBERS' NEWS



Thorben Cordes accepted a call for an assistant professorship (tenure-track) for „Super-resolution Microscopy“ from the University of Groningen, The Netherlands.

Alexander Holleitner received tenure (W2) at the Technische Universität (TU) Munich.



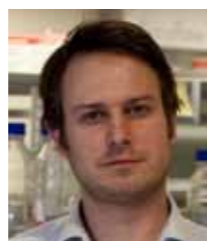
Stefan Kehrein accepted a call as a full professor (W3) for Theoretical Solid State Physics from the University of Göttingen.

Bettina Lotsch accepted a call for a W2 professorship at the Max Planck Institute for Solid State Research, Germany.



Frank Wilhelm-Mauch accepted a call for a W3 professorship for Theoretical Physics from the Saarland University.

NEW MEMBERS



New CeNS members from left to right: Philipp Baaske, Carsten Grashoff, Hubert Krenner, Theobald Lohmüller, Roman Zantl.

DR. PHILIPP BAASKE**NanoTemper Technologies**

Philipp Baaske studied Physics at the University Bayreuth with a specialization in Biophysics. After receiving his Diploma degree in 2005 he began his PhD studies in the System Biophysics group of Dieter Braun at LMU Munich. During his studies he developed a new technology to measure the thermal stability of biomolecules “within a snapshot” and proposed a solution to the so called “concentration problem of the origin of life”. His experiments with biomolecules in microthermal fields led to the development of Microscale Thermophoresis (MST), a new biophysical method for biomolecular interaction measurements. He founded the NanoTemper Technologies GmbH together with Stefan Duhr in May 2008 and finished his PhD in February 2010. With the NanoTemper team he has recently developed the label-free Microscale Thermophoresis, expanding the power of MST even further. In 2011 NanoTemper’s MST is already used by hundreds of scientists worldwide and is considered as a “game changing” technology within the drug development community. Philipp Baaske is CEO of NanoTemper Technologies GmbH.

DR. CARSTEN GRASHOFF**Max Planck Institute of Biochemistry**

Carsten Grashoff studied “Applied Sciences” at the University of Freiberg and received his Diploma degree in 2002. He performed his PhD studies at the Max Planck Institute of Biochemistry in Martinsried in the group of Prof. Reinhard Fässler, where he analyzed the role of the cell adhesion protein integrin-linked kinase (ILK). Using genetic mouse models he found, surprisingly, that ILK is dispensable as a kinase but critical for the organization of the f-actin cytoskeleton and the mechanical integrity of the cell. In 2007 he joined the lab of Prof. Martin Schwartz at the University of Virginia to establish a technique capable of mapping tension within cells. Using an interdisciplinary, biophysical approach he developed a genetically encoded tension sensor module sensitive to forces in the range of single pico-Newton (pN). Application of this module to proteins allows for the first time visualization and measurement of mechanical forces across distinct proteins in living cells. Since 2010 Carsten Grashoff is an Emmy Noether group leader at the Max Planck Institute of Biochemistry. His group of “Molecular Mechanotransduction” is exploring molecular details of cellular mechanotransduction.

DR. HUBERT KRENNER**University of Augsburg**

Hubert Krenner studied Physics at TU Munich where he received his Diploma degree at the Walter Schottky Institut (WSI) in the groups of Gerhard Abstreiter and Artur Zrenner in 2001. In 2006 he was awarded a doctoral degree for his work on electrically tunable single and coupled quantum dots in the groups of Gerhard Abstreiter and Jonathan Finley at the WSI. In May 2006 he joined the group of Pierre Petroff

at the Materials Department at the University of California at Santa Barbara (UCSB) as a Feodor Lynen Postdoctoral Fellow of the Alexander-von-Humboldt-Foundation. At UCSB he focused on electrically gated optical memory devices using single quantum nanostructures and in collaboration with the group of Dirk Bouwmeester, electro-mechanically tunable photonic crystal optical nano-resonators. In 2008 he returned to Germany to extend his research on tunable optically active nanostructures on surface acoustic waves in the group of Achim Wixforth at the University of Augsburg. Since 2011 he is the head of a Emmy Noether Junior Research group at the University of Augsburg. With his team he explores acoustically tunable planar nanophotonic circuits and nanophotonic elements and quantum emitters synthesized by bottom-up site-selective ion beam implantation.

DR. THEOBALD LOHMÜLLER**LMU Munich**

Theo Lohmüller studied Chemistry and Biology at the University of Erlangen-Nürnberg and the University of Würzburg. In 2004 he joined the group of Prof. Joachim P. Spatz at the Heidelberg University and the Max-Planck Institute for Intelligent Systems in Stuttgart (formerly Metals Research). In 2008 he was awarded his doctoral degree in Chemistry for his work on “Nanostructured Functional Materials”. After working as a Research Scientist for BASF at the Global Research Center in Singapore he joined the group of Prof. Jay T. Groves as a DFG PostDoc Fellow at UC Berkeley and the Lawrence Berkeley National Laboratory, Materials Sciences Division in 2009. In April 2011 he returned to Germany to join the chair of Prof. Jochen Feldmann at the Physics Department at LMU Munich as a group leader. He is interested in the physical chemistry of bio-inorganic hybrid nanomaterials and their application to living systems. A major part of his research is to find new ways to integrate nanooptics and plasmonic devices with supported membranes to study and manipulate the biophysical and chemical properties of single membrane receptors and molecules by Raman and fluorescence spectroscopy.

DR. ROMAN ZANTL**ibidi**

Roman Zantl received his PhD in physics from the Technical University Munich in 2001. In the group of Joachim Rädler he worked on the mesoscopic structure of cationic lipid DNA complexes. In the same year he cofounded ibidi and is since then responsible for R&D and sales. The ibidi core technology enables the large scale production of micro fluidic devices with complex designs and for various applications made of thermoplasts and soft silicones. In the main focus of ibidi are functional cell based assays. One example is the first chemotaxis assay for slow migrating cells like endothelial or cancer cells in three dimensional gel matrices over long time periods. Since 2001 there are more than 1000 scientific papers published with ibidi products.

MEMBERS' NEWS



Ralf Metzler was appointed as a full professor (W3) for Theoretical Physics at the University of Potsdam.

Jens Michaelis accepted a call as a full professor (W3) for Experimental Biophysics at the University of Ulm.



Roland Netz accepted a call as a full professor (W3) at the Freie Universität (FU) Berlin.

Lukas Schmidt-Mende was appointed as a professor for Hybrid Nanostructures at the University of Konstanz.



A PASSION FOR PRECISION

In 2011, the CeNS spin-off *nanotools* celebrated its 15th anniversary. Founded by CeNS members Dr. Heribert Lorenz and Dr. Bernd Irmer, together with Armin Kriele and Dr. Martin Wendel, *nanotools* has become well-established as a high-tech precision machining company, making smallest devices to the very nanometer. Situated in the very heart of Munich, they are today supplier to the leading semiconductor manufacturers worldwide as well as to all industries who require ultra precision components.

Dr. Irmer, how was the company *nanotools* founded and what motivated you to become an entrepreneur?

We started in 1996, simply as four friends working in the group of Professor Kotthaus (two PhD students, the group leader and one technician). Very soon it became obvious that this was nothing we could handle on Friday afternoons. To participate in (and finally to win) the first Munich Business Plan Competition (MBPW) gave us a huge boost in rethinking about our business and the chances involved – and doing the right thing, namely in founding a professional “real” company in 1997.

My motivation to become an entrepreneur? Well, I think you have to have a sense of making business and have to like the excitement about making things happen – then you will be an entrepreneur sooner or later....

Which was the role of the university and CeNS in the foundation of *nanotools*?

We got the best support one could imagine: we could just start doing our business. There were no bureaucratic barriers whatsoever, we could use expertise and equipment, and we have always had the full support from our boss. It was him and the organization behind him, who could have stopped our activities at an early stage – but the contrary was the case.

What are the products of *nanotools*?

We make very precise nano-machinery, i.e., we can manufacture almost any three-dimensional shape within nanometer precision at an automated, industry scale level. Our best selling products are sensors for Scanning Probe Microscopes (SPM/AFM), used for quality control in chip manufacturing. Today, there is almost no ipod, no smart phone, no Xbox or any computer which has not been manufactured with the help of our “nanotools”.

Who are your principal customers and where do you deliver your products to?

More than ¾ of the semiconductor manufacturing companies use our products, foundries like TSMC or GlobalFoundries as well as “classic” blue chip companies like IBM, Samsung or Infineon. Therefore, we export to where the semiconductor industry has their largest installed production capacities: Taiwan and China, South East Asia, Japan, USA and Europe. Also, all AFM system



Dr. Bernd Irmer, CEO *nanotools*

manufacturers are customers of us.

How did you acquire the entrepreneurial knowledge necessary to start running a company?

Luckily, our founding team was quite “mixed”, meaning we had many different skills. Today, it is the key to attract and retain highly skilled and motivated individuals. It is all about the team.

How did you proceed to secure funding?

At an early stage we had to decide between two options: faster, cash-driven growth with the help of an investor, or growing from self-generated cash flow at the lowest possible cost level. We were going the second way. Putting cost and therefore efficiency at a very high attention level was (and is) good. It helped us a lot in making the critical transition from a budget-minded organization to a customer, cash-minded organization. But not to forget, our biggest early “investor” was the university (or what is CeNS today) in letting us starting our business...

How many employees work for *nanotools* at present?

Here in Munich we are 15 full time, a total of 20 including part time and students. About half of them have a background in physics, others include classical music, geography, and automotive.... In total, with the other facilities and offices worldwide, the nanoworld-group had about 80 employees in 2011.

What are your major goals for the future?

To grow further and to stay profitable like always. Technologically, we need to stay on the roadmap of ever shrinking dimensions in the semiconductor industry. Currently we are making products for the 22nm node – and the next nodes are already under development. The smallest probe we are testing right now

is a small mushroom-like sensor with just 8nm total width – with a 4nm supporting post (CDR-8).... Regarding production we are currently investing quite a lot to keep pace with growing demand. It is always challenging for a small company like us to serve such a volatile market like semiconductor industry. Other industries are now also entering the nano-dimensions, i.e., they have an increasing need for measuring, controlling and also manufacturing devices on the nanometer level. This is a very promising opportunity for us.

Do you enjoy your job? Does it meet the expectations you had when you started *nanotools*?

Maybe I did not enjoy every single hour, but certainly overall. In the founding team, not everybody enjoyed the transition from an open, free, budget oriented university style working environment to a very strict, hectic, efficiency-driven, customer-oriented entity. But what is unique to a small, entrepreneurial company is the level of excitement and involvement: you are directly responsible of what you are doing, but you can also directly do what you think needs to be done.

What would you advise researchers who think about founding their own company?

Focus on the customer, focus on the market. Listen to them, they are right, they are paying the bill. If your technology makes them excited and buying, you are right. If they don't understand it, you might want to reconsider your business. Don't focus too much on planning, spend your energy on execution. Keep smiling when you change everything that you were doing until today.

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Website: www.nanotools.com

SPIN-OFF NEWS

NANORULERS FOR MICROSCOPY

In March 2011, STS Nanotechnology was founded by CeNS member Philip Tinnefeld (Since 2011 TU Braunschweig) and his PhD students Jürgen Schmied and IDK-NBT alumnus Dr. Christian Steinhauer. The company features innovative solutions for the calibration of super-resolution microscopes. Based on patented DNA origami technology, nanoscopic rulers are available for a wide range of microscopy applications.

www.sts-nano.com

NEASPEC SUCCESSFUL IN THE MUNICH BUSINESS PLAN CONTEST

In 2011, a team from Neaspec with IDK-NBT Alumnus Stefan Schiefer finished third in the final stage of the contest Münchner Business Plan Wettbewerb (MBPW) and won a prize money of 5.000 Euros. Neaspec is dedicated to delivering innovative solutions for nanoscale optical imaging & spectroscopy for research laboratories in industry and academic institutions.

www.neaspec.com

ETHRIS WINS GO-BIO AWARD 2011

The founders of ethris, CeNS member Prof. Christian Plank (TUM) and Dr. Carsten Rudolph (LMU), were among the six winners of the 4th round of the prestigious GO-Bio Competition of the Federal Ministry for Education and Research (BMBF). With the GO-Bio award, ethris will continue the development of the so called SNIM-RNA technology for “Transcript Therapies” in regenerative medicine.

www.ethris.com

MULTIPLE AWARDS FOR IBIDI

CeNS spin-off ibidi received an award from the „Deloitte Technology Fast 50“ competition for the third year in a row. The Fast 50 is an annual listing of the fastest-growing technology companies in Germany. ibidi was also honored in the “2011 STEP Award” competition: For their first ever entry, ibidi was awarded with a ranking in the top 10. In addition, ibidi received a special prize donated by the German stock exchange for their exceptional business concept.

www.ibidi.com

AWARDS 2011

>>> **Prof. Dieter Braun** received the **Klung-Wilhelmy-Weberbank Award 2011** by the Klung, Wilhelmy and Weberbank foundations and the Freie Universität Berlin. >>> **Prof. Thomas Carell** was appointed **Melvin Calvin Lecturer** in Organic Chemistry at the University of California, Berkeley and won the **František Šorm Award** of the Academy of Sciences of the Czech Republic. >>> **Prof. Patrick Cramer** was awarded the **Feldberg Foundation Prize** for Anglo-German Scientific Exchange. >>> **Dr. Enrico Da Como** won the **Young Talent TOTAL Award** of the European Materials Research Society. >>> **Prof. Herrmann Gaub** was honored by being elected as the German representative of the **Scientific Council of the Human Frontiers Science Program** and by being elected as a member of the **European Molecular Biology Organisation (EMBO)**. >>> **Prof. Peter Hänggi** was honored by the **Lars Onsager Lecture and the Lars Onsager Medal** of the Norwegian Institute of Technology and was elected as **Editor-in-Chief** of the European Physical Journal B. >>> **Prof. Thorsten Hugel** was awarded the **Rudolf-Kaiser-Preis** of the Rudolf-Kaiser-Foundation in the Stifterverband der Deutschen Wissenschaft. >>> **PD Dr. Stefan Ludwig** received a **Heisenberg Fellowship** of the German Research Council (DFG). >>> **PD Dr. Rossitza Pentcheva** was offered a **Rosalind Franklin Fellowship** of the University of Groningen, The Netherlands. >>> **Prof. Andrey Rogach** received the **"Grand Award" of the CityU Research Excellence Award** of the City University of Hong Kong. >>> CeNS Associate **Dr. Quirin Unterreithmeier** won the **PhD Award** of the "Münchner Universitätsgesellschaft" of LMU Munich. >>> **PD Dr. Eva Maria Weig** was rewarded with the **Akademiepreis für Physik** of the Akademie der Wissenschaften zu Göttingen. >>> **Prof. Achim Wixforth** was honored by the **C.B. Sawyer Memorial Award** of the IEEE International Frequency Control Symposium.



ERC GRANTS 2011

As in the year before, researchers of CeNS were highly successful in the 2011 European-wide call for applications of the European Research Council (ERC). Members of CeNS could secure a total of 5 renowned grants in the fields of Life Sciences and Physical Sciences in a highly competitive evaluation. The goal of the "Starting Independent Researcher Grants" (Starting Grants) and the "Advanced Investigator Grants" (Advanced Grants) is to stimulate scientific excellence by providing funding for innovative research projects that explore the frontiers of knowledge and look for risky, but highly promising ideas. The scientists are especially encouraged to go beyond the boundaries of disciplines in their projects.



CeNS members who received an ERC grant in 2011: Herrmann Gaub, Andreas Bausch, Florian Marquardt and Achim Hartschuh

Prof. Herrmann Gaub (LMU) received an **ERC Advanced Grant** for his research proposal "Designer Cellulosomes by Single Molecule Cut & Paste".

Prof. Andreas Bausch (TUM) was awarded an **ERC Advanced Grant** for his proposal "Self Organization in Cytoskeletal Systems". In addition, he was also successful with his application "Dynamics and Self-organisation in Complex Cytoskeletal Networks" for an **ERC Starting Grant**.

Prof. Florian Marquardt (University of Erlangen) won an **ERC Starting Grant** for his research project "Theory of optomechanical circuits".

Prof. Achim Hartschuh (LMU) received an **ERC Starting Grant** for his grant proposal "New tools for nanoscale optical spectroscopy - Functional imaging of single nanostructures using antennas".

More information: <http://erc.europa.eu/>

PUBLICATION AWARD

Each year, CeNS awards prizes for excellent publications of CeNS members that have been published during the past twelve months. With this award, successful cooperation projects within CeNS as well as outstanding research of individual research groups of CeNS are distinguished. From the numerous submitted articles which appeared in high-impact journals between October 2010 and October 2011, the CeNS board had a hard time to select the 21 winning publications.

Amongst these were successful CeNS-internal collaboration projects such as those between the groups of Doris Heinrich, Joachim Rädler and Thomas Franosch, Dieter Braun and Ulrich Gerland, Bert Nickel and Lukas Schmidt-Mende, Thomas Bein and Ernst Wagner, Christoph Bräuchle and Jens Michaelis, Tim Liedl and Philip Tinnefeld, and Friedrich Simmel and Philip Tinnefeld. In addition, outstanding articles from individual research groups which were published in renowned journals such as Science or Nature Nanotechnology were recognized. The announcement of the winners took place at the IDK-NBT/CeNS Come-Together-Event at the end of November.



CeNS members who won one of the CeNS publication awards 2011 for their joint publication: Thomas Franosch and Doris Heinrich with PhD student Börn Meier

EVENTS & ACTIVITIES

NIM-CeNS WINTER SCHOOL

The winter school, jointly organized with the Nanosystems Initiative Munich (NIM), has a long standing tradition. In 2011, the winter school took place in St. Christoph (Austria) from March 27th to April 2nd. The winter school brought together about 100 PhD students from diverse scientific fields to discuss the current nano research and to present their own results. The scientific program concentrated on Quantum Nanophysics, Hybrid Nanosystems, Nanosystems for Energy Conversion, Biomolecular Nanosystems, and Biomedical Nanotechnologies. Beside internal CeNS and NIM speakers, 14 invited speakers such as Daniel Fletcher (University of California, Santa Barbara), Jørgen Kjems (Aarhus Universitet, Denmark), Cécile Leduc (Université de Bordeaux, France), Serdar Sariciftci (Universität Linz, Austria) and Herre van der Zant (Kavli Institute Delft, The Netherlands) reported their newest results.

<http://www.nano-initiative-munich.de/events/winter/>



CeNS WORKSHOP VENICE

The 2011 CeNS workshop "Nanosciences: From Molecular Systems to Functional Materials" was held on the beautiful island of San Servolo from September 19th to 23rd. Internationally renowned scientists and graduate students of CeNS gathered for five days of lively exchange on nanosciences. In their stimulating talks, 26 top-level researchers from Canada, Japan, USA, Israel and Europe presented research topics on nanometer-scale science to 120 young and experienced researchers from physics, chemistry and life sciences. In addition to the talks, PhD students and junior researchers of CeNS presented their scientific results to their colleagues and to the guest speakers at two intensive poster sessions. In the course of the workshop, there were inspiring discussions between participants and speakers not only inside the lecture hall, but also beyond the official schedule during breaks and in the evenings thanks to the enchanting atmosphere of Venice.

www.cens.de/calendar/past-workshops-events/venice-2011



FOCUS WORKSHOPS

Several specific workshops, initiated and organized by CeNS members, were supported by CeNS in 2011. Financial aid was provided for the workshop "Physics of Low-Dimensional Systems and Materials" which took place from January 3rd to 7th at the National Institute for Theoretical Physics (NITheP) in Stellenbosch, South Afrika and was co-organized by CeNS member Prof. Jan von Delft. Furthermore, CeNS funded a workshop on Nano-Carbon Optics organized by Prof. Achim Hartschuh, held in Herrsching at lake Ammersee from October 6th to 9th. In addition, the workshop "Frontiers in DNA Nanoscience: Designed nucleic acid structures in physics, chemistry, and biology" (Prof. Hendrik Dietz, Prof. Tim Liedl and Prof. Friedrich Simmel, October 25th to 26th) and <interact>, a self-organized PhD symposium for life sciences in the Munich area (April 7th), were financially supported.

www.cens.de/calendar/past-workshops-events/

CeNS MEETS INDUSTRY

Every year, CeNS invites alumni and representatives from industry to present their companies and employment opportunities to the CeNS community, especially to the junior researchers of CeNS. In 2011, one IDK-NBT Alumnus, representatives of two CeNS spin-off companies as well as employees from large international companies talked about their career paths and gave insight into their companies' R&D activities.



Dr. Johann Jaud

Dr. Johann Jaud (Zeiss, Corporate Research & Technology) started the afternoon with an exciting talk about the research strategies of Zeiss ("From Life Science to Industrial Metrology - Corporate Research at Carl Zeiss"). His talk was followed by Prof. Jan Behrends, University of Freiburg and co-founder of Nanion, who provided insights into the development of the CeNS spin-off Nanion ("Channels and Pores into the Membrane Market - A Startup Story and a Progressive Perspective"). An unusual topic was presented by Frank Bernhardt, Fraunhofer Institut für Produktionstechnologie Aachen, who spoke about the challenges of a doctorate in the project-driven environment of Fraunhofer institutions ("PhD at Brownian Motion? How to Graduate among Engineers"). Dr. Friedemann Krause, Roche Diagnostics, reported about "From Quantum Mechanics to Personalized Health Care: The Long Journey of a Physicist". Last but not least, IDK-Alumnus Dr. Stefan Schiefer talked about his career path which led him from business consulting to a management position in the CeNS spin-off Neaspec ("Physics unplugged - A (un)typical career beyond R&D").



Dr. Stefan Schiefer

The event was followed by the traditional summer party, animated by the band "UnCeNSiert". Here, there was ample opportunity for all participants to discuss with the speakers and with other members and alumni of CeNS.

www.cens.de/calendar/past-workshops-events/cens-meets-industry-2011

NANOART GOES WEST AND EAST

From April to June 2011, twelve nanoscience research images by CeNS and NIM members were exhibited at the foyer of the "German House" New York. They were part of the Nano-Art exhibition "Pictures from the Invisible Frontier" which was organized, amongst others, by the German Center for Research and Innovation (GCRI) and the Center for Nanointegration Duisburg-Essen (CeNIDE). After their stay in the Big Apple, the pictures then moved to the West Coast where they were displayed at the University of California, Berkeley, during summer. The trip to the west ended in the very east: in October 2011 the nano images were presented at the University of Tsukuba, Japan.

www.cens.de/calendar/past-workshops-events/kunst/

MUNICH SCIENCE DAYS 2011

CeNS and NIM again organized a booth at this year's Munich Science Days themed "Health - a challenge", which took place at LMU Munich on October 23rd and 24th. About 20 mostly junior scientists from CeNS and NIM working on health-related topics presented their research to the public, ranging from the development of new drugs to analytical applications for biomedical research.

Young and older visitors could test a microfluidic setup in a joystick experiment as well as nanoexperiments for children, watch short movies, explore strategies to combat cancer in a computer simulation and discuss with the scientists from the groups of Prof. Bein, Prof. Bräuchle, Prof. Braun, Dr. Franke, Prof. Plank and Prof. Wagner about their research at the posters. The sometimes tricky questions of the popular nano quiz made visitors of all ages curious about the presented topics and stimulated lively discussions between the CeNS researchers and the public.

www.muenchner-wissenschaftstage.de/2011/



COLLOQUIUM

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

www.cens.de/calendar/cens-colloquium

PHD STUDENTS' CORNER

EXCHANGE PROGRAM WITH THE BRISTOL CENTRE FOR FUNCTIONAL NANOMATERIALS

In 2009, CeNS set up a cooperation agreement for PhD students with the Doctoral Program of the Bristol Centre for Functional Nanomaterials (BCFN) at the University of Bristol. Based on this reciprocal exchange arrangement, each year one to two doctoral students of each center spend 3 weeks in the labs of the respective partner institution to learn new research techniques and perform experiments. In 2011, IDK PhD student Christian Westermeier and BCFN PhD student Rebecca Boston participated in the exchange. Rebecca stayed in the group of Dr. Bert Nickel. Christian visited Heinrich Hoerber's lab in August 2010.



"My visit to Bristol was a valuable experience. The project in Prof. Hoerber's lab offered me an insight into experimental methods and scientific approaches of other groups and especially increased my knowledge of scanning microscopy techniques, an important issue of my own research field. Heinrich Hoerber and his group members, in particular Dr. Deepak Sahoo, offered me a very friendly and inspiring working atmosphere. In addition, the exchange and discussions with the BCFN students from different scientific fields were really interesting, providing me with an insight into their interdisciplinary projects and the broad spectrum of new technological setups in the impressive NSQI facility in Bristol."
Christian Westermeier, IDK-NBT PhD student

ADOBE ILLUSTRATOR

Professional illustrations of research results are crucial for successful publishing. To give the PhD students of CeNS a solid background in vector illustrations, CeNS organized two two-day Adobe Illustrator workshops on February 17th-18th and February 24th to 25th. The workshops were held by a professional IT training company and introduced the students into the basic functions and principles of the software, followed by exercises for special features of Adobe Illustrator and the direct application of the acquired knowledge by creating own illustrations.

www.cens.de/calendar/past-workshops-events/illustrator-workshop

SCIENCE ROCKS!

Every other Thursday at 5:45 p.m. during the semester, PhD students and postdocs of CeNS gather for an informal seminar where one of them presents his/her research topic. Before and after the talks, the students have the chance to meet other PhD students, make new acquaintances from other groups and discuss about nanosciences in a casual atmosphere. Science Rocks! is organized by volunteer PhD students.

www.cens.de/calendar/science-rocks/

GRANT WRITING

The aim of the Grant Writing workshop, held by Dr. Christina Schütte (ProSciencia) on March 24th to 25th, was to provide CeNS PhD students with strategies for writing successful grant or fellowship applications to various funding bodies. The participants had to prepare a short "mini-grant application" in preparation to the course, which was then evaluated by other participants and in an evaluation session within the course. By this method, extensive feedback for the participants on their applications was provided, and the PhD students became familiar with the view of potential evaluators.

www.cens.de/calendar/past-workshops-events/grant-writing

ENTREPRENEURSHIP AND BUSINESS SEMINAR

As in the last years, PhD students and postdocs of CeNS had the possibility to broaden their knowledge of entrepreneurial skills in a three-day workshop offered by the Entrepreneurship Center of LMU Munich on April 13th to 15th. The workshop covered the diverse aspects of starting a company, e.g., "From the Idea to the Business Concept" to "Starting a Company" and "Financing" and combined theory with hands-on exercises. Successful entrepreneurs and specialists shared their experience with the participants and encouraged them to develop an entrepreneurial mindset.

In addition, CeNS also offered a two-day workshop for CeNS PhD students focusing less on entrepreneurship but introducing into the basic principles of business management and economics. The workshop (September 29th-30th) was held by Dr. Christian Jörg and Dr. Ralph Stöckl (valucon) and provided insights into accounting and finance, marketing and much more.

www.cens.de/calendar/past-workshops-events

www.entrepreneurship-center.uni-muenchen.de

INTERNATIONAL DOCTORATE PROGRAM NANOBIOTECHNOLOGY



IDK-NBT SUMMER SCHOOL

In August 2011, nineteen PhD students of the Doctorate Program NanoBioTechnology gathered in Aiterbach at lake Chiemsee for the annual IDK-NBT summer school. The opening talk was given by Prof. Georg Seelig, assistant professor for Computer Science & Engineering and Electrical Engineering at the University of Washington about his research on the identification of systematic design rules for the *de novo* construction of biological control circuits with DNA and RNA components. Prof. Seelig gave a captivating and stimulating talk, designed for the interdisciplinary audience. In the subsequent sessions, IDK students presented their own research in 15 minutes talks and discussed it with the fellow IDK members. The presentations showed the diverse nature of the IDK-NBT, with topics ranging from "How life could evolve - dissipative systems in the molecular evolution" to "Tunable optical properties of copper chalcogenide nanocrystals (NCs)".



Another highlight was the "career session" with Prof. Georg Seelig, Prof. Philip Tinnefeld (Universität Braunschweig) and IKD-NBT-spokesman Prof. Joachim Rädler (LMU), who provided interesting insights into their own career paths and discussed advantages and drawbacks of career decisions with the students. Thanks to the openness of the speakers, the students were encouraged to ask all sorts of questions, and the lively discussion reflected the spirit of the whole summer school - intense and interactive in an open and relaxed atmosphere.

LECTURE SERIES NANOBIO TECH

Once a month, a lecture on nanobioscience topics held by researchers of CeNS and invited guests precedes the CeNS colloquium from 2:00 to 3:00 p.m. This series of lectures is part of the educational program of the International Doctorate Program NanoBioTechnology. The lectures of the series are recorded and are available online for members of CeNS.

www.cens.de/calendar/lecture-series

ENERGY AND INNOVATION

The enormous changes with respect to how we handle and consume energy and the impact on the environment are of great concern not only to scientists, but to all responsible citizens. In April 2011, the PhD students of the doctorate program IDK-NBT initiated and organized a discussion event with experts from relevant fields to get a deeper insight into the technical, economic and social preconditions necessary for the creation of a truly sustainable energy supply system. The workshop "Energy and Innovation" brought together four specialists from different fields and more than fifty junior researchers of CeNS for an evening of intense discussions. The workshop started with stimulating ignition talks by the invited speakers on "Between organisation and technology: Innovation in the energy system" (Prof. Thomas Hamacher), "Printed solar cells - Cutting costs through innovation" (Prof. Christoph Bräbe), "Renewable Energies in Rural Distribution Systems" (Dr. Rupert Schöttler), and on the Munich-based DESERTEC project Clean Power from Deserts (Tobias Grimm).



Prof. Joachim Rädler,
IDK-NBT spokesman

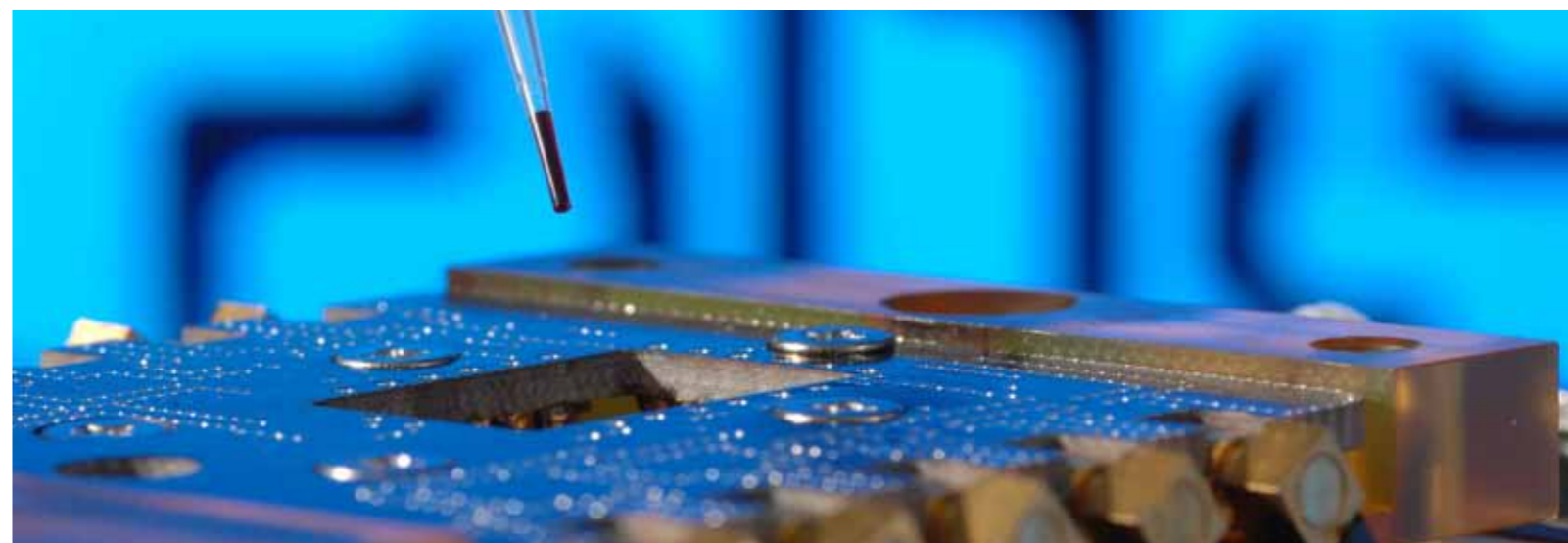
"This workshop which brought together experts from industry and academia exceeded my hopes and expectations by far. The discussions made clear how diverse and complex the interdependencies in the field of energy production are. Furthermore, the discussion gave a clear signal to the young generation that the changes in the energy system call for innovation which offers research challenges and interesting job opportunities."

In order to discuss about the specific topics in more detail, the participants then divided into four groups for an intense 30 min exchange with the respective speaker. The final highlight of the evening was a panel discussion led by Prof. Joachim Rädler (Spokesman of the Doctorate Program) where interesting questions of the audience were debated such as whether more financial support is needed for the "energy revolution", why research in the field of energy storage is still neglected, whether one needs centralized solutions and/or local energy production and how the renewable energy sector changes the job market for young researchers. Discussions were then continued at a welcome reception lasting till late in the evening.



Junior researchers discussing specific topics of energy supply in one of the simultaneously running discussion rounds.

SELECTED RESEARCH PROJECTS



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Silica nanomaterials for nanomedicine **40**

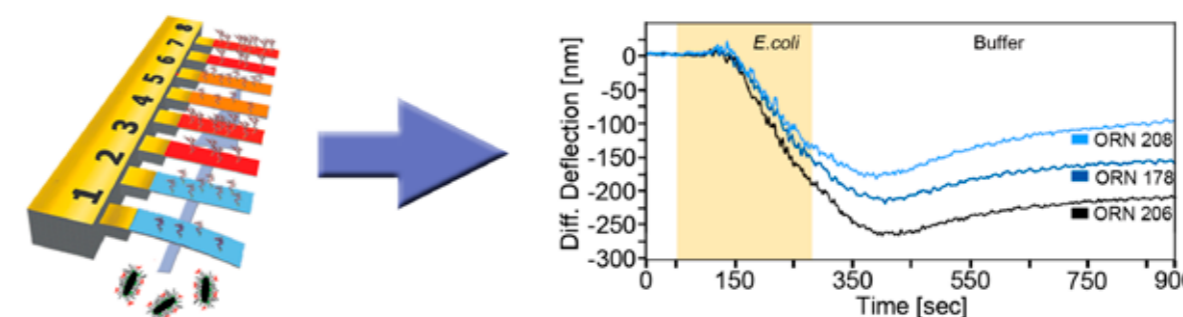
BIOLOGICAL APPLICATIONS FOR NANO-MECHANICAL DETECTION OF MOLECULAR RECOGNITION

Dr. Madeleine Leisner (LMU Munich, Faculty of Physics)

Advances in carbohydrate sequencing technologies have revealed the tremendous complexity of the glycome. Understanding the biological function of carbohydrates requires the identification and quantification of carbohydrate interactions with other biomolecules. The increasing importance of carbohydrate-based sensors able to specifically detect sugar binding molecules or cells has been shown for medical diagnostics and drug

screening. Biosensors with a self-assembled carbohydrate-based sensing layer (e.g. mannoside-based) can specifically detect carbohydrate–protein binding interactions (e.g. mannoside–ConA), as well as real time interaction of carbohydrates with different *Escherichia coli* strains in solution. Binding to the cantilever surface causes mechanical surface stress that is transduced into a mechanical force and cantilever bending. The degree and dura-

tion of cantilever deflection correlates with the interaction's strength. Carbohydrate-based cantilever biosensors can serve as a robust, label-free and scalable method to analyze carbohydrate–protein and carbohydrate–bacteria interactions. The cantilevers thereby exhibit specific and reproducible deflection with a high sensitivity range of over four orders of magnitude.



Carbohydrate-based biosensors for the specific detection of sugar binding molecules or cells.

A. Mader, K. Gruber, R. Castelli, B.A. Hermann, P.H. Seeberger, J.O. Rädler and M. Leisner: Discrimination of *Escherichia coli* Strains using Glycan Cantilever Array Sensors; *NanoLetters* 12, 420-423 (2012).

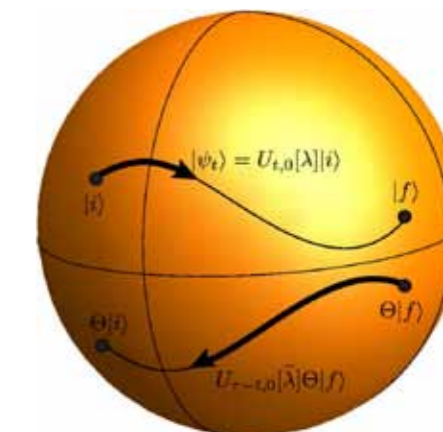
Leisner: www.theorie.physik.uni-muenchen.de/lisfrey/group_leisner

QUANTUM FLUCTUATION RELATIONS: FOUNDATIONS AND APPLICATIONS

Prof. Peter Hänggi (University of Augsburg, Institute of Physics)

Two fundamental ingredients play a decisive role in the foundation of fluctuation relations: the principle of microreversibility and the fact that thermal equilibrium is described by the Gibbs canonical ensemble. Building on these two pillars the reader is guided through a self-contained exposition of the theory and applications of quantum fluctuation relations. These are exact results that constitute the fulcrum of the recent development of non-equilibrium thermodynamics beyond the linear response regime. The material is organized in a way that emphasizes the his-

torical connection between quantum fluctuation relations and (non)-linear response theory. A number of fundamental issues are clarified which were not completely settled in the prior literature. The main focus is on (i) work fluctuation relations for transiently driven closed or open quantum systems, and (ii) on fluctuation relations for heat and matter exchange in quantum transport settings. Recently performed and proposed experimental applications are presented and discussed.



Fluctuation Theorems: Microreversibility for nonautonomous quantum systems.

M. Campisi, P. Hänggi and P. Talkner: Quantum fluctuation relations: Foundations and applications; *Reviews of Modern Physics* 83, 771-791 (2011).

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

MECHANISMS AND ADVANCEMENT OF ANTIFADING AGENTS FOR FLUORESCENCE MICROSCOPY AND SINGLE-MOLECULE SPECTROSCOPY

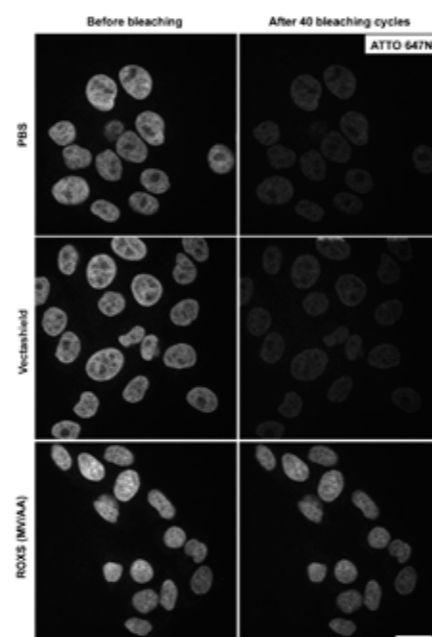
Prof. Thorben Cordes (University of Groningen, Faculty of Mathematics and Natural Sciences)

Prof. Philip Tinnefeld (TU Braunschweig, Department of Electro Engineering, Information Technology and Physics)

Modern fluorescence microscopy applications go along with increasing demands for the employed fluorescent dyes. In this work, antifading formulae are compared utilizing a recently developed reducing and oxidizing system (ROXS) with commercial antifading agents. To systematically test fluorophore performance in fluorescence imaging of biological samples, photobleaching experiments were carried out using fixed cells labeled with various commonly used organic dyes, such as Alexa 488, Alexa 594, Alexa 647, Cy3B, ATTO 550, and ATTO 647N. Quantitative evaluation of (i) photostability, (ii) brightness, and (iii) storage stability of fluorophores in samples mounted in different antifades (AFs) reveal optimal combinations of dyes and AFs. The data suggest that the ROXS based AFs significantly improve the performance of dyes in immunofluorescence imaging and often outperform classical AFs (see bleaching experiments and fluorescence intensities in the Figure). There are, however, also more specific effects that are summarized in a practical guidance outlining

which particular AF should be used for a given fluorophore (class). To learn more about the mechanism of the empirically found antifading agents single-molecule spectroscopy was used to study the influence of different AF concentrations on the blinking of single dye molecules. This leads to the conclusion that their empirical selection might be related to their additional oxidizing properties and that their stabilizing mechanism is also related to the ROXS concept. This fact of course underlines the importance of the ROXS concept not only for single-molecule spectroscopy but also for fluorescence applications in general.

Based on the described results we provide guidance for fluorescence imaging that details AF should preferably be used with a specific dye.



Confocal images of HeLa histone H2B-GFP expressing cells labeled with ATTO 647N-coupled GFP antibodies. Samples were embedded using different mounting media. Selected images of a time series with a) PBS b) Vectashield and c) ROXS (AA/MV) are shown here exemplarily. The ATTO 647N dye was excited at 635 nm (close to its absorption maximum at ≈ 644 nm). The panels show fluorescently labelled nuclei before and after 40 iterative cycles of confocal imaging and bleaching the entire field of view. Significantly less fluorescence intensity is left in the PBS- and VS-embedded samples, whereas ROXS effectively preserves fluorescence. Bar is 20 μm .

T. Cordes, A. Maiser, C. Steinhauer, L. Schermelleh, P. Tinnefeld: Mechanisms and Advancement of Antifading Agents for Fluorescence Microscopy and Single-Molecule Spectroscopy; Physical Chemistry Chemical Physics 113, 6679-6709 (2011).

Cordes: www.molecular-microscopy.nl

Tinnefeld: <https://www.tu-braunschweig.de/pci/forschung/tinnefeld>

DEVELOPMENT OF REPLICABLE ARTIFICIAL METAL CONTAINING DNA BASES

Prof. Thomas Carell (LMU Munich, Department of Chemistry)

Prof. Herrmann E. Gaub (LMU Munich, Faculty of Physics)

DNA is currently used as the silicon of the nano world to construct complex two and three dimensional structures. The available technologies offer detailed control about the two and three dimensional structure of these DNA based nano assemblies. Despite this beautiful spatial control the so far available structures possess no function. On the way to two and three dimensional DNA nano objects with defined functional properties it is desired to create DNA bases that offer next to selective base pairing a functional property such as electrical conductivity, magnetism or catalytic capabilities. In the last research period we have started to create artificial replicable DNA bases that can be inserted into large oligonucleotide

structures using the polymerase chain reaction. These new DNA base pairs are not connected to each other via hydrogen bonds but metal coordination forces. The so-called metal base pairs complex a metal ion such as copper²⁺ or manganese³⁺ in the middle of the DNA helix. We could in previous work show that such metal base pairs can even be placed in a stacking situation so that the complexed metal ion formed a string of metal ions inside the DNA duplex structure. In the last year we could realize

a tremendous step forward in our desire to create replicable metal base pairs. We were able to show that a salicylic aldehyde nucleobase in the presence of ethylenediamine and the respective metal ion is recognized specifically by a salicylic aldehyde triphosphate present in solution. Cross base pairing with canonical Watson Crick base pairs was not observed. This discovery enabled us to design PCR base protocols that allow the replication of functional metal ion base pairs inside DNA.

C. Kaul, M. Müller, M. Wagner, S. Schneider, T. Carell: Reversible bond formation enables replication and amplification of a crosslinking salen complex as an orthogonal base pair; Nature Chem. 3, 794 - 800 (2011).

Carell: www.carellgroup.de

Gaub: www.biophysik.physik.uni-muenchen.de

ON-SURFACE SYNTHESIS OF TWO-DIMENSIONAL POLYMERS BY REVERSIBLE POLYCONDENSATION OF DIBORONIC ACIDS

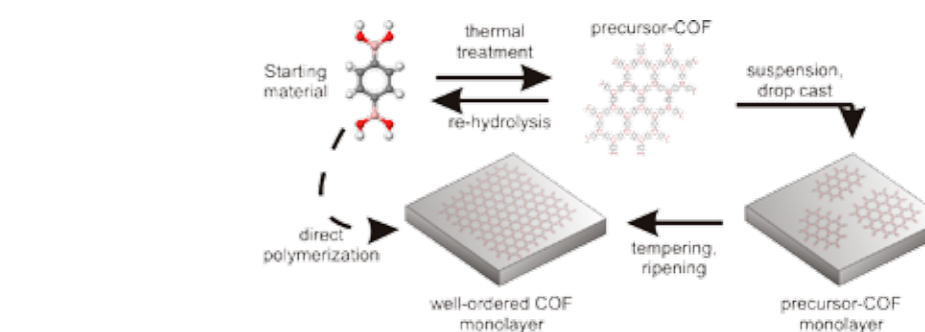
Prof. Thomas Bein (LMU Munich, Department of Chemistry)

Prof. Wolfgang Heckl, PD Dr. Markus Lackinger (TU Munich, Department of Physics, TUM School of Education & Deutsches Museum)

This project aims at the synthesis and characterization of surface-supported two-dimensional covalent organic frameworks (2D COFs). The pursued bottom-up approach utilizes polycondensation of boronic acids under slightly reversible reaction conditions. We demonstrate that the synthesis of 2D COFs is possible by two different straightforward methods: First, diboronic acid monomers are pre-polymerized by a mere thermal treatment into nanocrystalline precursor COFs. These are then suspended in a solvent and drop-cast onto the graphite substrate. In-situ STM imaging reveals the successful self-condensation into COFs, yet with a domain size below 10 nm. We also show that ripening by a thermal post-treatment under humid conditions yields extended domains of long-range ordered 2D COFs. While this multi-step preparation protocol allows fundamental studies of the polycondensation, a more straightforward preparation is desirable. In this respect, we demonstrate that direct polymerization from solution, i.e. without a preceding polymerization step, is also possible and results in 2D COFs with similar structural quality.

Both verification of the high thermal stability by an excessive thermal treatment and x-ray photoelectron spectroscopy (XPS) support the formation of covalent, rather than just supramolecular networks.

For both preparation methods the presence of water in polymerization or ripening steps is extremely important to maintain slightly reversible reaction conditions. Long-range ordered COFs are only obtained in the reversible regime, because only then faulty bonds that are unavoidable under normal growth conditions can be broken and reformed in the



Upper part: reaction scheme illustrating the two different preparation protocols. Both methods, i.e. direct polymerization of 1,4-benzenediboronic acid (dashed line) and deposition and subsequent growth of precursor-COFs, yield 2D COFs that are indistinguishable in Scanning Tunneling Microscopy (STM) topographs. Lower part: STM image with superimposed structural model of a 2D-COF resulting from the self-condensation of 1,4-benzenediboronic acid.

correct topology. For the successful preparation of 2D COFs, 1,4-benzenediboronic acid was chosen as a model compound. Yet, the newly developed approach can also be extended to various other diboronic acids. Thus novel 2D COFs can be tailored by appropriate design of diboronic acid building blocks.

J.F. Dienstmaier, A.M. Gigler, A.J. Goetz, P. Knochel, T. Bein, A. Lyapin, S. Reichmaier, W.M. Heckl, and M. Lackinger: Synthesis of Well-Ordered COF Monolayers: Surface Growth of Nanocrystalline Precursors vs. Direct On-Surface Polycondensation; ACS Nano 5, 9737 (2011).

Bein: <http://bein.cup.uni-muenchen.de>

Heckl: www.nano-science.de

Lackinger: www.2d-materials.com

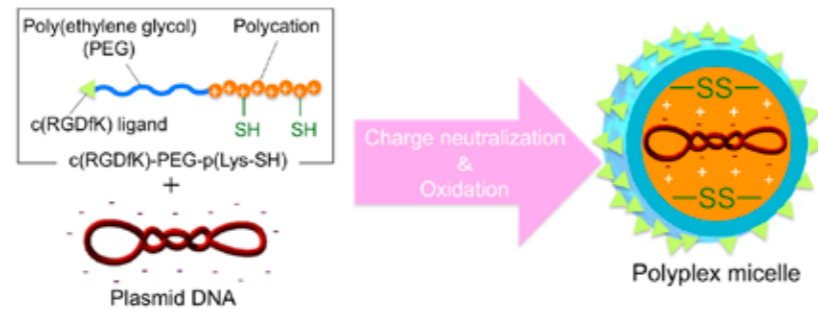
EFFECT OF INTEGRIN TARGETING AND PEG SHIELDING ON POLYPLEX MICELLE INTERNALIZATION STUDIED BY LIVE-CELL IMAGING

Dr. Nadia Ruthardt, Prof. Christoph Bräuchle (LMU Munich, Department of Chemistry)

α v β 3 and α v β 5 integrins are attractive target structures for cancer therapy as they are upregulated in tumor and tumor associated host cells and play a pivotal role for tumor growth and metastasis. Gene vectors such as polyplex micelles consisting of thiolated PEG-block-poly(lysine) copolymers complexed with plasmid DNA can be targeted to these specific integrins by equipment with a cyclic RGD peptide. In this study, we analyzed the effect of the RGD ligand on micelle endocytosis by comparing fluorescently labeled, targeted and untargeted micelles in live-cell imaging experiments with highly sensitive fluorescence microscopy and flow cytometry. Two micelle types with 12 kDa (PEG12) and 17 kDa (PEG17) PEG shell layers were examined to evaluate the influence of surface shielding on the internalization characteristics. Our results reveal three major effects: First, the RGD ligand accelerates the internalization of micelles into integrin expressing HeLa cells without changing the uptake pathway of the micelles. Both targeted as well as untargeted micelles are predominantly internalized

via clathrin mediated endocytosis. Second, the PEG shielding of micelles has an important effect on their targeting specificity. At high PEG shielding selective endocytosis of integrin targeted micelles occurs, whereas at low PEG shielding targeted and untargeted micelles show comparable internalization. In addition, PEG17 RGD(+) micelles induce the highest reporter gene expression. Third, our data demonstrate a

clear influence of the applied micelle dose on the internalization of integrin targeted micelles. We propose that PEG17 shielded micelles equipped with a cyclic RGD ligand are the favored system of choice for clinical therapy as they exhibit higher transgene expression, a higher specificity for integrin-dependent endocytosis compared to PEG12 shielded micelles, and are functional at low doses as well.



Schematic illustration of micelle formation between plasmid DNA and c(RGDfK)-PEG-p(Lys-SH)-polymer. Micelles are formed through polyanion complex formation between positively charged polylysine segments and negatively charged DNA. The charged micellar core is shielded by a PEG shell layer to which a cyclic RGD-peptide is attached as a targeting ligand. Covalent cross-linking of polylysine segments by disulfide bonds causes high stability of micelles.

F.M. Mickler, Y. Vachutinsky, M. Oba, K. Miyata, N. Nishiyama, K. Kataoka, C. Bräuchle, N. Ruthardt: Effect of integrin targeting and PEG shielding on polyplex micelle internalization studied by live-cell imaging; Journal of Controlled Release 156, 364-373 (2011).

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

Ruthardt: www.cup.uni-muenchen.de/dept/ch/pc/ruthardt.php

SENSITIZATION OF FULLERENES FOR PERFORMANCE ENHANCEMENT IN ORGANIC PHOTOVOLTAICS

Prof. Lukas Schmidt-Mende (University of Konstanz, Department of Physics)

PD Dr. Bert Nickel (LMU Munich, Faculty of Physics)

A common approach in organic solar cells is to stack two organic materials, one acting as an electron acceptor, and one as a donor. Here, the organic layers have to perform multiple tasks. First, sunlight has to be efficiently absorbed by the organic material, which, in the case of molecular materials, leads to the formation of bound excitons. Second, these excitons have to reach the heterojunction between the acceptor and donor layer by diffusion. At the interface, excitons can split up into electron and

hole. Finally, for continuous photocurrent generation, both carrier types have to be extracted efficiently by the contacts. The experimental challenge is that while some organic materials, such as strong dyes, show high absorption properties, others, such as fullerenes show superior transport properties. By a combination of experimental techniques including spectroscopy and x-ray scattering, we show that sensitization of the fullerene layer by a perylene dye allows remarkably higher power conversion efficiency. Steady state photolumi-

nescence, transient absorption and transient photocurrent decay studies suggest a fluorescence resonance energy transfer from the photo-excited dye to the fullerene as the origin for the improved power conversion efficiency. Here, it is possible to decouple the light absorption process in the dye from the charge transport in the fullerene resulting in an overall performance improvement. The presented sensitization method is proposed as a viable new concept for performance enhancement in organic photovoltaic devices.

H. Hesse, J. Weickert, C. Hundschell, Xinliang Feng, K. Müllen, B. Nickel, A. J. Mozer, L. Schmidt-Mende: Perylene sensitization of fullerenes for improved performance in organic photovoltaics; Advanced Energy Materials 1, 862-869 (2011).

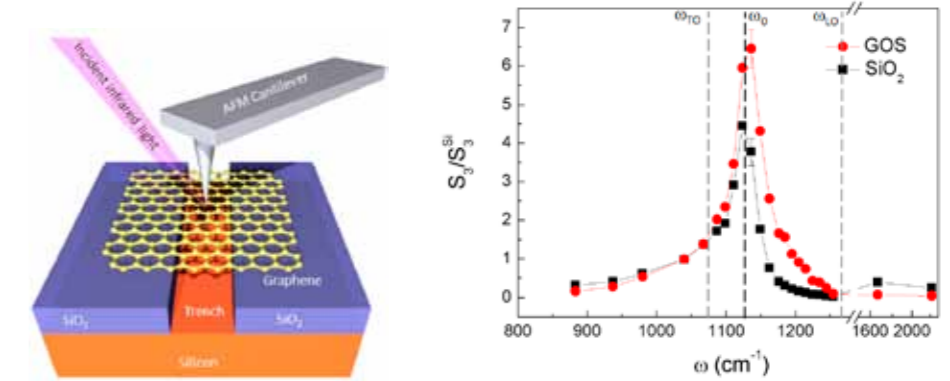
Schmidt-Mende: <http://cms.uni-konstanz.de/physik/schmidt-mende>

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

LOCAL INFRARED PROBING OF GRAPHENE

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

Surface plasmons are fundamental collective electron modes that enable functionalities at the intersection of nanophotonics and electronics. Dirac plasmons of graphene, which are the density waves of Dirac fermions, are predicted to enable both low loss and efficient wave localization up to mid-infrared frequencies. Theoretical studies show that the combination of tunability and low loss is highly appealing for implementation of nanophotonics, optoelectronics, and transformation optics based on Dirac plasmons. This study reports on the infrared spectroscopy and nanoscopy of monolayer graphene on SiO₂, a prototypical photonics material. The Dirac plasmon is probed by confining mid-infrared light at the apex of a metalized tip of radius as small as 10-20 nm. This dramatic localization of light yields a more than 100-fold increase in the in-plane component of the incident wavevector q compared to free-space propagation, a precondition for probing slowly propagating plasmons. At these high wavevectors the Dirac plasmon dramatically enhances the interaction of light with the SiO₂ substrate as demonstrated in the Figure. Detailed modeling of high- q , ultra-localized infrared spectra shows that this



Single layer graphene on SiO₂ probed by infrared-spectroscopic nanoscopy. The metal AFM tip serves to generate the 20nm-sized probe spot. The backscattering peak at the SiO₂ phonon frequency is strongly influenced by graphene. The enhancement is up to 400% near 1170 cm⁻¹.

effect is produced by concerted action of graphene electrons and SiO₂ phonons. The result affirms an underexploited capability of tip-based optical nanoscopy to probe collective charge modes far away

from $q=0$ of conventional optical spectroscopy, and also establishes graphene as a new medium supporting plasmonic effects that can be controlled by gate voltage.

S. Amarie and F. Keilmann: Broadband-infrared assessment of phonon resonance in scattering-type near-field microscopy; Phys. Rev. B 83, 45404 (2011).

Z. Fei, G.O. Andreev, W. Bao, L.M. Zhang, A.S. McLeod, C. Wang, M.K. Stewart, Z. Zhao, G. Dominguez, M.Thiemens, M.M. Fogler, M.J. Tauber, A.H. Castro-Neto, C.N. Lau, F. Keilmann, D.N. Basov: Infrared nanoscopy of Dirac plasmons at the graphene/SiO₂ interface; Nanoletters 11, 4701 (2011).

Keilmann: www.attoworld.de/SharedPages/People/KeilmannFritz/KeilmannFritz.html

THE JOSEPHSON PHOTOMULTIPLIER

Prof. Frank Wilhelm-Mauch (Saarland University, Faculty of Natural Sciences and Technology II)

It is generally believed that counting single microwave photons is impossible as there is no material with a work function in the microwave range. In a joint theory/experiment project with the group of Robert McDermott, University of Wisconsin, Frank Wilhelm's group has developed and demonstrated a photodetector for microwaves based on a Josephson junction, the Josephson Photomultiplier (JPM). Unlike microwave amplifiers which measure electric and magnetic fields, this device directly responds to the photon number. This device has been tested and in its first attempt reached efficiencies of 70%. Its quality was demonstrated the Hanbury-Brown Twiss effect, i.e., the temporal correlations of two-photon events in thermal vs. coherent states. The JPM is expected to greatly enhance the capability to fully characterize the quantum state of microwaves. Currently, the Wisconsin-CeNS team is working on detailed understanding of detector backaction and protocols for this type of tomography using multiplexed JPMs.

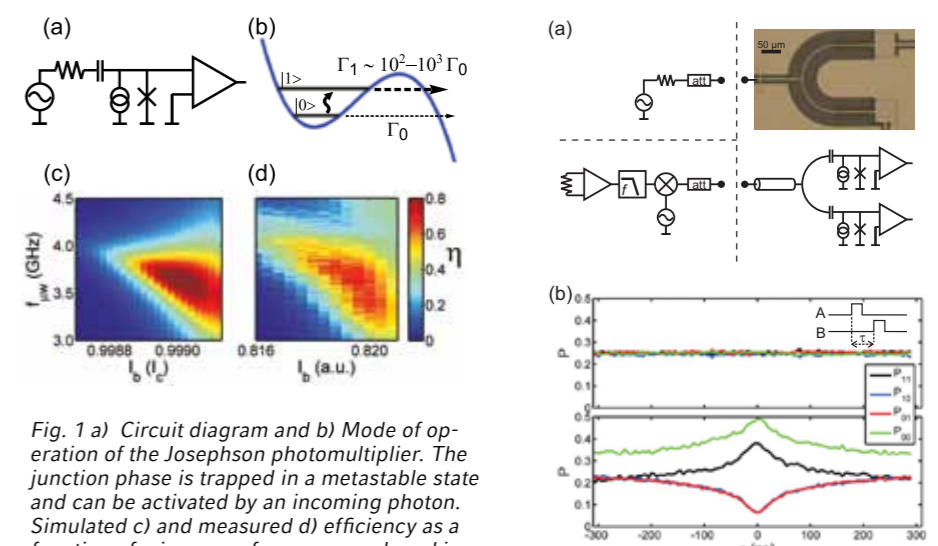


Fig. 1 a) Circuit diagram and b) Mode of operation of the Josephson photomultiplier. The junction phase is trapped in a metastable state and can be activated by an incoming photon. Simulated c) and measured d) efficiency as a function of microwave frequency and working point.

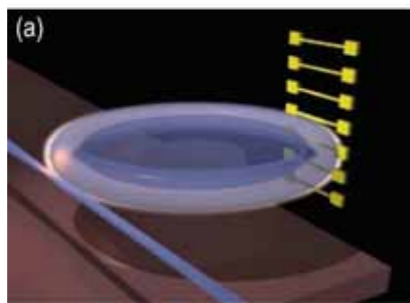
Y.-F. Che, D. Hover, S. Sendelbach, L. Maurer, S.T. Merkel, E.J. Pritchett, F.K. Wilhelm, and R. McDermott: Microwave photon counter based on Josephson Junctions; Phys. Rev. Lett. 107, 217401 (2011).

Fig. 2 a) Circuit diagram and micrograph of a 2-JPM sample. b) coincidence rates for coherent (top) and thermal (bottom) sources showing the Hanbury-Brown Twiss effect.

CAVITY OPTOMECHANICS AND COOLING NANOMECHANICAL OSCILLATORS USING MICRORESONATOR ENHANCED EVANESCENT NEAR-FIELD COUPLING

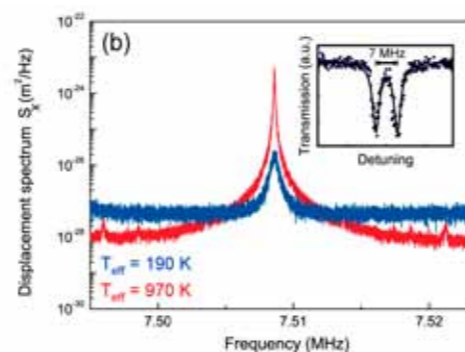
Dr. Eva M. Weig, Prof. Jörg P. Kotthaus (LMU Munich, Faculty of Physics)

Investigation of coupling phenomena between the vibrational modes of a nanomechanical resonator and photons confined in the optical mode of a high finesse cavity allows to study the influence of light induced backaction on the mechanical properties of the resonator. Cavity nano-optomechanics is suited to probe a variety of phenomena: Dynamical backaction can cool the thermal vibrations of the resonator towards its quantum ground state. Alternatively it can amplify its motion which can give rise to self-sustained oscillation. In a collaboration with Tobias Kippenberg (EPF Lausanne), a hybrid approach particularly favourable for cavity nano-optomechanics is chosen which independently optimizes both optical and mechanical properties of the system: The whispering gallery mode of an ultra-high finesse silica microtoroid is employed as an optical cavity. A high stress silicon nitride nanoresonator vibrating with an eigenfrequency of order 10 MHz is brought close to the toroid to enter the evanescent field of the optical mode. This gives rise to dispersive near field coupling with optomechanical coupling coefficients exceeding 200 MHz/nm, corresponding to a vacuum optomechanical coupling rate larger than 4 kHz. It is shown that both the mode spectrum as well as modal patterns of the Brownian motion of the nanoreso-



(a) Illustration of the hybrid cavity nano-optomechanical coupling scheme relying on the near field coupling of a nanomechanical SiN string (yellow) entering the evanescent field of the whispering gallery mode of a silica microtoroid cavity (blue). (b) Amplification and cooling of the nanomechanical resonator using three mode coupling. Starting from room temperature, the vibrational temperature could be considerably enhanced or reduced. The inset depicts the two employed optical cavity modes, consisting of a clockwise and counter-clockwise propagating mode doublet.

nator can be analyzed via the microtoroid transmission. Furthermore, radiation pressure backaction leads to cooling and amplification of the mechanical mode, giving rise to coherent self-oscillation at nano-Watt power levels. Finally, going beyond the standard two mode approach of cavity optomechanics where the coupling a single mechanical and a single optical mode is conveniently investigated, the feasibility of three mode coupling is demonstrated. To this end, two optical modes spaced by the resonance frequency of the nanomechanical



cal mode are employed, a scheme which allows for Raman-type amplification and cooling of the mechanical motion.

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DOPING FOR ORGANIC SOLAR CELLS

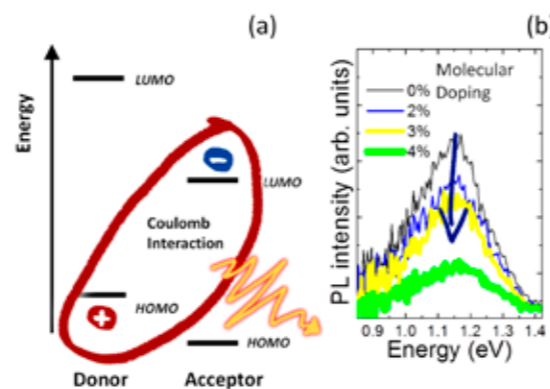
Dr. Enrico Da Como, Prof. Jochen Feldmann (LMU Munich, Faculty of Physics)

Organic solar cells prepared from conjugated polymers and fullerene molecules promise to be one of the most promising technologies for the realization of third-generation photovoltaic devices. This material system consists of a thin film in which the two components are mixed forming a heterojunction with interpenetrated domains at the nanoscale. This self-organized nanostructure ensures efficient exciton diffusion to the interface between the two materials, where a type II heterojunction is expected to split excitons and separate charges. The charge separation process involves a transient in which the charges are localized at the interface between the two materials (Fig.1a). The localization is a consequence of the low dielectric constant of these materials which entails strong Coulomb interactions and the energetic disorder typical of these amorphous materials. Electron and hole pairs at the heterojunction can form a charge transfer exciton which can be probed by near infrared photoluminescence (Fig.1b). Charge transfer excitons

represent a recombination channel limiting the overall power conversion efficiency and the suppression of this recombination channel is known to improve the performance of devices. In this work we have used molecular doping to fill localization states in the polymer. Such innovative approach proved to be effective for a more efficient separation of charge carriers at the interface as observed by the quenching of the charge transfer exciton photoluminescence (Fig.1b). These important results and concept are now implemented in prototype devices exhibiting improved power conversion efficiencies.

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a) Energy scheme for an organic type II junction showing the formation of charge transfer excitons at the interface. b) Quenching of charge transfer exciton photoluminescence upon doping of the conjugated polymer.

SINGLE MOLECULE FRET ON DNA ORIGAMI

Prof. Tim Liedl (LMU Munich, Faculty of Physics)

Prof. Philip Tinnefeld (TU Braunschweig, Institute of Physical and Theoretical Chemistry)

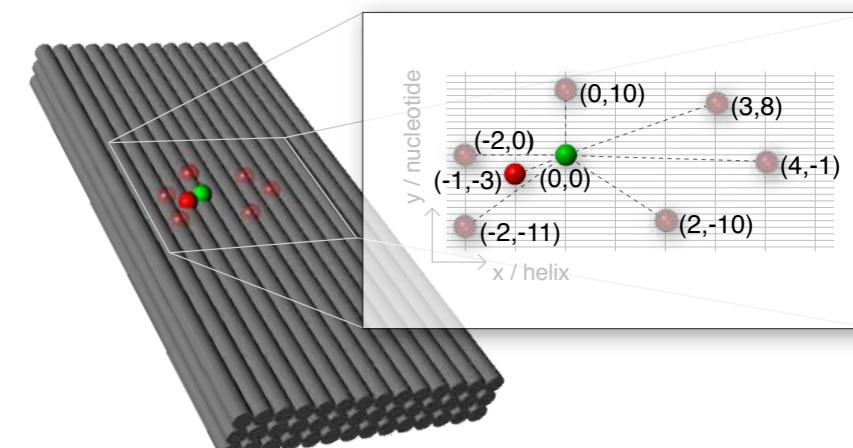
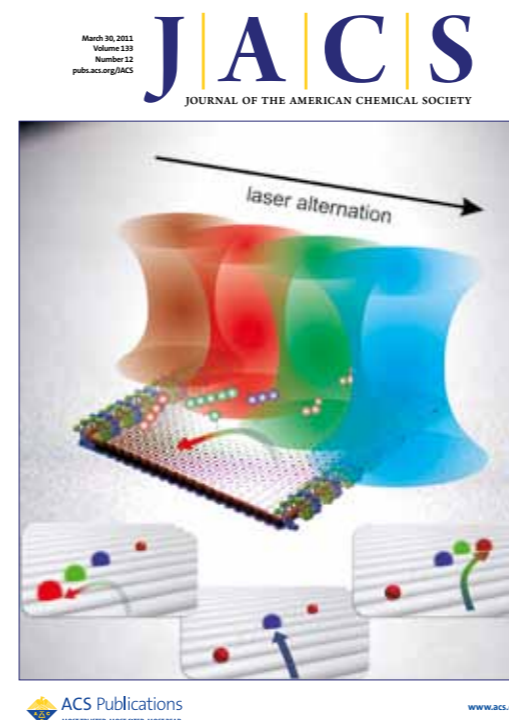
The DNA origami technique allows positioning arbitrary objects precisely with respect to each other on the nanometer scale. Therefore, a ~8 kbases long DNA strand is folded into predefined shapes by the aid of ~200 short synthetic oligonucleotides, termed 'staple strands'. The individual staple strands can be easily modified to incorporate biomolecules at specific sites within the nanostructure. Combining this method with single-molecule fluorescence techniques has led to several applications including a new reference system for fluorescence resonance energy transfer (FRET) and the switching of energy transfer pathways on the single-molecule level. Commonly double-stranded DNA has been used as a spacer molecule to inves-

tigate the distance dependence of FRET. Employing the DNA origami technique to build a "spectroscopic ruler" with varying distances between donor and acceptor dye has several advantages. The designed DNA origami blocks have a superior stiffness and allow placing the dye molecules all oriented in the same direction. In contrast to dsDNA, for the DNA origami block, the Förster radius could directly be obtained based on single-molecule FRET measurements.

Guided by the vision of constructing complex energy transfer networks by self-assembly, a rectangular DNA origami was employed as a molecular breadboard to precisely position individual fluorophores (see figure). In this artificial system, the

path of energy transfer can be manipulated on the nanoscale. With the aid of a 'green' jumper dye, the light could be guided from the 'blue' input dye to either of two output dyes, 'red' or 'IR'. The analysis was performed using a single-molecule four-color FRET approach with alternating laser excitation.

The feasibility of single-molecule FRET experiments in these DNA objects is an exemplary demonstration of the unique positioning precision of the DNA origami technique, since the energy transfer efficiency is sensitive to distance changes in the sub-nanometer range.



DNA origami is used as a molecular breadboard to arrange fluorescent dyes on the nanoscale. Left: Energy transfer paths can be manipulated by an intermediate jumper dye, which is inserted at different positions to direct the excited-state energy to two alternative output dyes, as revealed by single-molecule four-color FRET. The image is featured on the front cover of JACS, issue 12, 2011. Right: Energy transfer between pairs of fluorescent dyes can be analyzed on a rigid ruler that is composed of multiple parallel DNA strands.

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Tinnefeld: <https://www.tu-braunschweig.de/pci/forschung/tinnefeld/people/tinnefeld>

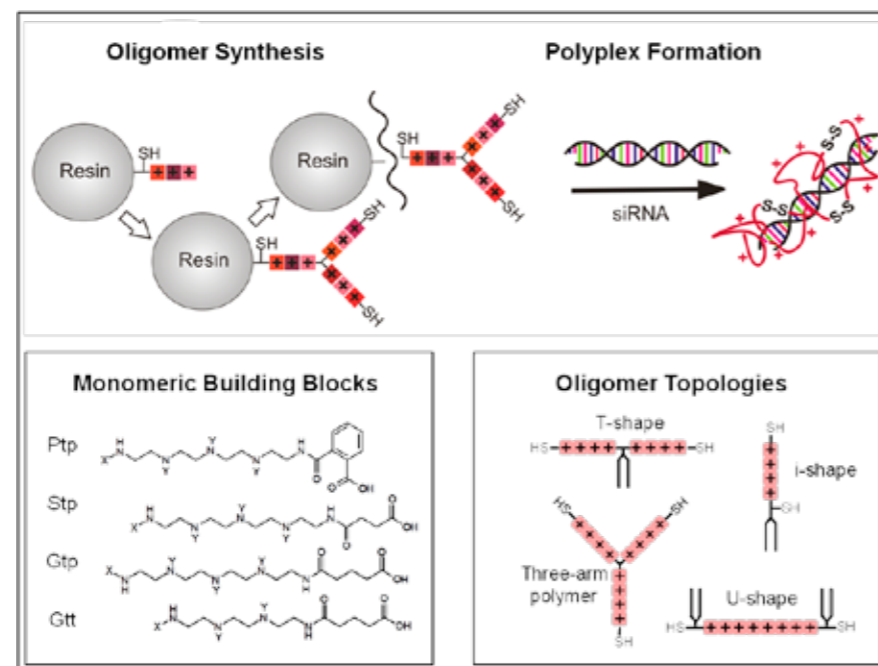
PRECISE SEQUENCE-DEFINED MULTIFUNCTIONAL POLYMERIC CARRIERS FOR DNA AND RNA THERAPY

Prof. Ernst Wagner (LMU, Department of Pharmacy)

Prof. Christoph Bräuchle (LMU, Department of Chemistry)

Prof. Joachim Rädler (LMU, Faculty of Physics)

Therapeutic delivery of siRNA or pDNA presents encouraging treatment options for cancer and other indications. The different tasks in extra- and intra-cellular delivery of the therapeutic nucleic acids request for dynamic carriers. Like natural viruses, such carriers have to be bioresponsive, sensing their environment and facilitating the next delivery step (Wagner 2011). Functional modifications include PEG shielding and ligands for receptor targeting, or endosome-destabilizing agents (Lächelt, 2011). The necessity of generating sophisticated multifunctional structures presents an interesting task for modern synthetic and supramolecular chemistry (Troiber 2011). A library of >300 monodisperse sequence-defined cationic polymers was established by using novel artificial oligoamino acids and solid phase supported synthesis (Schaffert 2011a,b). Screening for pDNA and siRNA carriers, clear structure-activity relationships were obtained for the various monomer building blocks and molecular shapes of cationic oligomers (see Figure 1). Three-armed structures and lipidic diacyl-modified structures with i-shape, T-shape, U-shape configuration were identified as core structures with low toxicity and high in vitro and in vivo efficacy in pDNA or siRNA transfer. Selected nanosystems were decorated with shielding PEG and cell targeting ligands. These functions were integrated into the cationic carrier either by precise solid phase synthesis, or by click-conjugation to siRNA (Dohmen 2011). Favor-



Novel precise oligomers as efficient carriers for pDNA and siRNA.

able biophysical characteristics (group of Joachim Rädler) and receptor-enhanced uptake (Christoph Bräuchle) were obtained. In sum, based on solid phase supported synthesis, precise peptide-like new carriers with low toxicity were synthesized displaying successful in vitro and in vivo gene transfer and gene knockdown, including also siRNA dependent antitumor effects in mouse models.

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

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

Rädler: <http://softmatter.physik.lmu.de>

RELAXATION OF HOT ELECTRONS IN A DEGENERATE TWO-DIMENSIONAL ELECTRON SYSTEM: TRANSITION TO ONE-DIMENSIONAL SCATTERING

PD Dr. Stefan Ludwig (LMU Munich, Faculty of Physics)

Prof. Stefan Kehrein (Göttingen University, Faculty of Physics)

The energy relaxation channels of hot electrons far from thermal equilibrium in a degenerate two-dimensional electron system are investigated in transport experiments in a mesoscopic three-terminal device. This study is based on using the electronic Venturi effect as shown in Fig. 1 and described in Ref. [1]. A transition from two dimensions at zero magnetic field to quasi-one-dimensional scattering of the hot electrons in a strong magnetic field is observed. In the two-dimensional case, electron-electron scattering is the dominant relaxation mechanism, while the emission of optical phonons becomes more and more important as the magnetic field is increased. The observation of up to 11 optical phonons emitted per hot electron allows us to determine the onset energy of longitudinal-optical phonons in GaAs at cryogenic temperatures with a high precision to be 36.0 meV. Numerical calculations of electron-electron scattering [Fig. 2(a)] and the emission of optical phonons [Fig. 2(b)] underline our interpretation in terms of a transition to one-dimensional dynamics.

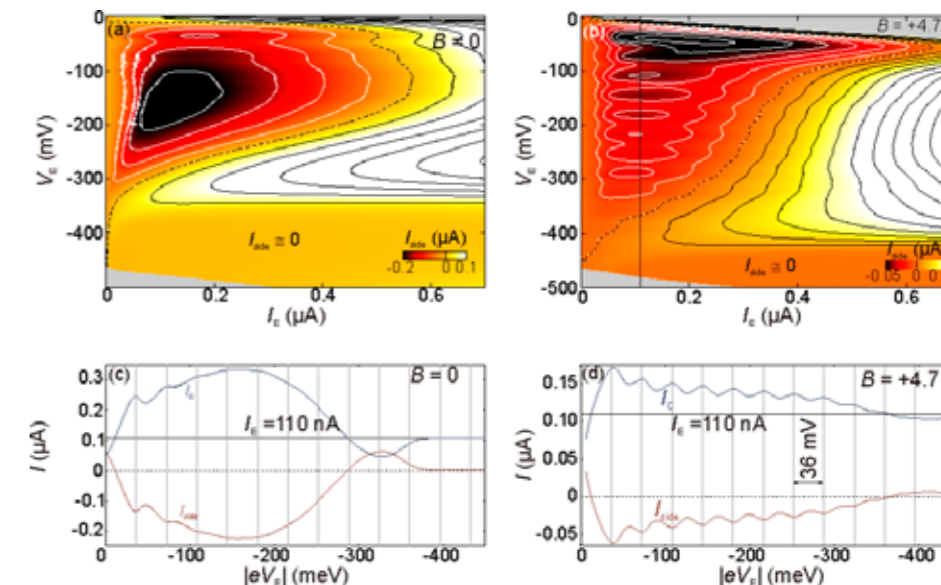


Fig. 1: (a),(b) Side current versus total current and emitter bias voltage for $B = 0$ and $B = 4.7$ T. The area of amplification ($I_{side} < 0$) is enclosed by dashed lines. (c), (d) Slices at a total current of 110 nA. The oscillations in (d) are due to the emission of optical phonons, which is strongly enhanced at high magnetic field.

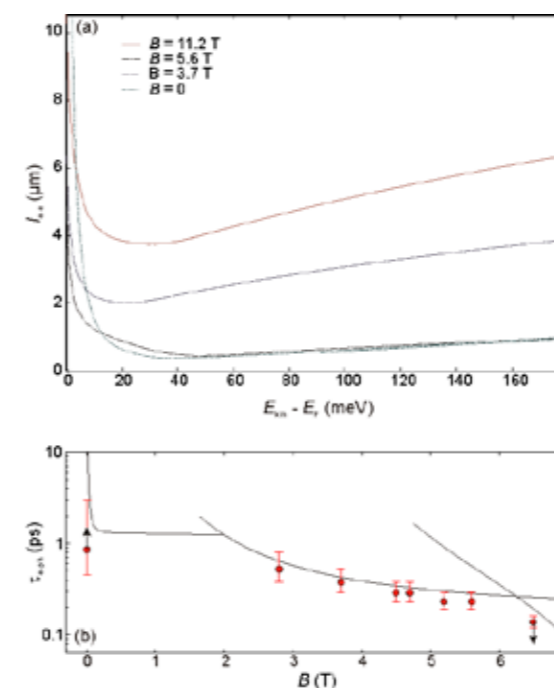


Fig. 2 (a) Numerically calculated electron-electron scattering lengths as a function of excess kinetic energy for different magnetic fields. Data like those shown in Fig. 1 are consistent with these scattering length results. (b) Red disks: Electron-optical phonon scattering times estimated from experimental data. Solid lines: results of numerical calculations, describing transitions between different modes. The total scattering rate is a sum of all contributions, which is consistent with the fact that all experimental data points lie below the solid lines.

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Kehrein: www.uni-goettingen.de/en/307176.html

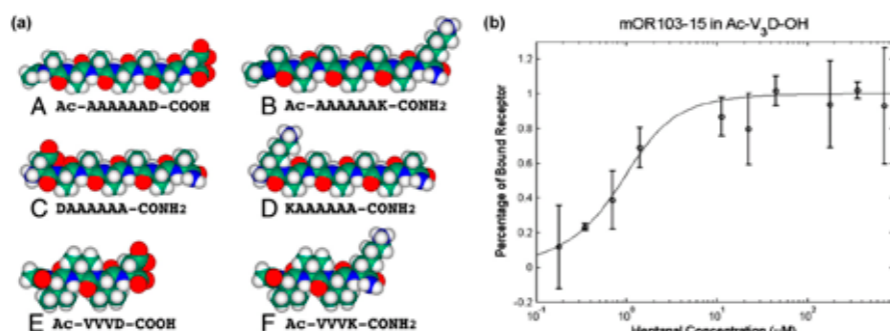
QUANTIFYING THE BINDING TO GPCR MEMBRANE RECEPTORS

Prof. Dieter Braun (LMU Munich, Faculty of Physics)

Dr. Philipp Baaske, Dr. Stefan Duhr (NanoTemper Technologies GmbH)

In a collaboration with Shuguang Zhang, MIT, we demonstrated that label-free thermophoresis, using the intrinsic fluorescence of tryptophane, is sensitive enough to measure the binding of small molecules to human G-Protein coupled receptors. These receptors are one of the major targets for pharmaceuticals and the quantification of binding was previously only possible in cell-based assays or by labeling the binder - both are not highly flexible or powerful approaches. To show that the binding could be quantified with the highly sensitive microscale thermophoresis method, is another breakthrough of the CeNS startup company NanoTemper which is commercializing the approach.

In general, two major bottlenecks in elucidating the structure and function of membrane proteins are the difficulty of producing large quantities of functional receptors, and stabilizing them for a sufficient period of time. Selecting the right surfactant is thus crucial. Here we report using peptide surfactants in commercial



Measurement of binding to membrane proteins. (a) Membrane proteins are solubilized in membrane rafts made from peptides. (b) Binding to the native target molecule is confirmed by label-free microscale thermophoresis.

Escherichia coli cell-free systems to rapidly produce milligram quantities of soluble G protein-coupled receptors (GPCRs). These include the human formylpeptide receptor, human trace amine-associated receptor, and two olfactory receptors. Immunoaffinity purification yielded receptors at >90% purity. Secondary structure analysis using circular dichro-

ism indicated that the purified receptors were properly folded. Microscale thermophoresis, a novel detection technique that uses thermal gradients, showed that these receptors bound their ligands. The structural and ligand-binding results from cellfree produced proteins were comparable to those expressed and purified from HEK293 cells.

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Braun: www.biosystems.physik.lmu.de

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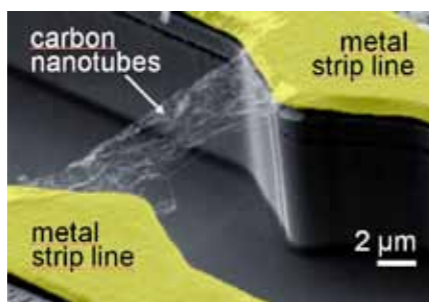
TIME-RESOLVED PHOTOCURRENT DYNAMICS IN CARBON NANOTUBES

Prof. Alexander Holleitner (TU Munich, Walter Schottky Institute and Department of Physics)

Dipl.-Ing. Stephan Manus (LMU Munich, Faculty of Physics)

Carbon nanotubes are promising building blocks for future optoelectronic circuits. However, so far there were no electronic methods to analyze the picosecond optoelectronic dynamics of such nanotubes. In this project, coplanar stripline circuits were introduced to resolve the ultrafast photocurrent dynamics of freely suspended carbon nanotubes in the time-domain. By applying an on-chip pump-probe laser spectroscopy it was demonstrated that carbon nanotubes, contacted by metal electrodes, exhibit a picosecond photocurrent response. A combination of an optically induced ultrafast displacement current, transport of photo-generated charge-carriers at the Fermi

velocity to the electrodes, and interband charge-carrier recombination processes were found to dominate the ultrafast photocurrent of the carbon nanotubes.



A carbon nanotube network is contacted by two coplanar metal strip lines.

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Manus: www.nano.physik.uni-muenchen.de

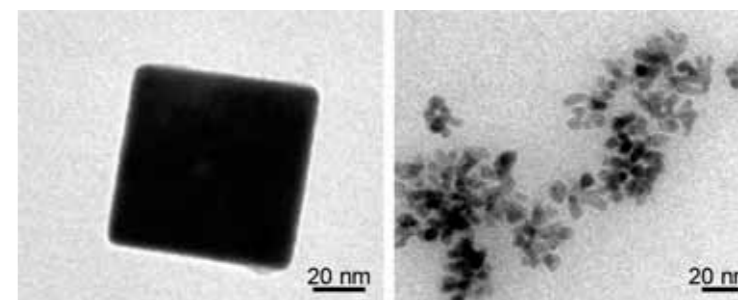
PYRITE NANOCRYSTALS: A PROMISING MATERIAL FOR LARGE-SCALE PHOTOVOLTAICS

Dr. Frank Jäckel, Prof. Jochen Feldmann (LMU Munich, Faculty of Physics)

Prof. Andrey L. Rogach (City University of Hong Kong, Department of Physics and Materials Science)

Semiconductor nanocrystals are recently receiving considerable interest for photovoltaic applications. This is motivated by the hope to combine the advantages of inorganic and organic materials, respectively. These include high mobilities, small exciton binding energies, and the possibility of solution processing. However, in order to be applicable for photovoltaics on the large-scale such nanocrystals need to be made from earth-abundant and non-toxic materials. One such promising candidate material is pyrite, i.e. iron sulfide (FeS₂). In this project, for the first time, a shape-controlled, scalable synthesis of phase pure pyrite nanocrystals has been achieved. Depending on the ini-

tial precursor concentrations either pyrite nanodendrites or nanocubes can be prepared. In solution, the nanocrystals can be reversibly self-assembled which leads to an increased absorption in the red and near-infrared spectral region due to interactions between the closed-packed nanocrystals. This increased absorption, which is also



Transmission electron micrographs of a pyrite nanocube (left) and pyrite nanodendrites (right).

found in solid thin films of the nanocrystals, is beneficial for potential applications in photovoltaic cells, which are currently under investigation.

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Rogach: <https://portal.cityu.edu.hk/bbcswebdav/users/arogach/Homepage/Prof%20Andrey%20Rogach.htm>

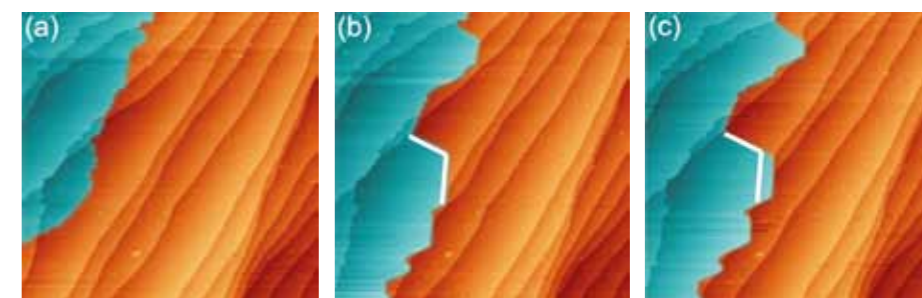
IN-SITU MONITORING OF GRAPHENE GROWTH BY STM

Prof. Joost Winterlin (LMU Munich, Department of Chemistry)

One of the unique properties of graphene is its extremely high charge carrier mobility which may be used in future graphene-based, ultrafast electronic devices. However, there is currently no method for graphene synthesis that can be up-scaled to industrial processes and that provides, at the same time, graphene with a high enough quality for devices. An important up-scalable synthesis method is chemical vapor deposition (CVD) of hydrocarbon molecules on metal surfaces. Very large graphene sheets have already been made by this technique, but the single-crystalline areas within the sheets are still relatively small, and the charge carrier mobilities of these samples are accordingly modest. In this project scanning tunneling microscopy (STM) has been used to directly monitor the growth of graphene on metal surfaces and possibly find ways of better controlling the growth. These are challenging experiments because the CVD requires very high temperatures where ordinary STM equipment cannot be used. A special high-temperature STM that can operate at up to 1000 °C has been used for these experiments. It was achieved to record movies showing the growth of graphene sheets

in situ, under the conditions of the CVD. An unexpected finding was that the metal surface, in this case the (0001)-oriented surface of a ruthenium single crystal, is not static. The metal surface fluctuates, and its morphology rearranges in a complex way as it is overgrown by the graphene sheet. The data show how the metal atoms rearrange when the graphene sheet crosses atomic steps of the ruthenium surface, the most common defects on metal surfaces. It was found that the effects can be con-

trolled to some extent: At relatively high temperatures and low pressures of the hydrocarbon molecules used for the CVD, the atomically flat terraces of the ruthenium surface start to grow, together with the graphene sheet. This effect can be explained by subtle chemical interactions between the graphene and the metal. It can lead to very large, single-crystalline graphene areas, possibly an important ingredient for improving the metal-based synthesis route to graphene.



Three frames from an STM movie, recorded during CVD of ethylene on a ruthenium surface at 665 °C. A graphene monolayer (blue) grows on the ruthenium single crystal surface (orange). In the first frame the graphene layer moves across the atomic steps of the metal. Then the ethylene pressure was lowered, and the two following frames show the beginning of a different growth mode. Atomically flat ruthenium terraces start to grow (see white marks), together with the graphene layer. At yet higher temperatures very large, single-crystal graphene domains can be obtained in this way.

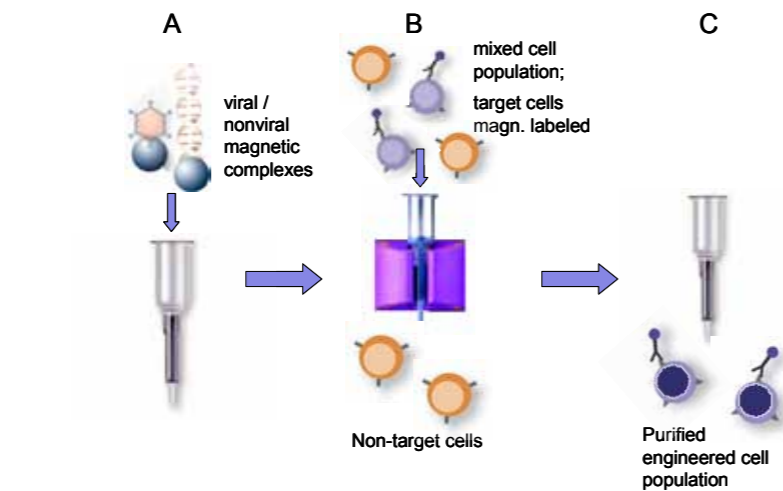
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Winterlin: <http://www.cup.uni-muenchen.de/pc/winterlin/>

COMBINED ISOLATION AND STABLE NONVIRAL TRANSFECTION OF HEMATOPOIETIC CELLS – A NOVEL PLATFORM TECHNOLOGY FOR EX VIVO HEMATOPOIETIC STEM CELL GENE THERAPY

Prof. Christian Plank (TU Munich & University Hospital Rechts der Isar, Institute of Experimental Oncology)

Research applications and cell therapies involving genetically modified cells require reliable, standardized, and cost effective methods for cell manipulation. The feasibility of using genetically engineered cells for therapy in humans has been demonstrated using various cell types, for example tumor cells or stem cells. Actual or potential applications are as diverse as immune gene therapy for the treatment of cancer, of hereditary diseases, and many applications in regenerative medicine. Prof. Plank's lab provided a novel methodology for performing genetic modification and cell isolation in a single standardized procedure, the so called "Magselectofection". It integrates "Magnetofection" and cell "Selection": Gene vectors associated with magnetic nanoparticles are transferred into target cells ("Magnetofection") while being passaged and separated through a high gradient magnetic field cell separation column ("Selection"). The gradient magnetic field is used to rapidly



concentrate and internalize the full applied vector dose into the target cells. Thereby the integrated method yields excellent target cell purity and recovery. Upscaling in an automated cell separation

device is feasible. Once optimized, validated, and approved, the method could facilitate future clinical applications of genetically engineered cells.

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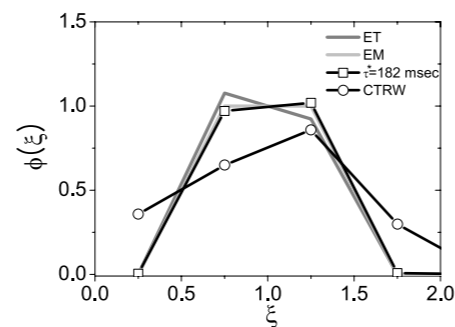
Plank: <http://plank-lab.net/>

NON-ERGODICITY IN SINGLE PARTICLE TRAJECTORIES

Prof. Ralf Metzler (University of Potsdam, Institute of Physics and Astronomy & Physics Department, Tampere University of Technology, Finland)

Modern tracking techniques provide single trajectory information of tracers in complex environments, ranging from human motion patterns or movement ecology of animals in the macroscopic world down to the on/off traces of q-dots or the motion of individual tracers in living cells. In a large variety of systems anomalous diffusion is revealed, i.e., the deviation from the typical linear time evolution of the mean squared displacement known from Brownian motion. It turns out that under conditions of anomalous diffusion even long time averages behave differently from the associated ensemble average. In some cases the time averages remain random variables, even when the measurement time is increased arbitrarily. Our most recent results show that even for completely ergodic

processes the relaxation behaviour under confinement differs between ensemble and time averages. This immediately poses the question how individual time series measured in experiment are interpreted physically. We studied such behaviour for individual time traces of lipid granules in yeast cells, finding a pronounced violation of ergodicity. A detailed analysis shows excellent agreement with continuous time random walk processes. In particular we also show that the amplitude scatter between the mean squared displacements of individual trajectories matches this random walk model (SEE FIGURE). We study the non-ergodic behaviour of time averages theoretically and compare the different standard classes of anomalous diffusion theories.



Distribution of the relative amplitude scatter of the time averaged mean squared displacement measured for lipid granules in living yeast cells. The grey lines show the measured profile. The black lines show the predictions of a continuous time random walk with and without waiting time cutoff (Jeon et al, *Phys Rev Lett* 106, 048103 (2011)).

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Metzler: www.agnd.uni-potsdam.de/~metz/

MEASURING MELTING CURVES USING THERMOPHORESIS

Prof. Dieter Braun (LMU Munich, Faculty of Physics)

Dr. Philipp Baaske, Dr. Stefan Duhr (NanoTemper Technologies GmbH)

Measuring parameters such as stability and conformation of biomolecules, especially of nucleic acids, is important in the field of biology, medical diagnostics and biotechnology. We present a thermophoretic method to analyse the conformation and thermal stability of nucleic acids. It relies on the directed movement of molecules in a temperature gradient that depends on surface characteristics of the molecule, such as size, charge and hydrophobicity. By measuring thermophoresis of nucleic acids over temperature, we find clear melting transitions and resolve intermediate conformational states. These intermediate

states are indicated by an additional peak in the thermophoretic signal preceding most melting transitions. We analysed single nucleotide polymorphisms, DNA modifications, conformational states of DNA hairpins and microRNA duplexes. The method is validated successfully against calculated melting temperatures and UV absorbance measurements. Interestingly, the methylation of DNA is detected by the thermopho-

retic amplitude even if it does not affect the melting temperature. In the described setup, thermophoresis is measured all-optical in a simple setup using a reproducible capillary format with only 250 nl sample consumption. The thermophoretic analysis of nucleic acids shows the technique's versatility for the investigation of nucleic acids relevant in cellular processes like RNA interference or gene silencing.

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Baaske, Duhr: www.nanotemper-technologies.com

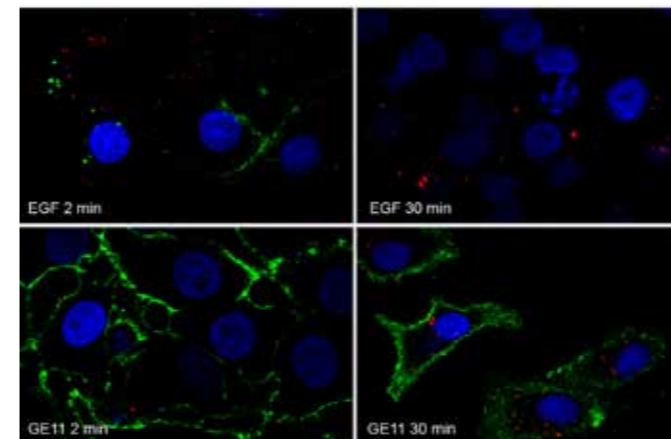
A FULLY SYNTHETIC, EGFR-TARGETED GENE TRANSFER SYSTEM AVOIDING RECEPTOR ACTIVATION

PD Dr. Manfred Ogris, Prof. Ernst Wagner (LMU Munich, Department of Pharmacy)

Delivery of therapeutically active nucleic acids into target cells requires a delivery system, either based on recombinant viruses, or as a potentially safer alternative, synthetic carrier molecules. As a synthetic carrier, polycations are utilized to condense nucleic acid by electrostatic interaction with their negatively charged phosphate backbone leading to formation of virus sized particles, termed polyplexes. Specificity and efficien-

cy of macromolecular drug delivery can be boosted by utilizing cell binding and internalizing ligands. The epidermal growth factor receptor (EGFR) being frequently upregulated in tumors is a valid target for delivery of macromolecular drugs. Its natural ligand, EGF, binds to EGFR with high affinity, but also activates the receptor leading to downstream-signaling resulting in enhanced cell proliferation. In this study, recombinant EGF was replaced by synthetic, EGFR binding peptides. Peptides were covalently coupled via a hetero-bifunctional polyethylene-glycol (PEG) linker to linear polyethyleni-

mine, the currently most effective polycationic gene delivery reagent. With EGF and EGF derived peptides as ligand, targeted gene delivery was accompanied by EGFR activation (see fig 1) which results in phosphorylation of downstream signals Akt and Erk. In contrast, the peptide GE11 enabled EGFR targeted delivery in the absence of EGFR activation. Further studies in collaboration with the Erasmus Medical Center Rotterdam (The Netherlands) showed the beneficial effect of EGFR targeting with GE11 peptide after local injection into an orthotopic model of prostate cancer. The concept of fully synthetic nucleic acid targeting allows a more convenient carrier synthesis, but will also simplify processes in the further preclinical development of such targeted carriers.



Human liver cancer cells (HUH7) were incubated with fluorescently labeled polyplexes (red) for either 2 minutes (left) or 30 minutes (right). Polyplexes were either targeted with recombinant EGF (top row) or peptide GE11 (bottom row). Thereafter, cells were fixed and the EGFR stained on the cell surface with an antibody (green); cell nuclei are stained with DAPI (blue). Already at 2 minutes, EGF induced EGFR clustering and internalization due to induction of macropinocytosis, which is more pronounced after 30 min. In contrast, GE11 targeting avoids this activation, but allows similar polyplex internalization after prolonged incubation.

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Ogris: www.cup.uni-muenchen.de/pb/aks/ewagner/m_ogris.htm

Wagner: www.cup.uni-muenchen.de/pb/aks/ewagner/e_wagner.htm

MANIPULATION OF DIPOLAR EXCITONS IN COUPLED QUANTUM WELLS

Prof. Jörg P. Kotthaus (LMU Munich, Faculty of Physics)

Prof. Alexander W. Holleitner (TU Munich, Walter Schottky Institute and Department of Physics)

The growing interest in the field of optics on semiconductor heterostructures is motivated not only by newly opened prospects for fundamental studies of the quantum nature of excitons, such as potential Bose-Einstein condensation of excitons in coupled quantum wells, but also by possible applications. As optics becomes a major networking media in the communications industry, the demand for devices that could easily merge optical signals and semiconductor electronics is rapidly increasing. A prerequisite for optoelectronics based on optical excitations in semiconductor systems is a reliable technique enabling a control over lifetime and number of such excitations. By using a coupled quantum well system, the lifetime of an elementary optical excitation, an exciton, can be adequately manipulated by an electric Stark field.

Yet the exciton density cannot be easily controlled since, at larger densities, the dynamics of photogenerated carriers usually prevents exciton formation and confinement. This practical limitation could be overcome by applying an external confining field. It is shown experimentally that formation and trapping of dipolar excitons in the illumination spot can be dramatically enhanced by a quantizing magnetic field. This method allows enhancement of the exciton densities up to $\sim 10^{11} \text{ cm}^{-2}$ demonstrating very high trapping efficiency [1]. The single carrier dynamics plays also a crucial role in the physics of electrostatically defined traps, in which the potential energy of dipolar excitons is voltage-tuned to be lower inside the trap than in the surrounding environment (Fig. 1a). In excitonic antitraps, the charge-carrier dynamics can be tailored in a way that the overall photon emission is surpris-

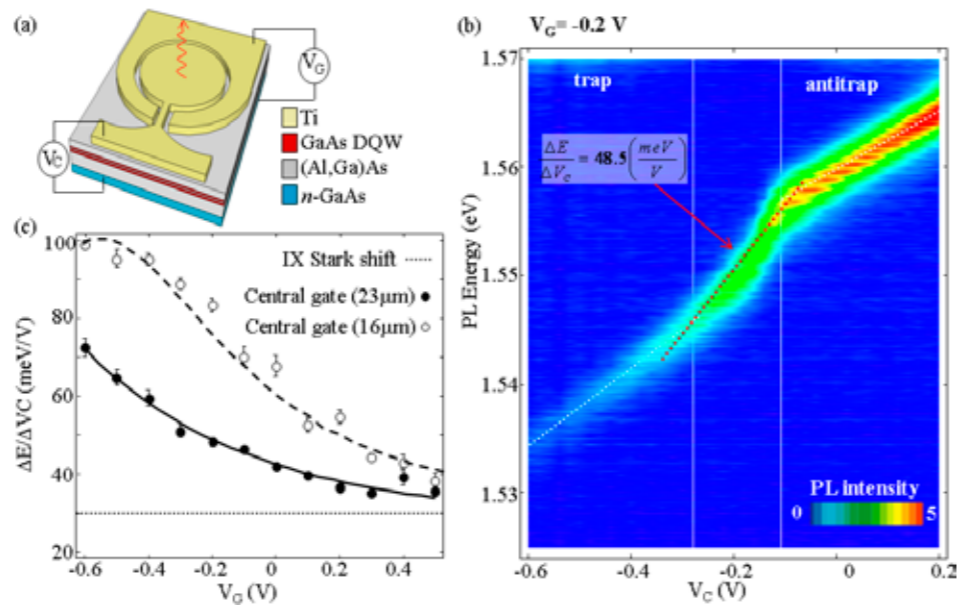


Fig. 1. (a) Sketch of the trapping/antitrapping devices. Yellow: the central and the surrounding guard gates. (b) PL energy of dipolar excitons as function of voltage on the central gate. Vertical lines mark the transition of the trap-antitrap configuration. Dotted white lines highlight the linear Stark shift in the trap (left) and antitrap (right) configuration. The dotted red line represents a linear fit for the transition region. (c) Energy tuning ratio E/VC from the linear fit in the transition region vs. guard gate voltages, measured for 2 devices. Dotted horizontal line marks the slope of the Stark shift in the deep trap.

ingly and efficiently enhanced compared to a trap configuration. Introducing the concept of an excitonic antitrap allows the realization of efficient nanoscale electro-optical devices based on the gate-voltage tuneable photoluminescence (PL) from a double quantum well [2]. It is demonstrated that large emission energy modulation ratio is achieved with a small ($< 5\%$) variation of emission intensity (Fig. 1b). Thanks to the nanofabrication of the device, the energy tuning ratio is enhanced over 3 times compared to the bare Stark shift slope $\sim 30 \text{ meV/V}$ (Fig. 1c). These findings both open and expand opportunities for nanoscale photonic devices. To study the correlated behavior of dipolar

excitons trapped in quasi-equilibrium at low temperatures also new electrostatic trap designs were developed in which local optical generation of excitons is spatially separated from the trap. This enables to collect precooled excitons in a trap outside the laser focus and study their emission behavior as a function of density, temperature and other environmental parameters [3]. These experiments aim at an increased fundamental understanding of excitonic interactions and possible phase transitions of such interacting bosons.

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Kotthaus: www.nano.physik.uni-muenchen.de

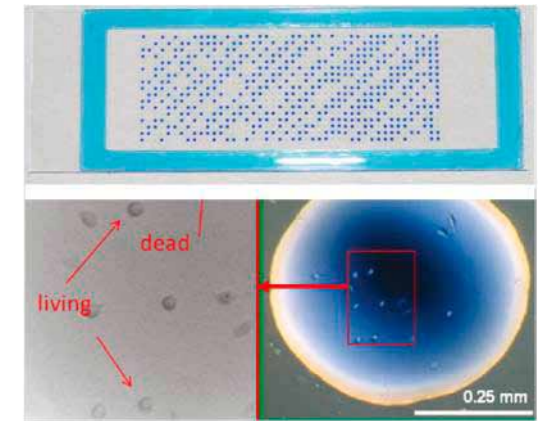
Holleitner: www.nanophonics.de

"ONE CELL – ONE WELL": INKJET PRINTING OF SINGLE CELL MICROARRAYS

Prof. Ulrich S. Schubert (Friedrich-Schiller-Universität Jena, Faculty of Chemical and Earth Sciences)

High-throughput single-cell measurements of cellular responses are of great importance for a variety of applications, including drug and toxicity testing and basic cell biology, with single cell biochip applications emerging as a rapidly expanding field of research. Moreover, single-cell analysis approaches have become clinically important for cytotoxicity assays, and the demand for more practical ways of preparing arrays of single living cells will increase with the advent of the emerging field of cellomics. Motivated by this, we have developed a facile new approach that allows for high density arrays of isolated single cell cultures to be prepared on unmodified surfaces. While drop-on-demand technologies, like inkjet printing, allow for spatially arrayed sub-nanoliter quantities of cell suspensions to be dispensed as standing arrays of individual nanobioreactors, the inherently high surface-to-volume ratio makes water evaporation a real problem, and the application of this challenging; by supplementing the process with a oxygen-permeable mineral

oil layer, hundreds of independent droplets containing living cells can be generated on a single slide, allowing for statistically significant quantities of single cells to be prepared in a spatially addressable way. A new approach to prepare arrays of sessile droplets of living single cell cultures using a liquid hydrophobic barrier prevents the samples from dehydrating, and allows for spatially addressable arrays for statistical quantitative single cell studies. By carefully advancing a thin layer of mineral oil on the substrate over the droplets during the printing, dehydration of the droplets can be prevented, and the vitality of the cells can be maintained. 1,200 spots are readily printable on a single glass slide, providing between 400 and 600 isolated cells in a single array. This approach offers a facile, flexible route to the preparation of a large number of isolated single cell experiments, independently addressable at predefined locations



Spatially addressable wells: layout of cellular well plate after deposition of trypan blue to selected wells (top), dark wells with viability staining, unselected wells are colorless and intact. Bottom right: Micrograph of an individual spot with viability staining containing cells. Bottom left: Micrograph of the individual cells after 7 h of incubation.

on the surface. Currently, this methodology is further explored in cooperation with the group of Joachim Rädler.

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Schubert: www.schubert-group.de

KONDO EXCITON: QUANTUM QUENCH OF KONDO CORRELATIONS IN OPTICAL ABSORPTION

Prof. Jan von Delft (LMU Munich, Faculty of Physics)

One of the most celebrated phenomena in many-body physics is the Kondo effect, which describes how the tiny magnetic field associated with the spin of a single localized spin is screened by delocalized spins of an electron reservoir. The present papers report a theoretical proposal for how to optically detect signatures of Kondo correlations in self-organized quantum dots, and a subsequent experimental realization thereof.

The studies show that, remarkably, the interactions that give rise to the Kondo effect can be switched off by the absorption of a single photon, and yield detailed insights into the subsequent decay of Kondo correlations. The experiment studies the

absorption lineshape of photons incident on a quantum dot that was designed to be quite strongly coupled to the delocalized electrons in the surrounding material. Moreover, the quantum dot was tuned such that its absorption properties are dominated by only a single electron, localized in this dot. Before photon absorption, the dot exhibits the Kondo effect: the spin of the localized electron is strongly correlated with the spin of delocalized electrons, which act to screen the spin of the localized electron, thus reducing its magnetic moment. When an incident photon is absorbed, another electron is excited from a low-lying (valence) energy level into the same level that contains the first electron. This sudden change constitutes

a quantum quench. It disrupts the Kondo correlations with the delocalized electrons in the surrounding material, causing the Kondo effect to die out shortly after the quench. This leads to initial and final groundstates that exhibit Anderson orthogonality, leading to absorption lineshapes that diverge in power-law fashion, with characteristic exponents that reflect the degree of orthogonality. The present experiment demonstrated that these power-law exponents could be tuned by applying a magnetic field, in good agreement with theoretical calculations performed in Munich.

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

PROTO-REPLICATION BY SELECTIVE DEGRADATION

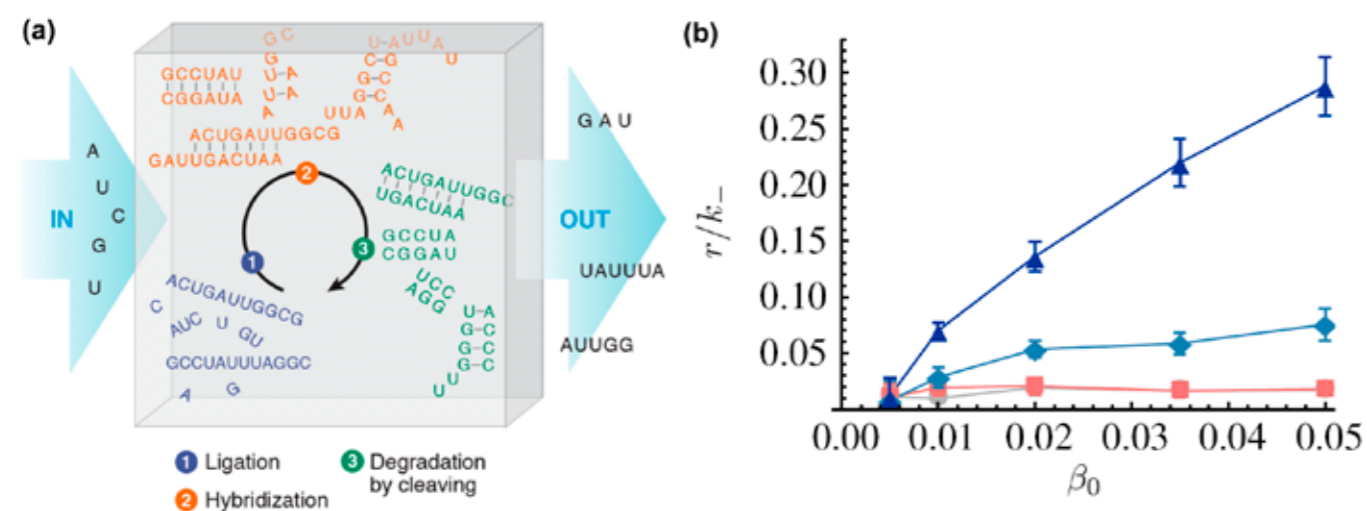
Prof. Dieter Braun (LMU Munich, Faculty of Physics)
Prof. Ulrich Gerland (LMU Munich, Faculty of Physics)

At the core of early evolution are ways to replicate genomic information. While a RNA world scenario insists that base by base replication by highly evolved, catalytically active RNA is the first step, it is hard to understand how such 200-base pair proteins should come about and which evolutionary advantage it should have since they replicate not themselves, but any other RNA molecule. We proposed in a close collaboration with the theory group of Ulrich Gerland that a pool of RNA molecules with polymeriza-

tion activity, but no template-directed ligation activity allows to reach replication-like behavior. At the core of the process is the sole idea that double stranded RNA will degrade less fast by backbone hydrolysis than single stranded RNA. The results show that emergent properties of the whole sequence pool select sequences as a whole and not based on single base replication.

Thus we study how a precursor for such a replicator might arise in a hydrothermal RNA reactor, which accumulates longer

sequences from unbiased monomer influx and random ligation. In the reactor, intra- and intermolecular base pairing locally protects from random cleavage. By analyzing stochastic simulations, we find temporal sequence correlations that constitute a signature of information transmission, weaker but of the same form as in a true replicator.



Replication by selective degradation. (a) Scheme of the RNA reactor, which can be imagined as a temperature-gradient-driven convection process in a porous media. The building blocks are ligated to form random polymers (step 1). The polymers associate (hybridize) to a duplex structure if they encounter a complementary sequence (step 2). The RNA molecules are degraded, preferentially at the nonhybridized sites (step 3). The process then restarts with some of the strands that result from the previous cycle. (Copyright Physics Viewpoint, Albrecht Ott) (b) The result is an extended lifetime of like sequences which can be modeled with a replication process.

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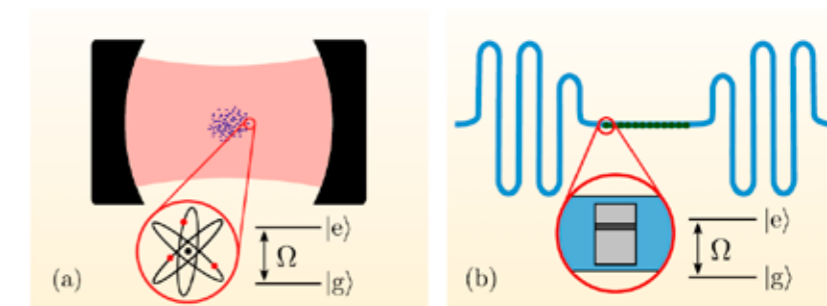
SUPERRADIANT PHASE TRANSITIONS AND THE STANDARD DESCRIPTION OF CIRCUIT QED

Prof. Jan von Delft (LMU Munich, Faculty of Physics)

Recent years have seen rapid progress in fabrication and experimental control of superconducting circuit QED systems, in which a steadily increasing number of artificial atoms interact with microwaves. These developments set the stage to study collective phenomena in circuit QED. An interesting question in that context is whether a system with many artificial atoms undergoes an equilibrium phase transition as the coupling of artificial atoms and electromagnetic field is increased (at zero temperature). Phase transitions of this type have been intensely discussed for cavity QED systems and are known as superradiant phase transitions (SPTs). However, in cavity QED systems with electric dipole coupling their existence is doubted due to a no-go theorem. Recently, it has been claimed that SPTs are possible in the closely related circuit QED systems with capacitive coupling. This would imply that the no-go theorem of cavity QED does not apply and challenges the well-

established analogy of circuit and cavity QED. In this work, the equilibrium behavior of a superconducting circuit QED system containing a large number of artificial atoms is investigated. It is shown in a full microscopic analysis that circuit QED systems are also subject to the no-go theorem. It is argued that such a microscopic analysis is necessary since the standard description of circuit QED systems by an effective

model (EM) is deficient in the regime considered here. A toy model is used to illustrate this failure of an EM. Finally, we close a possible loophole of the no-go theorem by generalizing it from two-level to multilevel (artificial) atoms. Thus, this work restores the analogy of circuit and cavity QED and rules out SPTs in these systems under realistic conditions that have not been covered before.



Cavity QED system with N atoms (a) and circuit QED system with N Cooper-pair boxes as artificial atoms (b).

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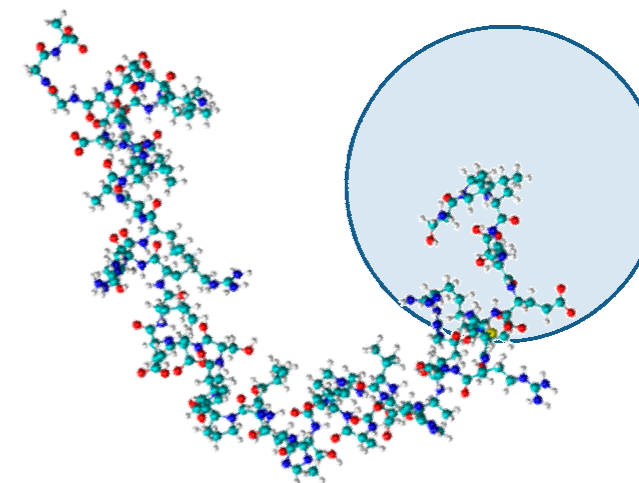
NUCLEI-SELECTED NMR - A SUB-LINEAR SCALING QUANTUM-CHEMICAL METHOD

Prof. Christian Ochsenfeld (LMU Munich, Department of Chemistry)

NMR spectroscopy plays an important role in elucidating molecular structures and dynamics in complex chemical and biochemical systems. However, the assignment of NMR spectra remains a difficult task where many assumptions are necessary for determining molecular structures. Here, the quantum-chemical calculation of NMR shielding tensors can provide crucial information for the interpretation of experimental data and deriving molecular structures. Nevertheless, reliable quantum-chemical calculations are highly challenging due to their computational effort that increases dramatically with molecular size. Therefore, we present a new ab-initio method that allows to compute NMR shieldings for selected nuclei with an effort scaling only as M^0 instead of M^3 (with molecular size M) in the rate-determining step at the Hartree-Fock (HF) and Density-Functional Theory (DFT) levels. The new sub-linear scaling ab-initio method by Beer et al. allows for a detailed simulation of, e.g., reactive centers within large molecules and also of solvent effects and molecular dynamics, where often just a few shieldings are of interest. Our method

is generally applicable and shows typical speedups of about one order of magnitude for molecules with about 500–1000 atoms as compared to our already fast linear-scaling

methods (not to mention conventional M^3 schemes). Due to the reduced scaling the benefit becomes more and more important for larger systems.



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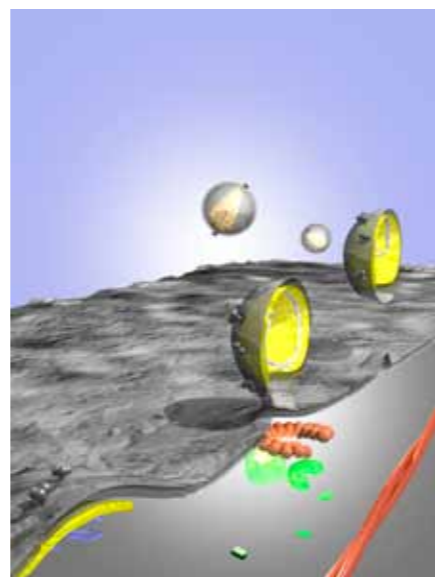
ASSEMBLY OF HIV

Prof. Don C. Lamb (LMU Munich, Department of Chemistry)
Prof. Christoph Bräuchle (LMU Munich, Department of Chemistry)

Viruses are unable to reproduce on their own but require a host organism. For example, nascent HIV particles hijack proteins from the Endosomal Sorting Complex Required for Transport (ESCRT) to bud from the host cell. To investigate the interaction between HIV and cellular components, the group of Prof. Lamb has applied ultrasensitive fluorescence microscopy methods to follow the assembly of HIV in real time. From previous experiments, they found that HIV assembly occurs in three phases: delivery and assembly of the main structural viral protein, Gag, at the assembly site (Phase I), a lag phase where Gag assembly is complete (Phase II) and release (Phase III). In the current work, they investigated the interaction of the ESCRT associated protein, VPS4, with nascent HIV assembly sites. VPS4 is known to recycle ESCRT components. Baumgärtel et al. found that VPS4 complexes assemble at nascent HIV budding sites during both Phase I and Phase II of assembly. The interactions are short

with an average duration of 35 s. Only a small number of interactions (between 1 – 5 events) were observed during the assembly of single HI virions. The interactions occurred mainly during Phase II and viruses that interacted with VPS4 only during Phase I were not released from the host cell. In fact, only virions that had interacted with VPS4 were observed to be released during the experiment. This results lead to the conclusion that interactions with VPS4 are necessary for HIV release.

Using image correlation spectroscopy in collaboration with Prof. Wiseman from McGill University, the group of Prof. Lamb could analyze the size of the interacting VPS4 complexes. VPS4 was found to be monomeric in the cytosol and to assemble into complexes of 30-40 GFP-tagged VPS4 subunits during its interaction with HIV. As the active form of VPS4 is thought to be a dodecamer, the results indicate that several dodecamers are involved.



A simplified pictorial diagram of the assembly of HIV particles. The structural Gag proteins are shown in yellow, the plasma membrane (and trimers of the Env protein) in grey, the viral genome in blue, ESCRT proteins in orange and actin filaments are shown in red. The VPS4 proteins (green) assemble into multiple dodecamers at HIV budding sites and promote virus release.

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

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

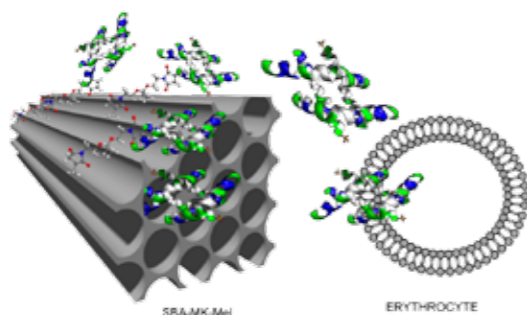
PH-RESPONSIVE RELEASE OF ACETAL-LINKED MELITTIN FROM SBA-15 MESOPOROUS SILICA

Prof. Thomas Bein (LMU Munich, Department of Chemistry)
Prof. Ernst Wagner (LMU Munich, Department of Pharmacy)

Mesoporous silica systems are of great interest in novel concepts for targeted drug delivery. One of the most important aspects of these systems is the control of the drug release as a function of certain external parameters such as pH or temperature. For biomedical applications, it would be highly desirable to have pH-responsive linkers between the substance to be delivered and the porous host, since the pH drops from 7.4 to 5.5

upon endosomal uptake of drug carriers. In this collaborative project the researchers have integrated specially designed acetal-linkers for a pH-responsive release of melittin from SBA-15 type mesoporous silica. Melittin, the active component of bee venom, is a small peptide containing 26 amino acids. It acts as a membrane invading agent, leading to a local disruption of lipid membranes. The chosen acetal offers a reasonable stability under extracel-

lular conditions (pH 7.4) while undergoing fast hydrolysis in an acidic milieu at pH 5.5. Large-pore SBA-15 type mesoporous silica with a pore-diameter of about 11 nm was functionalized with 3-mercaptopropyl-trimethoxysilane by post-synthetic grafting, followed by attachment of maleimide-containing acetal-linkers and cysteine-terminated melittin. The pH-sensitive cleavage of the acetal-melittin bonds (at pH 5.5) and the effective release of melittin from the mesoporous host was clearly demonstrated in an erythrocyte leakage assay.



A pH-labile immobilization of the peptide melittin with acetal linkers in the pore system of a SBA-15 host allows release of the peptide upon pH decrease from 7.4 to 5.5. The release is shown by melittin-induced lysis of mouse erythrocytes. The obtained results can be used as novel release for new silica-based peptide delivery systems in targeted cancer therapy.

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Bein: <http://bein.cup.uni-muenchen.de/>

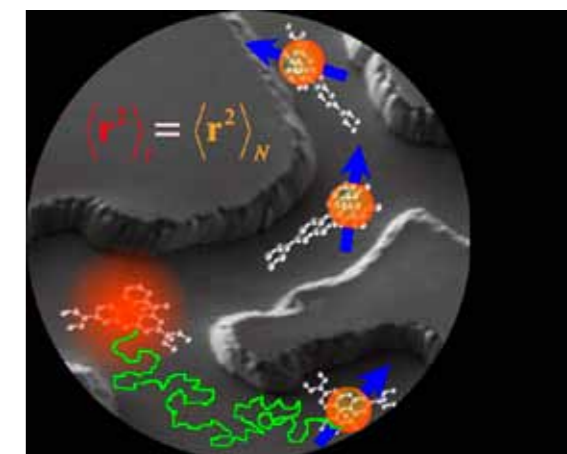
Wagner: www.cup.uni-muenchen.de/pb/aks/ewagner

TEST OF ERGODICITY - SINGLE-PARTICLE AND ENSEMBLE DIFFUSIVITIES

Prof. Christoph Bräuchle (LMU Munich, Department of Chemistry)
Prof. Jens Michaelis (LMU Munich, now at Ulm University, Physics Department)

Diffusion is the omnipresent, random motion of matter, such as atoms and molecules, driven by thermal energy and is the key for innumerable processes in nature and technology. In nearly every chemical reaction diffusion is the key mechanism of bringing the reactants in close proximity, which is an essential prerequisite before any reaction can take place. Central to the dynamics of diffusion, and in general matter, is the ergodic theorem, which states that for systems in the equilibrium state the time average taken over a single particle is the same as the ensemble average over many particles. However, while being formulated as a theorem more than a century ago, no experimental validation has so far been reported.

Here, for the first time, experimental proof of this fundamental theorem is presented by measuring under identical conditions the diffusivities of guest molecules inside a nanostructured porous glass using two conceptually different approaches. The data obtained through the direct observation of dye molecule diffusion by single molecule tracking experiments, that is, the time-average, is in perfect agreement with the ensemble value obtained in pulsed-field gradient NMR experiments.



The random translational motion of single dye molecules incorporated in a customized porous glass system was observed directly by single molecule fluorescence microscopy. (The red spot symbolizes fluorescence emission of a single dye molecule.) Additionally, the ensemble diffusion coefficient could be measured by pulsed field gradient (PFG) nuclear magnetic resonance (NMR) under the same conditions. (The blue arrows represent the nuclear spin.) By obtaining similar values for the diffusivities, the ergodic theorem could be confirmed experimentally.

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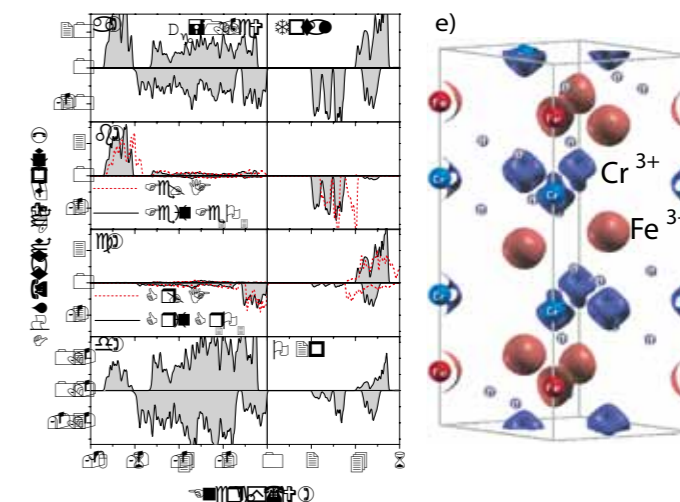
Bräuchle: <http://www.cup.uni-muenchen.de/pc/braeuchle/>

Michaelis: <http://www.uni-ulm.de/nawi/nawi-biophys/mitarbeiter/jensmichaelis-new.html>

FERRIMAGNETISM AND BAND GAP NARROWING IN ARTIFICIAL LAYERED CR DOPED α - Fe_2O_3

PD Dr. Rossitza Pentcheva (LMU Munich, Department of Earth and Environmental Sciences)

Based on density functional theory (DFT) calculations with a Hubbard U-term, we design an artificial ferrimagnet FeCrO_3 of ilmenite type out of the two antiferromagnets α - Fe_2O_3 and α - Cr_2O_3 . By varying the concentration of Fe in α - Cr_2O_3 , a phase diagram of the relative stability of different chemical and magnetic arrangements is provided with respect to the end members. At 50% Fe-doped α - Cr_2O_3 , the ilmenite-like structure with alternating Fe and Cr layers and antiparallel orientation of magnetic moments competes energetically with a phase-separated structure containing a mixed Fe-Cr interface layer. The magnetic interaction parameters between $\text{Fe}(3d^5)$ and $\text{Cr}(3d^3)$ ions in the digital ferrimagnetic heterostructure, extracted by mapping the DFT total energies to a Heisenberg Hamiltonian, indicate a hematite-like magnetic order with parallel intralayer and antiparallel interlayer alignment. Furthermore, the GGA+U calculations predict a reduction of the band gap of Cr doped Fe_2O_3 to 1.9 eV compared to the parent compounds Fe_2O_3 (2.1 eV) and Cr_2O_3 (3.2 eV) which makes this system promising for photovoltaic and photocatalytic applications.



(a) Total and (b–d) projected density of states (DOS) for the layered FeCrO_3 structure showing that the band gap, defined by occupied Cr 3d and O 2p and empty Fe 3d states is reduced with respect to the parent compounds; (e) The corresponding spin-density displays the ferrimagnetic coupling and characteristic orbital occupation of Fe^{3+} ($3d^5$, spherical shape, red) and Cr^{3+} ($3d^3$ with occupied t_{2g} orbitals shown in blue).

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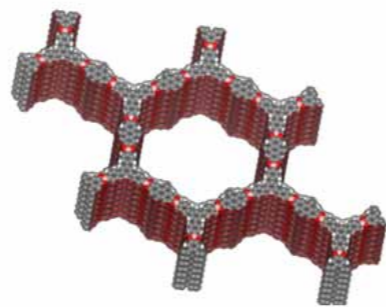
Pentcheva: www.kristallographie.geowissenschaften.uni-muenchen.de/personen/professoren/pentcheva/index.html

A COVALENT ORGANIC FRAMEWORK WITH 4 NM OPEN PORES

Prof. Thomas Bein (LMU Munich, Department of Chemistry)

Structural control in the synthesis of porous crystalline materials with well-defined pore size is essential for applications in gas storage, catalysis, separation, optics and chemical sensing. Particularly, large pores reaching several nm diameter would allow the design of a multitude of nano-devices interacting with large guest molecules. Thus, to gain maximum control over local structure, chemistry and physics in a pore system, it would be highly desirable to have access to multi-nm pores with molecularly defined walls. While several mesoporous metalorganic frameworks have been reported, they typically offer only fairly small windows compared to the cage sizes. In this collaborative project with the Knochel group at LMU the researchers have achieved the synthesis of a new mesoporous Covalent Organic

Framework BTP-COF, with a fully accessible hexagonal pore system having an open diameter of 4.0 nm. These dimensions are extremely large for any type of crystalline material. Covalent Organic Frameworks are constructed through the condensation of organic building blocks such that highly porous materials with widely tunable physical and chemical properties result. The new BTP-COF was synthesized under solvothermal conditions by co-condensation of 1,3,5-benzenetris(4-phenylboronic acid) (BTPA) and the polyol 2,3,6,7-tetrahydroxy-9,10-dimethyl-anthracene (THDMA). The synthesis parameters for the new COF structure were found and optimized in a high throughput screening approach using a robotic dosing system and microwave synthesis.



Giant pores: A Covalent Organic Framework obtained from the co-condensation of a tetrahydroxyanthracene and a trigonal boronic acid forms a crystalline hexagonal channel structure with mesopores of 4.0 nm diameter.

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Bein: <http://bein.cup.uni-muenchen.de>

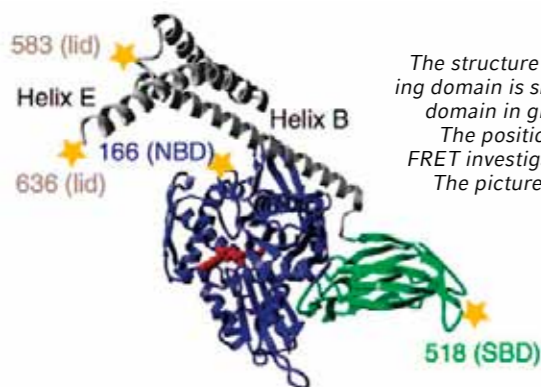
THE ROLE OF CHAPERONE PROTEINS

Prof. Don C. Lamb (LMU Munich, Department of Chemistry)

Proteins are the biomolecules that perform the majority of the processes necessary for life. Protein biosynthesis occurs through translation of the genetic DNA into messenger RNA (mRNA), transcription of the mRNA into a polypeptide chain and finally folding of the protein into its final functional form. Chaperones are an important class of proteins that assist nascent proteins in reaching their final functional structure. Deficiencies in the chaperoning process can lead to disease and aging. The heat shock protein 70 BIP (heavy chain-binding

protein) is a chaperone protein in the endoplasmic reticulum and is important in the folding of immunoglobulin proteins, keeping the C_H1 domain (constant heavy domain 1) unfolded until it can interact with the appropriate binding partner. BiP consists of two domains, the nucleotide-binding domain and the substrate-binding domain (see Figure). Using single-pair Förster Resonance Energy Transfer with Pulsed-Interleaved-Excitation, the group of Prof. Lamb investigated the conformation of BiP in the presence of different cochaperons and substrates in collaboration

with the group of Prof. Buchner from the Technische Universität München. Through these investigations, they could show that nucleotide binding resulted in concerted motions of the different domains of BiP. In addition, BiP can distinguish between the binding of a small peptide versus the full, authentic protein substrate, C_H1, through the conformation of the substrate-binding domain. Marcinowski and coworkers could also shed light on the role of the cochaperon, ERdj3, in the functional cycle of BiP. The interaction of ERdj3 with BiP primes the conformation of BiP for binding of a substrate, thereby increasing the stability of the substrate-bound complex. Overall, these results indicate that there are complex and intricate interactions between the chaperone, co-chaperone and the substrate during the functional cycle of BiP.



The structure of the Hsp70 BiP. The nucleotide-binding domain is shown in blue and the substrate-binding domain in green with the lid portion shown in grey. The positions that were labeled for the single-pair FRET investigations are given and marked with stars. The picture is provided courtesy of the Technische Universität München.

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

DYNAMIC MODULATION OF PHOTONIC CRYSTAL NANOCAVITIES USING GIGAHERTZ ACOUSTIC PHONONS

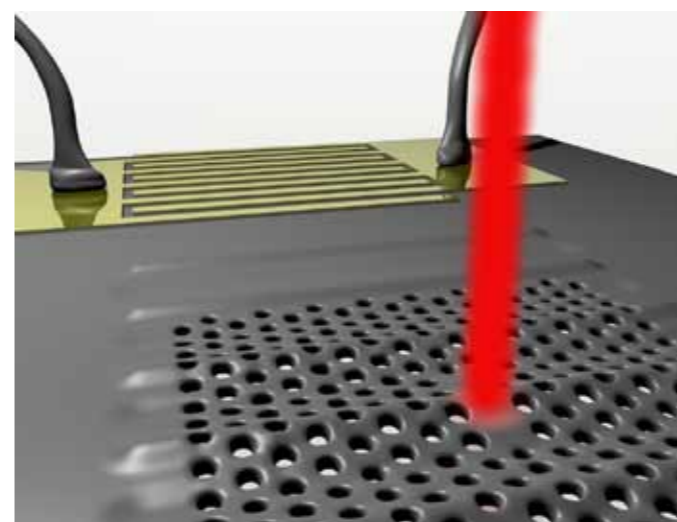
Dr. Hubert Krenner, Prof. Achim Wixforth (University of Augsburg, Institute of Physics)

Photonic crystal membranes are a particularly promising platform to realize future quantum photonic circuits. In collaboration with colleagues from UC Santa Barbara, the team of Hubert Krenner and Achim Wixforth at University of Augsburg fabricated such free-standing nanomembranes which are patterned with a periodic array of holes. This periodic arrangement of semiconductor and air forms as a perfect mirror and inhibits the propagation of light inside the membrane over a broad range of wavelengths, the so-called photonic bandgap. By deliberately skipping three holes, a high-quality optical nanoresonator with a length of few hundred nanometers is created. Light of a well-defined wavelength which would fall inside the photonic bandgap can be trapped and stored over long timescales in-

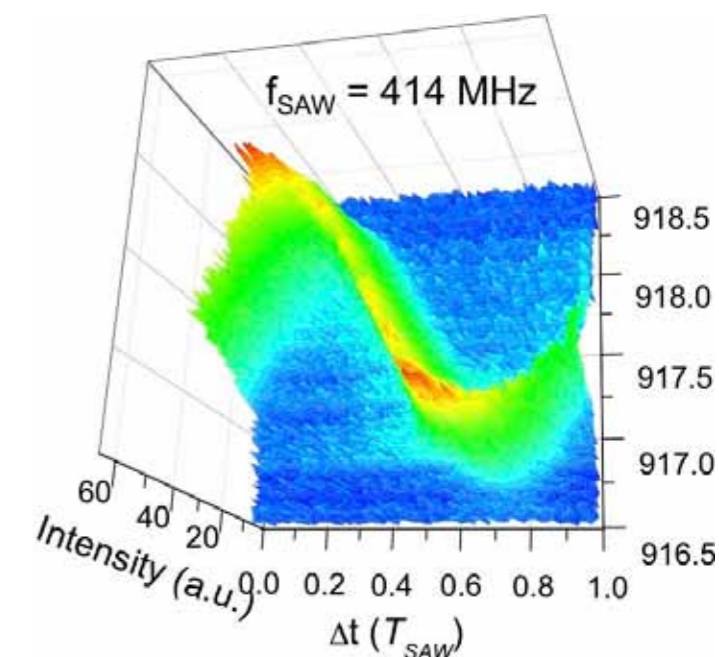
side this defect. To monitor the resonance wavelength of the nanophotonic mode, a layer of self-assembled quantum dots was embedded in the center of the membrane. In contrast to classical light sources these artificial atoms are quantum light emitters and send out individual, single photons. A key challenge to use a coupled system consisting of a quantum dot and a nanophotonic mode is to tune the wavelengths of the two parts into resonance faster than their quantum mechanical interaction occurs. The CeNS team succeeded to push this tuning speed by more than a factor of ten compared to conventional approaches by using surface acoustic waves. These nanoquakes pioneered by Achim Wixforth and his group periodically stretch and compress the optical nanoresonators as shown in Fig. 1. This geometric deforma-

tion in turn shifts the nanophotonic mode to longer and shorter wavelengths, respectively which can be directly resolved the experimental data presented in Fig. 2.

The Augsburg researchers plan to use their unique tool to switch on and off the coherent quantum mechanical interaction between single photons and a quantum dot artificial atom located inside the nanocavity. Moreover, they hope that their nano-quake can be used to locally excite nanomechanical vibrations inside the photonic lattice and thus convert mechanical to optical energy and vice versa.



A nano-quake propagates across a photonic crystal and dynamically tunes the wavelength of nanocavity.



Direct experimental verification of the dynamic modulation of the nanocavity resonance wavelength by the surface acoustic wave.

D.A. Fuhrmann, S.M. Thon, H. Kim, D. Bouwmeester, P.M. Petroff, A. Wixforth, and H.J. Krenner: Dynamic Modulation of Photonic Crystal Nanocavities Using Gigahertz Acoustic Phonons; Nature Photonics 5, 605–609 (2011).

Krenner: www.physik.uni-augsburg.de/exp1/mitarbeiter/02_seniors/krenner_hubert

Wixforth: www.physik.uni-augsburg.de/exp1/mitarbeiter/01_profs/wixforth_achim

SINGLE MOLECULE MECHANICS

Prof. Herrmann E. Gaub, Dr. Ann Fornof (LMU Munich, Faculty of Physics)

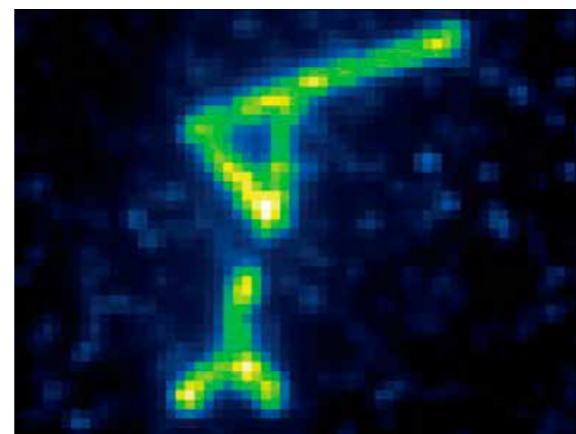
As more and more recent investigations point out, force plays an important role in cellular regulation mechanisms, single molecule force measurements became of general importance. Biological responses to mechanical stress are often based on force-induced conformational changes of single molecules (1). Single molecule force spectroscopy allows assessing molecular forces with AFM and unbinding forces of interacting bio-molecules were thoroughly scrutinized (2,3). Therefore a worldwide standard for sufficient calibration of AFM force experiments was realized in an international approach (4).

To improve the yield of force measurements in a high throughput manner a molecular force assay based on measuring comparative unbinding forces of bio-molecules was invented to mechanically characterize protein-DNA interactions (5). Another unique advantage of measuring binding or unbinding forces in biological applications was realized in this assay since the interaction force between certain molecules and not the mere presence of one of them is detected. As a proof of principle, binding of the protein EcoRI to its DNA recognition sequence was measured and the corresponding dissociation constant in the sub-nanomolar range was determined.

Furthermore, a simplified set-up employing FRET pairs on the molecular level improved the readout by standard epifluorescence. Due to these advancements a feature size of a few microns is sufficient for the measurement process. This will open a new paradigm in high-throughput screening with all the advantages of force-based ligand detection.

These measures of molecular force hierarchies and the recently improved nano-mechanical precision led to a nano assembling technology referred as single molecule cut & paste (6). SMC&P combines the Ångstrom positioning precision of the atomic force microscope (AFM) with the selectivity of molecular recognition. It can be applied to select individual molecular building blocks, such as enzymes, and place them at a chosen position on a construction site.

Up to now, researchers had only used DNA oligomers as general molecular handles and anchors. But to make SMC&P widely applicable, an all-protein approach is required. Therefore a novel handle system



Fluorescence image of a scheme with a cantilever and an antibody "painted" by molecular cut and paste.

based on a short peptide on the molecular building blocks, which is recognized by a specific antibody at the AFM tip proved to fulfill these tasks. Molecular arrangements can be assembled one by one with a precision much better than the resolution limit of the light microscope. These most recent results are an important step towards the assembly of all-protein molecular devices.

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WATCHING SELF-ASSEMBLY IN REAL TIME – INSIGHT INTO GROWTH MECHANISM OF SILICA NANOCANNELS

Prof. Jens Michaelis (LMU Munich, now at Ulm University, Physics Department)

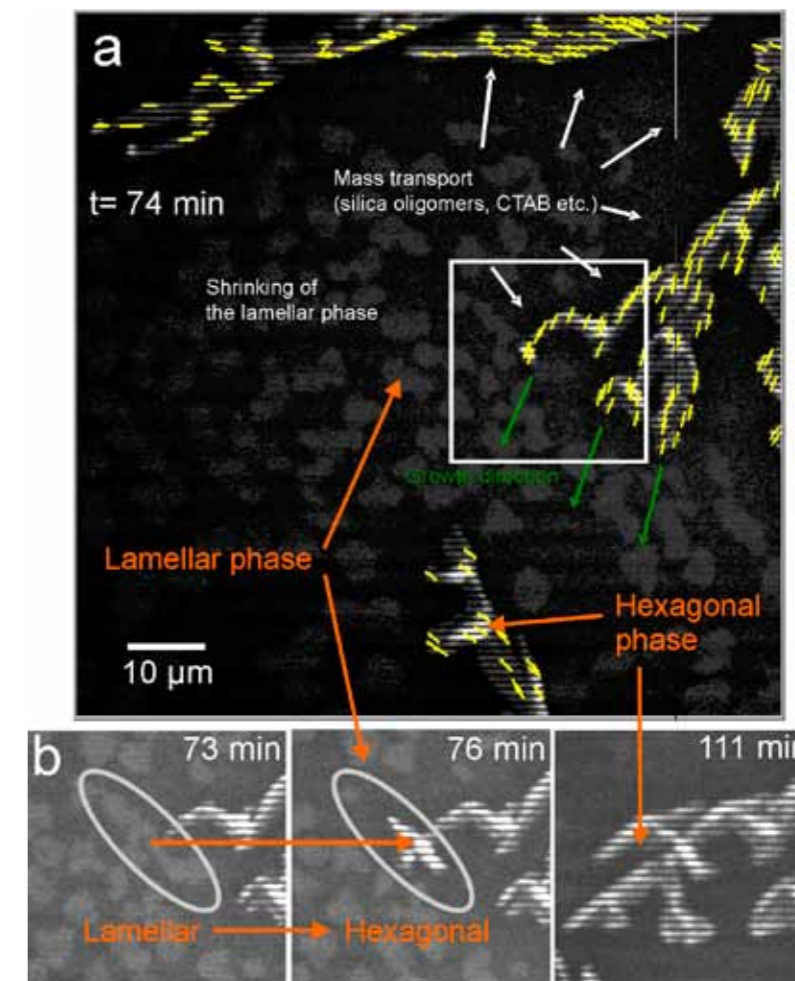
Prof. Christoph Bräuchle (LMU Munich, Department of Chemistry)

Periodic mesoporous materials show a large variety of nanostructures and their widely tunable properties make them highly attractive materials for numerous applications in nanotechnology, e.g. molecular separation, nano-optics, molecular electronics, nanomedicine and catalysis. Although mesoporous silica films exhibit well-defined local nanometer sized structures, they show randomly oriented domains (of e.g. hexagonally arranged pores) whose sizes do not exceed several hundreds of nanometers. This is by far not enough to realize the enormous potential for applications of such systems. A long standing question in this field is therefore the thorough understanding of the self-assembly and growth mechanism of such mesoporous structures. Until now, failure to understand growth restricts the means of its control and thus limits the achievable domain sizes.

The labs of Prof. Christoph Bräuchle and Prof. Jens Michaelis have therefore teamed up to shed light onto the self-assembly and growth mechanism of mesoporous silica channel systems. They were able to observe domain growth in real time by fluorescence polarization imaging and atomic force microscopy (AFM). This method allows for direct insight into growth kinetics and mechanisms. In their experiments they could determine the conditions for the growth of large domains forming on top of a mesoporous thin film substrate which acts as a reservoir for the reactive species. More importantly, they could unravel some of the key steps in this self-assembly process and found that transient lamellar structures precede the formation of the hexagonal layers. The layer growth then follows two pathways, first, rapid conversion of lamellar to hexagonal phase through a seeding mechanism and, secondly, slower mass transport of the self-assembling components towards the growing hexagonal layers. This information was then used to control

domain size and create ultra-large well ordered domains which were not obtainable so far. The controlled growth of such ultra-large domains will undoubtedly allow the realization of applications of these materials, in particular in molecular separation.

Here, millimeter-sized domains are required with tunable channel diameters (2 – 10 nm) in order to separate molecules according to their size.



Fluorescence polarisation microscopy reveals growth mechanism of silica nanochannels. (a) Overview of growing domain of hexagonally ordered silica nanostructures. By rotating the excitation polarisation and detecting the emitted fluorescence signal from dye molecules incorporated into the silica nanostructures hexagonally ordered domains (striped patterns) and disordered lamellar phase (grey areas) can be distinguished. (b) Time-line of a selected area (marked by white box in (a)). In successive scans of the same area the conversion from disordered to ordered domains can be followed. By analysing the stripe patterns and comparing to the polarisation direction of the fluorescence excitation, the orientation of the dye molecules and with that also that of the channels can be determined (yellow bars in (a)). Copyright: Nature Nanotechnology.

C. Jung, P. Schwaderer, M. Dethlefsen, R. Köhn, J. Michaelis* and C. Bräuchle*: Visualization of the self assembly of silica nanochannels reveals growth mechanism", (* corresponding authors); *Nature Nanotechnology* 6, 87 (2011).

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

Michaelis: <http://www.uni-ulm.de/nawi/nawi-biophys/mitarbeiter/jensmichaelis-new.html>

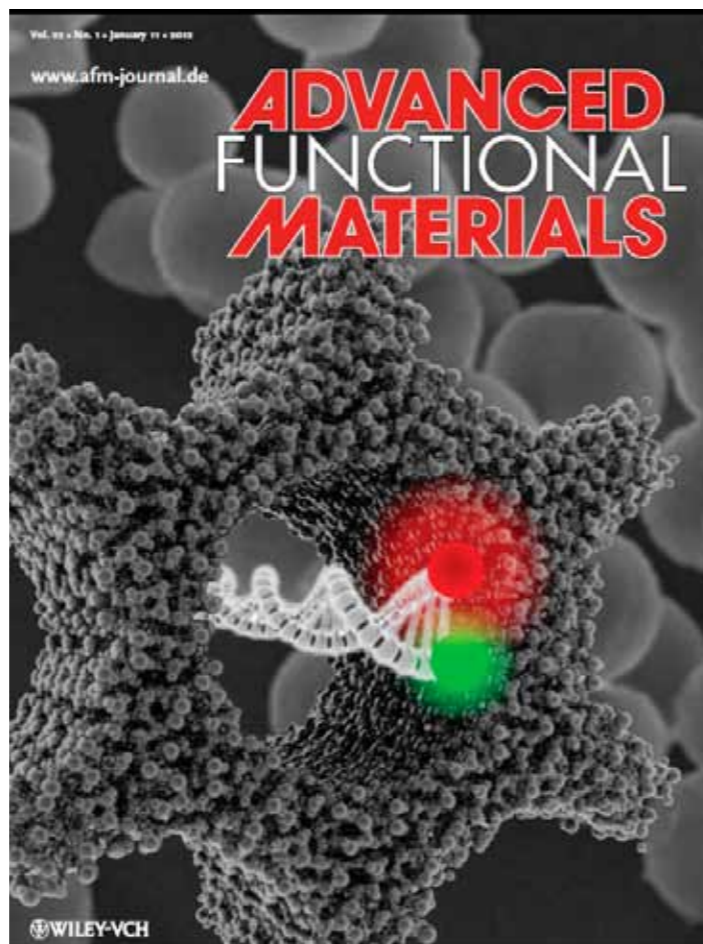
SILICA NANOMATERIALS FOR NANOMEDICINE

Prof. Christoph Bräuchle (LMU Munich, Department of Chemistry)

Prof. Thomas Bein (LMU Munich, Department of Chemistry)

Prof. Heinrich Leonhardt (LMU Munich, Department of Biology II)

Oligonucleotides used in gene therapy and silencing are fragile compounds that degrade easily in biological environments. Porous biocompatible carrier particles may provide a useful strategy to deliver these therapeutics to their target sites. Development of appropriate delivery vehicles, however, requires a better understanding of the oligonucleotide-host interactions and the oligonucleotide dynamics inside carrier particles. Template-free SBA-15 type mesoporous silica particles were investigated and their loading characteristics with siRNA depending on the surface functionalization of their porous network reported. The siRNA uptake capability of the particles can be controlled by the composition of the functional groups. Fluorescence recovery after photobleaching measurements revealed size-dependent mobility of siRNA and double-stranded DNA oligonucleotides within the functionalized silica particles and provided evidence for the stability of the oligonucleotides inside the pores. Hence, this study demonstrates the potential of mesoporous silica particles as a means for alternative gene delivery in nanomedicine.



Mesoporous silica particles represent a novel, highly versatile class of drug-delivery systems. These materials were used as a host for the incorporation of short oligonucleotides as model in gene therapeutics.

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THESES



DIPLOMA & MASTER THESES

Marc Ablay: *DNA Origami Process Optimization* (LMU, T. Liedl); **Daniela Aschenbrenner:** *Analysis of RNA binders by means of the Molecular Force Assay (MFA)* (LMU, H. Gaub); **Erik Simon Bader:** *Structural characterization of the Spt6 tandem SH₂ domain binding to phosphorylated CTD peptides* (LMU, P. Cramer); **Christoph Bock:** *The Vicsek model with repulsion* (LMU, E. Frey); **Stefanie Bolte:** *Electronic and Structural Characterization of III-V Semiconductor Nanowires with Surface Probe Microscopy and Transmission Electron Microscopy* (LMU/TUM/Uni Augsburg, T. Bein & G. Abstreiter); **David Borowsky:** *Transportmessungen zur Untersuchung der 0.7-Struktur in Quantenpunktkontakten* (LMU, S. Ludwig); **Andreas Brenneis:** *Optische und optoelektronische Charakterisierung von InAs-basierten Nanodrähten* (TUM, A.W. Holleitner) & **Ellen Broda:** *Risks and Chances of Nanoparticles* (LMU, C. Bräuchle); **Martina Bucher:** *Untersuchung von Farbstoff-Gold Wechselwirkungen anhand selbst assemblierter DNA Nanostrukturen* (LMU, P. Tinnefeld); **Pierre-Luc Dallaire-Demers:** *Supercurrent noise in rough Josephson junctions* (University of Waterloo, F. Wilhelm); **Beate Dirks:** *Impact of two-dimensional Gold Nanoparticle Arrays on the Optoelectronic Properties of GaAs Nanowires* (LMU, A.W. Holleitner & J.P. Kotthaus); **David Doennig:** *Density functional theory investigations of the electronic and magnetic properties of transition metal oxide interfaces* (LMU, C. Scheu & R. Pentcheva); **Felix R. Donhöfner:** *Spektroskopische Untersuchung und numerische Simulation von selbstorganisierten Quantenpunkten in Feldeffekt-Strukturen* (LMU, A. Högele); **Stefan Fischbach:** *Ladungsträgerdynamik in rutheniumdekorierten Cadmiumsulfidnanostäbchen und Systemoptimierung hinsichtlich Photokatalyse* (LMU, J. Feldmann); **Erik Flügel:** *Gemini surfactant-assisted synthesis of mesostructured zinc imidazoles* (LMU, B. Lotsch); **Georg Glasbrenner:** *Impedanzspektroskopie an organischen Halbleiterschichten in wässriger Umgebung* (LMU, B. Nickel); **Maria Götz:** *Postsynthetic Modification of Covalent Organic Frameworks* (LMU, T. Bein); **Michael Gruber:** *Wechselwirkung von Alpha-Synuclein mit Zellmembranmodellen* (TUM, T. Hugel); **Michael Guggemos:** *Aufbau eines Messplatzes mit optischem Kryostat zu Untersuchungen der optischen Eigenschaften von V₂O₃-Nanostrukturen am Metall-Isolator-Übergang* (Uni Augsburg, H. Krenner & A. Wixforth); **Benjamin Hackner:** *Synthesestudien zu einem Desoxyglucosederivat zur Herstellung eines glycomimetischen Antikörpers* (LMU, T. Carell); **Matthias Hartlieb:** *Functional hydrogels from poly(2-oxazoline)s for bioapplications* (FSU Jena, U.S. Schubert & M. Gottschaldt); **Matthias Hauck:** *Optische Spektroskopie der Wechselwirkung zwischen Quantenpunkten und ihrer elektronischen Umgebung* (LMU, A. Högele); **Christoph Heinzl:** *Synthese und mikrostrukturelle Charakterisierung von CuInS₂ Filmen für Anwendungen in der Photovoltaik* (LMU, C. Scheu & T. Bein); **Daniel Hera:** *Einfluss des Füllstoffs auf die mechanischen Eigenschaften von Schichtsilikat-gefüllten TPE Nanokompositen* (FSU Jena, U.S. Schubert & R. Weidisch); **Monika Holzner:** *Nucleosome Remodelling by Chd1* (LMU, J. Michaelis); **Gerrit Huy:** *Intermolekularer Transport im medizinischen Kontext* (LMU, D. Heinrich & J. Rädler); **Lars Jäger:** *Akustoelektrische Transportuntersuchungen an zweidimensionalen Quanten-Trögen* (Uni Augsburg, H. Krenner & A. Wixforth); **Thomas Jähnert:** *Polymers for organic radical batteries* (FSU Jena, U.S. Schubert & M.D. Hager); **Peter Käshammer:** *Investigation of the interaction of native point defects with grain*

boundaries and dislocations in multicrystalline silicon by Molecular Dynamics simulations (LMU/TUM/Uni Augsburg, T. Bein & T. Sinno); **Sebastian Nino Karpf:** *Building of an ultra-stable diode-laser for biosensing* (joint project with T. Kippenberg) (LMU, B. Nickel); **Christoph Kastl:** *Optoelectronic Quantum Transport in Mesoscopic Semiconductors* (TUM, A.W. Holleitner); **Botan Khani:** *Robust Time-Optimal Control for the One-Dimensional Optical Lattice for Quantum Computation* (University of Waterloo, F. Wilhelm); **Florian Knall:** *Manipulation von Exzitonen in einzelnen Quantenpunkt-Nanostrukturen mittels akustischer Oberflächenwellen* (Uni Augsburg, H. Krenner & A. Wixforth); **Johannes Knebel:** *Evolution of cooperation in bacterial biofilms* (LMU, E. Frey); **Peter Krenn:** *Heterodyne dielektrische Detektion von nanomechanischen Resonatoren* (LMU, J. P. Kotthaus); **Monika Lacher:** *Synthese, Charakterisierung und photokatalytische Aktivität C-dotierter Kohlenstoffnitride durch Umsetzung von Dicyandiamid unter ionothermalen Bedingungen* (LMU, B. Lotsch); **Silvia Laube:** *Targeting membrane heat shock protein 70 by non-viral vectors for gene delivery into tumor cells* (LMU, M. Ogris & C. Scheu); **Sebastian Laurien:** *Driftkorrektur für super-aufgelöste Proben mit DNA PAINT Technik* (LMU, P. Tinnefeld); **Andreas Mader:** *Biosensorik für biochemische Erkennungsprozesse* (LMU, M. Leisner & J. Rädler); **Milan Padilla:** *Photocurrent dynamics in semiconducting nanowires* (TUM, A.W. Holleitner); **Wolfgang Mühlbacher:** *Crystal structure of a newly-discovered CTD interacting domain in Schizosaccharomyces pombe Ctk3* (LMU, P. Cramer); **Philipp Nickels:** *Towards Applications of DNA Origami in Life Sciences* (University of Applied Sciences Munich, H. Clausen-Schaumann); **Christoph Oriefe:** *Towards High Throughput Thermophoresis* (LMU, D. Braun); **Tobias Preiß:** *Protein-Nanoparticle Interaction measured by Two-Photon Fluorescence Correlation Spectroscopy* (LMU, J. Rädler); **Sven Schneider:** *Fluoreszenzspektroskopie einzelner Moleküle in Nano-Aperturen* (LMU, P. Tinnefeld); **Minn Peng:** *Investigating correlated movements of DNA Holliday Junction bound to DNA Origami by dint of single-molecule Prism-based TIRF Microscopy* (TU Braunschweig, P. Tinnefeld); **Matthias Rakowski:** *Rechnerunterstützte Untersuchung der Zellmotilität anhand von Dictyostelium discoideum mit verschiedenen Substraten* (LMU, D. Heinrich & J. Rädler); **Annekathrin Ranft:** *Colloidal Porous Frameworks for the Fabrication of Photonic Multilayer Systems* (LMU, B. Lotsch); **Richard Reigert:** *Ausbreitung akustischer Oberflächenwellen in photonischen Kristallarrays und interferometrische Amplitudenbestimmung von akustischen Oberflächenwellen* (Uni Augsburg, H. Krenner & A. Wixforth); **Florian Rieger:** *Analysis of fluctuations in models of population dynamics* (LMU, E. Frey); **Christoph Schaffer:** *Elektronische und strukturelle Eigenschaften dünner Schichten aus Hexa-peri-hexabenzocoronene (C₄₂H₁₈)* (LMU, B. Nickel); **Wolfgang Schinner:** *Spektroskopie von Kohlenstoffnanoröhren im elektrostatischen Feld* (LMU, A. Högele); **Julia Schmidt:** *Einfluss von Alpha-Synuclein auf Struktur und Diffusität substratgestützter Membranen* (LMU, B. Nickel); **Maria Schnödt:** *miRNA-143-regulated transgene expression in cancer cells* (LMU, M. Ogris); **Robert Schreiber:** *Toward nano-antennas based on DNA origami* (LMU, T. Liedl); **Sarah Schulz:** *Entwicklung eines Enzym Assays für die HIV-1-Protease als Basis für parallelisiertes Einzelmolekül Drug Screening* (LMU, P. Tinnefeld); **Marcus Schulze:** *Ruthenium(II) 2,6-di(quinolin-8'-yl)pyridine and polymer structures* (FSU Jena, U.S.

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