CINSaT Center for Interdisciplinary Nanostructure Science and Technology

Newsletter 1/2017

UNI KASSEL
VERSITÄT

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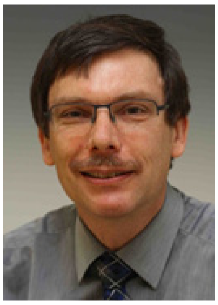
photo: Press and Public Relations Office University of Kassel, Studio Blåfield

Preface

Welcome to the second CINSaT newsletter



Time has passed quickly and I am proud to introduce our second newsletter after relaunch. Although only half a year since the last issue appeared, already many events happened and activities started showing the strong vitality of our center. The doubling of the page count of this issue is clearly reflecting this fortunate circumstance. Many thanks to all article writers who contributed to this strongly improved CINSaT newsletter. First of all, a brief report will be given about the last member plenary meeting with the most important decisions and discussion points, which includes also new memberships, new focused topics and related speaker names.

In this issue, there is now a contribution of the students, nicely reporting about their exciting exchange semester at the Jyväskylä University in Finland, an Erasmus partner of the University of Kassel and of CINSaT. Five students continued their nano science program in Jyväskylä during this winter semester. Also very welcome is a new periodic page for student representatives. This time, a brief introduction is given by the student representatives of the Faculty of Mathematics and Natural Sciences. The informational exchange and research activities are the core part of the newsletter. This part is now greatly expanded. In this issue, Thomas Baumert is reporting on an interdisciplinary approach using ultra-short shaped pulses for cell perforation, André Knie is reporting on a new analytical technique on UV spectroscopy, which may allow in future to study liquid - solid interfaces on the nanoscale, and I myself together with Bernd Witzigmann are reporting on breakthroughs in quantum dot lasers for high-performance telecom applications.

A very interesting new concept of interdisciplinary research activities is reported by Hartmut Hillmer, Rudolf Pietschnig and Arno Ehresmann. Here, the interdisciplinary topic was mainly driven by the intensive discussion and cooperation of several PhD students coming from the involved physics, engineering and chemistry groups, which know each other from several CINSaT meetings. First results were already reported in the last spring meeting. Very exciting and successful was also the contribution of many CINSaT members on the new support initiative of the university to improve the research profile. Here substantial money will be invested in cooperative research initiatives, which should enable the joint groups to apply for a coordinative research project such as „DFG-Forschergruppe", „Sonderforschungsbereiche" or „DFG-Graduiertenschule". Two of them (PhosMOrg by Raffael Schaffrath, PROTON by Thomas Niendorf) will be presented in this issue. Further ones will be presented in one of the next newsletters.

Several new members have joined CINSaT within the last year till now or have changed their status, i.e., from associate to full membership. Cyril Popov and Thomas Giesen introduce themselves with a brief introduction to their research topics. Subsequently, the research topics of CINSaT members are presented. In this issue, Markus Maniak presents his group „Cell Biology" and Thomas Kusserow his „Nanophotonics" group. In February, we had our last spring colloquium of CINSaT with about 80 attendees and excellent talks. At this event, we had as extraordinary speaker Prof. Mosbrugger, general manager of the Senckenberg Society. A brief report about this very successful meeting is given in the report section. Finally, announcements are given, e.g., for the next fall meeting, but also for other events. At the end, don't miss the nano arts page with some contribution from Maniak's Cell Biology group.

Enjoy the reading of this issue.

Johann Peter Reithmaier

General

Latest information from the CINSaT management

Here, we briefly report about major issues from the last member plenary meeting taking place at the AVZ, Heinrich-Plett-Str. 40, on May 3, 2017.

(a) New members

The following membership applications were approved by the CINSaT plenary assembly:

- Prof. Christiane Koch (physics, FB10)
- Prof. Peter Lehmann (electrical engineering, FB16)
- Prof. Arno Müller (biology, FB10)

The following membership status changes from associate to full member were approved by the CINSaT plenary assembly:

- PD Dr. Cyril Popov (nano diamond, INA, FB10)
- apl. Prof. Dr. Thomas Fuhrmann-Lieker (macromolecular chemistry and molecular materials, FB10)

(b) Focused topics

The existing focused topics were approved and a new topic was added. Also, the responsible speakers of each topic were announced and confirmed.

(1) Threedimensional Nanostructures (Hartmut Hillmer)
(2) Biosensing (Friedrich Herberg)
(3) Photonics (Thomas Kusserow)
(4) Chiral Systems (Thomas Baumert)
(5) Quantum Technology (Kilian Singer) ⇒ new topic
(6) Nanostructures in Natural Sciences, Engineering Sciences and the Arts (Bernhard Middendorf / Thomas Niendorf)

(c) Scientific advisory board

The following advisory board members of the current board accepted the prolongation for the next period.

- Prof. Markus-Christian Amann (electrical engineering, TU München)
- Prof. Hans-Joachim Freund (chemical physics, MPI Berlin, Fritz-Haber-Institute)
- Prof. Andreas Offenhäuser (bioelectronics, Research Center Jülich)

We are currently looking for two more board members to establish the new scientific advisory board to get approved by the university till fall of this year.

(d) CINSaT secretary position

We urgently need support of the management to continue our efforts in the organization and public relation issues of CINSaT. Unfortunately, due to administrative reasons, the position opening launched in spring this year wasn't successful and has to be renegotiated with the university again. Due to the current limitations of the personnel resources of the management, we have to apologize that additional activities have to be minimized and interaction speed with members can be significantly slowed down until the situation has improved.

Education

Erasmus program Jyväskylä, Finland

How do you come up with the idea of doing your exchange in Finland? – by Jendrik Gördes

Jendrik Gördes

In one of our lectures in the beginning of 2016, we got introduced to the possibility of doing an exchange semester in Jyväskylä. We could be the first students to take part in the new exchange program between both nanoscience departments. As the third semester in the master provides a good opportunity to do an exchange, we decided to apply for it.

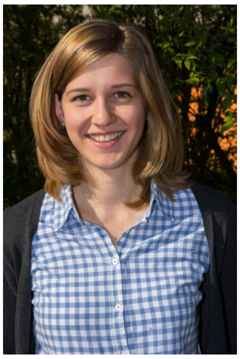
But before we actually took the plane to Finland, we had to go through several administrative steps. Luckily, we got a lot of help from Prof. Fuhrmann-Lieker and Leena Mattila from the international office in Jyväskylä regarding our applications. We only had to register for the Erasmus program, which involves a short English language test, and apply for a student apartment. At the arrival, you get access to your apartment via your student tutor. They have already picked up the key for you as well as your survival kit. Their job is to help you get started with your Finnish life as well as to spend some time with you to do typical Finnish activities.

After you finally settled in Jyväskylä, your student life begins. The educational system in Finland is strongly heading for student success and the relationship to the teachers is more informal, for example you address them by their first names. They easily give you advice and more time for essays if you need some. For their lunch break most students usually go to one of the student cafeterias where the food is cheap and surprisingly good. Each of the ten cafeterias has its own menu but you can always find lactose-free or gluten-free food as well as vegetarian food. The meal usually contains a main and side dish as well as some salad. You can choose the quantity of salad and side dish you want by yourself. Additionally, you can add some bread and a glass of milk or fruit juice for free.

After your lectures, if you are interested in sports, you have the possibility to get a sports sticker which gives you access to the fitness center and a lot of sports facilities. As a result, some of us registered for a course about typical Finnish sports, such as floorball, Finnish baseball and walking in the darkness.

The Science Campus with its iconic bridge spanning over the Jyväsjärvi.

Getting started in Jyväskylä – by Meike Reginka



Meike Reginka

When you first arrive in your shared flat in Jyväskylä, the student housing organization offers a survival package with necessary things like duvet, pillow, sheets, cutlery, pots and dishes. Most of the students also get themselves a second hand bicycle to get around town. Not only in order to get to university but also for free time activities bikes dominate the transportation in Jyväskylä. They can be seen all around town and even in winter with snow, ice and temperatures below zero the student city is full of bikes.

Summer, on the other hand, is shaped by long days and moderate temperatures that allow dipping in one of Jyväskylä's many lakes or even swimming to the island Lethisaari with its sauna and barbecue facilities (for the „lazy" ones the commune runs row boats for visitors). The transition between summer and winter is quick so that we had the first snow in the early November days. The Finns even have an own word for that: Ensilumi. The daytime gets rare and warmer clothes are needed. But we all agree that the lack of sunlight didn't affect us a lot, because the daily life of an Erasmus student is exciting enough to compensate this only drawback of the Finnish winter. And on our arrival back home around Christmas we realized how long the days in Germany actually are.

What is nice in summer, but surely desired in winter, is the regular sauna visit. We all experienced that Finnish sauna culture means that there are no real rules: everyone can do it as they like regarding duration, frequency, water throwing, drinks and communications. All of the student residences in Jyväskylä have a sauna schedule so that you can go to sauna in gender separated shifts or you simply book your own weekly sauna shift for a whole month for only a couple of euros. Fun fact: would you have guessed that there are at least 3 saunas on the campus, one of them next to the conference room in the nanoscience building?

The International Office at the Seminaarinmäki Campus.

Learning Finnish or "We have 15 cases, but that's only singular!"

Lucas Rickert

To calm people who are considering a stay in Finland, but are intimidated by the "horror" stories told about the Finnish language and its difficulties: you can manage totally fine completely with English in Jyväskylä, since basically all lectures are given in English; the university staff is fluent in English and also the majority of the population in the city speaks very good English. Even if you would like to refresh your English, the university offers courses on that behalf. But you still have to deal at least a little bit with Finnish: because the university requires at least 2 ECTS in a Finnish language course.

Nearly all of us chose the Intensive summer course: 4 weeks to learn the fundamentals in Finnish, which others learn over a whole semester. And since there are 30 other people from all over the world and with different academic backgrounds struggling with the language too, new friends are easily made. And we did struggle a lot! Be it the roughly 30 forms in which a word can appear according to its case or if it's singular or plural, or the fact that Finns like to create extremely long words (since Finnish is an agglutinative language, which creates context by adding more and more morphemes to a basic word). For example, the phrase "In my houses" is just taloissani, with taloi (houses), -ssa (in) and –ni (my). And that is just the written Finnish, spoken Finnish appears to be a new language itself.

Nonetheless, we ended up also completing Finnish 2, providing a basic language skill of A2. This is equivalent to grocery shopping, going out and having an easy discussion on an everyday topic completely in Finnish. But rather than this more or less useful skill for our later life, it was surely the incredible, multi-cultural and multi-academic atmosphere during the language sessions, which make us highly recommend choosing Finnish language modules during a stay in Jyväskylä.

View from the Science Campus on the frozen Jyväsjärvi.

Faculty of Mathematics and Natural Sciences - Student Representatives

We, the student representatives of faculty 10, currently consist of 12 elected members and several volunteers. Our main task is to support the interests of the faculty's students. In order to optimally represent these interests, we contribute in many councils and commissions in- and outside of the faculty, such as the faculty council and the student association conference as well as appointment committees, examination boards and further more. Simply put: we contribute to all working groups which somehow affect the students' interests. In particular, we have a say in appointment committees which choose qualified teaching staff from a number of applicants.

To keep in contact with the students and also to create an attractive campus environment at the AVZ, we host the annual summer and Christmas parties as well as the freshmen orientation, which should ease the first steps into studies. When it comes to the management of those events, we strongly depend on the helping hands of our students. Especially the summer and Christmas parties encourage the communication between the different departments by gathering the people of our faculty. Furthermore, there are three different rooms which are at any time available for the students in order to create more learning space in addition to the cafeteria and library. Moreover, these rooms are used for cheerful get-togethers and our public meetings, which usually take place every two weeks and are announced on our homepage and on Facebook.

If you have questions, suggestions or complaints, feel free to contact us by e-mail or personally in our meetings. We hope to be at your service as quickly as possible. You can also visit and support us anytime you like. We are looking forward to meeting you!

Group photo of the student representatives.

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Student Representatives

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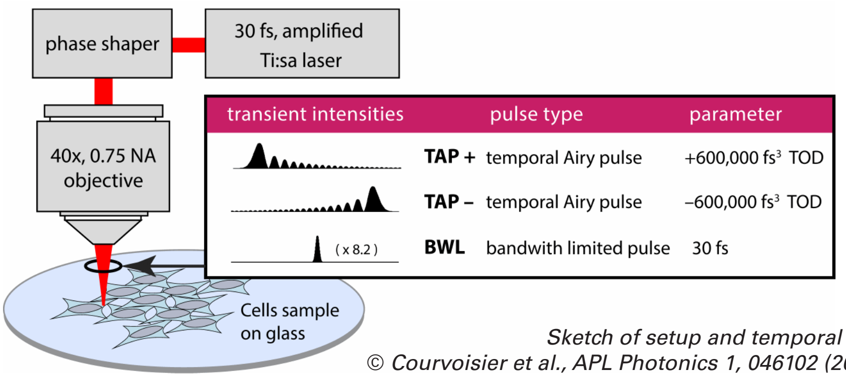
Research Highlights

Temporal Airy pulses control cell poration

Physicists of the University of Kassel and the University of Geneva explored the advantages of temporal pulse shaping for cell poration, transfection and laser surgery.

Over the last decade, physicists from the Kassel group “Experimental Physics III” - headed by Prof. Dr. Thomas Baumert - have investigated the interaction of ultrashort laser pulses and dielectrics. They established that the transient behavior of the electronic system, during excitation, is highly dependent on the temporal shape (the temporal intensity profile) of the ultrashort laser pulse. Experiments conducted in cooperation with colleagues from the GAP-Biophotonics group (Prof. Jean-Pierre Wolf) of the University of Geneva showed that this control-scheme is advantageous for the optoporation of cells. The genetic modification of cells and organisms does not only find application in biological research and medicine but is also becoming relevant for industrial aspects like hydrogen production or waste management. Aside from viral-based methods, the poration (or transfection) of cells is the key instrument for genetic manipulation: through chemical or physical processes, the outer membrane of the cell becomes transiently permeable for large molecules like strands of DNA. For poration with laser light (pulses) the energy is typically localized at the cell membrane by a plasmonic device like nano spheres and mediated by the creation of a cavitation bubble. However, the use of for example nano spheres can be problematic outside of research applications because they can be toxic to a biological system.

In first proof-of-principle experiments, dead HeLa cells (human cancer cells) were directly treated with single temporally shaped ultrashort laser pulses on a single cell level. The following examination under an electron microscope showed that the temporal pulse shape has a significant influence on the type of damage and the efficiency of poration. For example, switching pulse shapes controls the damage between clear holes and recesses damage in the cell membrane. In addition, temporary Airy pulses need less energy to reach equal poration efficiency than standard bandwidth-limited pulses. More importantly, they exhibit six times less peak intensity, which is expected to reduce phototoxicity to the cell. This year, trials with living cells* have begun. A clever combination of fluorescent dyes enables the international research team to differentiate between successful and non-successful poration as well as dead and surviving cells within a single experiment.



Sketch of setup and temporal pulse shapes.
© Courvoisier et al., APL Photonics 1, 046102 (2016) (adapted)

**The authors would like to thank the CINSaT member Prof. Dr. Markus Maniak and his co-workers in the Department of Cell Biology in Kassel for providing help and equipment for the live cell experiments.*

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Further Information

http://aip.scitation.org/doi/10.1063/1.4948367

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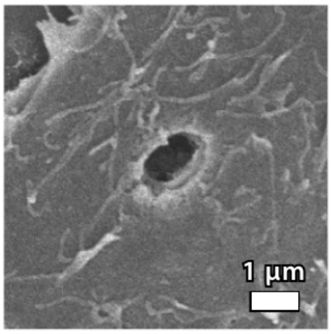

SEM image cell porated with single ultrashort laser pulse. © Courvoisier et al., APL Photonics 1, 046102 (2016) (adapted)

CINSaT members explore the interface of liquid and gas phase water

Despite its importance, the structure and dynamics of liquid water are still poorly understood in many aspects. Very recently, a group, led by CINSaT's Dr. André Knie, took a step further and reported the observation of optical fluorescence upon soft X-ray irradiation of liquid water. Detection of spectrally resolved fluorescence was achieved by a combination of a few tens of a micron liquid microjet in vacuum and synchrotron radiation based fluorescence spectroscopy. They observed a genuine liquid-phase fluorescence manifested by a broad emission band in the 170–340 nm (4–7 eV) photon wavelength range. In addition, another narrower emission near 300 nm could be assigned to the fluorescence of OH (A state) in the gas phase, the emitting species being formed by Auger electrons escaping from liquid water.

The discovered broad liquid-phase emission band is regarded as a new spectroscopic fingerprint of electronically excited liquid water, which can be utilized in the search for water in the liquid phase in interstellar space. Both features can also be used for the investigation of the dynamics of liquid water both on the surface and in the bulk of the liquid, and are believed to find several future applications. The researchers particularly envision the Auger electron induced excitation across the interface as a potential novel tool for the characterization of aqueous-solution–air interfaces. The technique they presented can also contribute to advances in the emerging technology in X-ray excited luminescence, e.g., in the field of biomedical imaging.

In a CINSaT context, the liquid microjet as well as its combination with fluorescence spectroscopy could be applied to any liquid or soluble sample. Soon, it will be combined with electron impact excitation for further investigations of the interface region of liquids, solutes and nano-particles.

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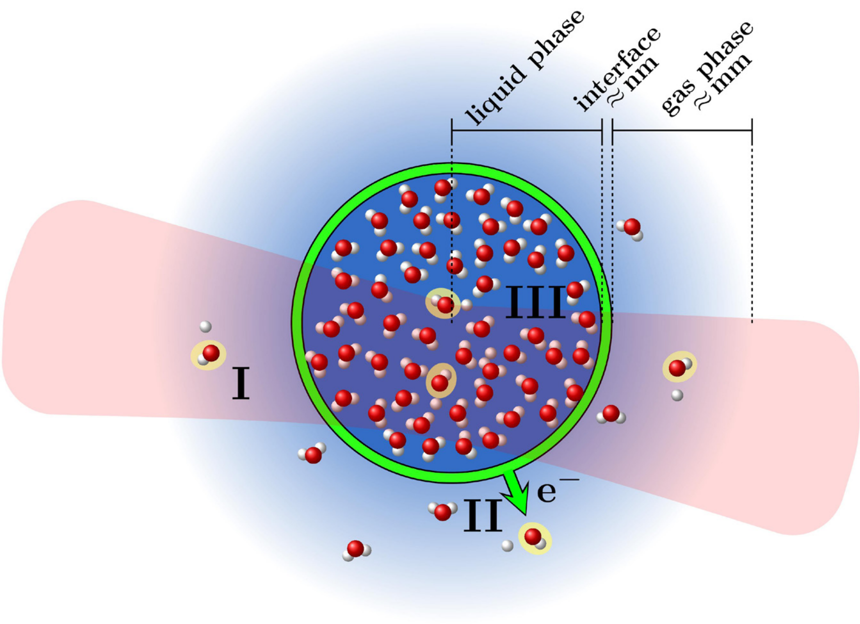
Further Information
http://pubs.acs.org/doi/abs/10.1021/



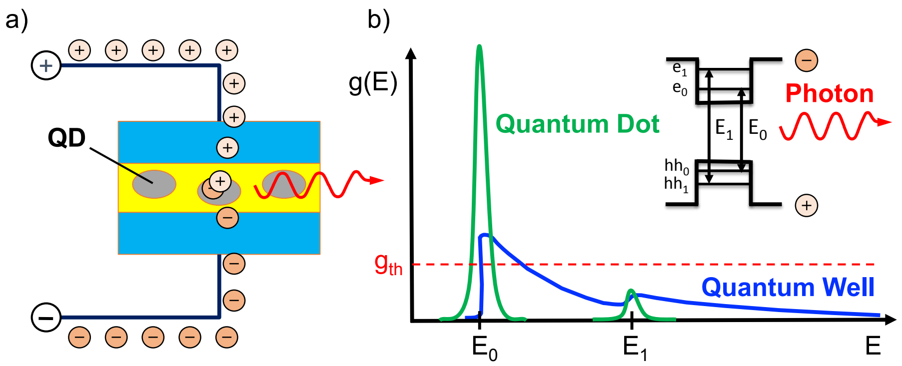
Sketch of the experiment and the findings: The synchrotron light (indicated in shaded red) interacts with the liquid microjet (depicted as a cut through the jet at the interaction region). Around the liquid (dark blue) the evaporating water molecules form a decreasing density gas phase layer (gradient blue) in the vacuum of the experiment. The X-ray photons interact with the gas phase molecules (I) leading to ionization, dissociation and fluorescence. Within the first few nm of the liquid (interface region green) emitted electrons can escape the liquid and scatter with surrounding molecules leading to distinct fluorescence signals (II). Inside the bulk of the liquid free electrons and a range of excited molecules and radicals result in a very wide fluorescence band (III). (Reprinted with permission from Hans et al., J. Phys. Chem. B 121 (10). Copyright 2017 American Society)

Quantum dot laser

Researchers at University of Kassel and Technion (Haifa, Israel) obtained new record values for modulation speed, temperature stability and emission linewidth in quantum dot lasers.

Since the invention of the semiconductor laser in 1962, one of the major driving forces for the development of this key optoelectronic device is the application in optical communication. Due to the strongly increasing demand in communication capacity, in particular in recent years by smartphones and video on demand, novel ideas are necessary to follow up the bandwidth requests in the future. Nanotechnology can significantly contribute bringing quantum physics into play to overcome current limitations in device performance.

Over the last few years, the research group of Prof. Dr. Johann Peter Reithmaier at the Institute of Nanostructure Technologies and Analytics (INA) has worked intensively in cooperation with the research group of Prof. Dr. Gadi Eisenstein at the Israel Institute of Technology in Haifa (Israel) and the theory group of Prof. Dr. Bernd Witzigmann, head of the Computational Electronics and Photonics group at electrical engineering department of the University of Kassel, on the development of novel laser materials and laser devices based on quantum dots. Recently, these joint groups succeeded in obtaining new record values, out-performing any type of quantum dot laser in modulation speed, temperature stability and emission linewidth.



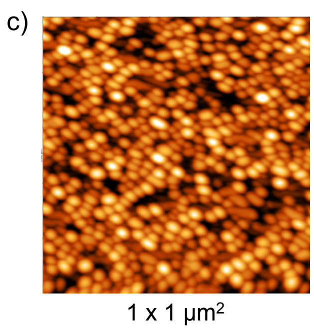


Fig. 1. a) Schematic illustration of carrier injection into a QD laser diode; b) optical gain shown schematically as function of the energy for a quantum dot and well material system (g_{th} = threshold gain). The inset shows possible optical transitions in a confined semiconductor quantum system between electron and hole states. c) Atomic force microscopy (AFM) picture of InAs QD layer grown on an InGaAlAs/InP heterostructure. The QD heights are about 3-5 nm, lateral widths at about 10-15 nm.

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The basic idea for this breakthrough is to realize a nanostructured semiconductor material which allows to use the injected carriers in an electrically driven device in the most efficient way for light generation. In conventional semiconductor laser diodes, the active material consists of quantum wells (QW) confining electrons only in one direction. In a quantum dot (QD) laser, the electrons and holes will be confined in all three dimensions and the charge carriers can only recombine at the QD locations, as schematically illustrated in Fig. 1 a). In Fig. 1 b), the optical gain of a quantum well and of a nearly ideal QD material can be seen. The inset shows the allowed optical transitions between electron and hole states in a quantized semiconductor quantum system corresponding to the transition energies E_0 and E_1 of the main plot. In this plot, the fundamental difference between QW and QD material behavior is depicted. In a QW material, the charge carriers are distributed over a wide energy range resulting in a broadened optical gain. However, only the carriers contributing to the gain above the threshold gain g_{th} are used for laser light generation. In a QD material the transition energies are discrete and mainly concentrated at the ground state transition E_0. This results in a much more efficient usage of carriers than in the conventional quantum well case. As a consequence, many laser properties, like threshold current, modulation speed, temperature stability, and laser linewidth are directly related to it. However, as seen in Fig. 1c), the real QD material shows significant dot size variation, which leads to a larger variation of transition energies in comparison to a single QD or an ideal homogeneous QD material. For a long time in QD laser material development these size fluctuations have prevented to utilize many of the basic properties of ideal QD materials with atom-like features. Only very recently [1], the QD size variation could be significantly reduced to a level which allows to utilize several properties related to atom-like features in a solid-state optical gain material for the first time.

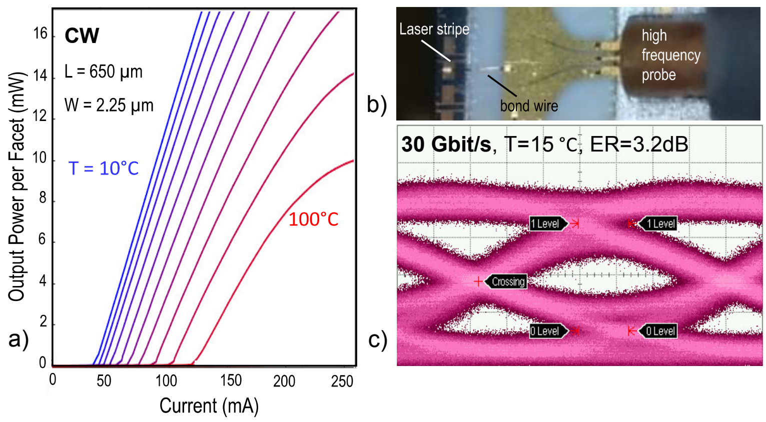


Fig. 2. a) Light-output characteristics of a QD laser with a ridge waveguide geometry (width = 2.25 µm, length = 650 µm) at operation temperatures of 10 up to 100 °C (in steps of 10 K); b) Optical microscope picture of a 340 µm long laser mounted on a high-frequency submount (only one laser of an array is bonded). The ceramic piece is for impedance matching between the 50 Ohm probe and the 3-5 Ohm resistance of the laser; eye-diagram of directly modulated QD laser at a pseudo random digital modulation speed of 30 GBit/s (ER = extinction ratio).

The joint research effort results in highly temperature stable lasers for the long-wavelength (1.55 µm) telecommunication wavelength range based on this new generation of QD laser material. These InP-based lasers show, in comparison to conventional QW lasers made in the same material system, strongly improved temperature stability with pulsed operation temperatures up to 195 °C. In Fig. 2 a), light-output characteristics of lasers operated in continuous-wave (cw) for different operation temperatures are shown with very low temperature dependence of threshold current and slope. In Fig. 2 b), a short 340 µm long cavity laser is shown, mounted on a high-frequency (HF) submount and contacted by an HF probe. In Fig. 2 c), an eye-diagram is shown for digital modulation of the laser operated at a data rate of 30 GBit/s. The diagram shows the arbitrary overlap of „0“ and „1“ intensity states generated by a pseudo random bit generator. If there is a clear open eye, one can easily distinguish between the two digital states. The maximum data rate obtained with such lasers is 35 GBit/s, which is a record value for any QD laser [2]. With such lasers, it would be possible to realize next generation 400 GBit/s data links based on 16 wavelength channels, which is a goal in the European research project „SEQUOIA“ [3].

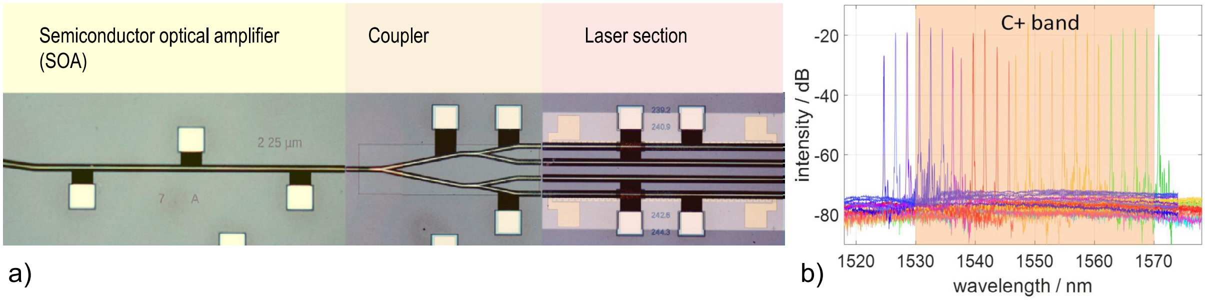


Fig. 3. a) Optical microscope picture of an integrated narrow-linewidth widely tunable light source. The chip consists of three functional sections and an array of DFB lasers with different grating periods (thin stripes on the right). Nearby the lasers, micro-heaters are integrated. The rectangular structures are contact pads for electrical injection; b) emission spectra of the laser chip for different operation temperatures of a single laser. By operating different lasers one after the other, a wavelength range of 46 nm can be covered quasi-continuously.

Within the frame of another European-wide organized project „SASER" [4], the joint research group worked on narrow-linewidth lasers based on similar QD laser material. Here, a monolithically integrated narrow-linewidth light source has been developed for future high-capacity backbone networks heading for data rates of multi-TBit/s up to 100 TBit/s. In this case, coherent communication is established, where data is encoded in amplitude, phase and polarization for each wavelength. To decode the phase of an optical wave, one needs a stable reference laser which can be tuned in wavelength for the different wavelength channels. In Fig. 3 a), a micro-scope picture of the laser chip is shown, which consists of an array of 4 DFB lasers (DFB = distributed feedback) emitting at different wavelengths related to the grating period, a waveguide coupler section and an optical amplifier to compensate the optical losses in the coupling section. For the first time, these types of devices were realized with a QD material and show record narrow emission linewidths down to 110 kHz (i.e., 2x109 times less than the emission wavelength of 1.55 μm) [5]. In Fig. 3 b), the emission spectra are shown for different operation conditions which allow a wavelength tuning over more than the C+ communication band between 1530 and 1570 nm.

There is currently a large interest by the semiconductor and optical communication industry to implement this disruptive QD technology in mass products on a chip level, in particular integrated with silicon chip technology, for low-cost high-speed optical communication in computer centers and main frame computers, in high-capacity backbone networks as well as for on-chip integration in future highly-integrated microelectronics.

[1] S. Banyoudeh, J.P. Reithmaier, „High-density 1.55 μm InAs/InP(100) based quantum dots with reduced size inhomo geneity", J. Cryst. Growth 425, pp. 299-302 (2015).

[2] S. Banyoudeh, A. Abdollahinia, V. Sichkovskyi, O. Eyal, G. Eisenstein, J.P. Reithmaier, „Temperature-Insensitive High-Speed Directly Modu-lated 1.5 μm Quantum Dot Laser", IEEE Photon. Technol. Lett. 28 (21), pp. 2451-2455 (2016).

[3] EU project „SEQUOIA", link: http://www.uni-kassel.de/projekte/sequoia/home.html

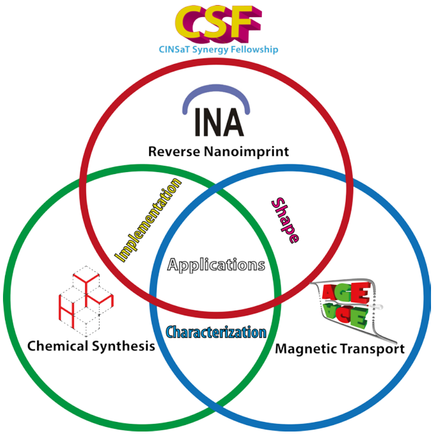
[4] Eureka-project „SASER", link: http://projects.celticplus.eu/saser/, funded by BMBF

[5] Becker, V. Sichkovskyi, M. Bjelica, A, Rippien, F. Schnabel, M. Kaiser, O. Eyal, B. Witzigmann, G. Eisenstein and J.P. Reithmaier, „Widely Tunable Narrow-Linewidth 1.5 μm Light Source Based on a Monolithically Integrated Quantum Dot Laser Array" Appl. Phys. Lett. 110, 181103 (2017).

New Projects

Functionalizable particles with magnetic properties

Three groups joined forces to create a new research strategy in the multidisciplinary field of designed, functionalized micro- and nanoparticles combining the knowledge of engineers, chemists and physicists alike.



The beginning

Honoring the spirit of CINSaT, three PhD students from different fields of expertise (chemistry, electrochemical engineering, and physics) realized that combining their skills may create a new long-term research strategy towards the fabrication, characterization and application of designed, functionalized micro- and nanoparticles.

It all started a few years ago with a conversation between the group heads Hillmer, Pietschnig and Ehresmann on whether and how the nanoimprint technique can be used to fabricate functionalized micro- and nanoparticles of defined shape. While the Hillmer group has an outstanding expertise in a variety of nanoimprint techniques, the Pietschnig group adds expertise for a functionalization by chemical methods, and the Ehresmann group adds expertise for a functionalization by physical methods.

Therefore, ideas were discussed to use rare earth metals in imprinted polymer micro- and nanoparticles as guest-host systems for optical functionalization and magnetic thin film coverage or embedded magnetic nanoparticles for an actuation of the particles. Although these ideas were fascinating, none of the PhD students of the three groups at that time started practical work on these topics.

During the last few months, however, based on discussions that led to finding common goals for their doctoral works, the three students have decided to devote their time and skills to this research strategy. During the spring meeting of the members of CINSaT, the students have presented their preliminary results and how the collaboration is coming together from their part. In two proof of concept works it has been shown that the functionalization of particles by implementing rare earth metals as guest particles in a guest-host system is possible for specifically designed particle shapes. A proof of concept work carried out by the two PhD students Dipl.-NanoSc. Uh-Myong Ha (INA) and M.Sc. Kristijan Krekić (HYM) as well as their co-supervised student B.Sc. Burhan Kaban. A follow-up proof of concept has been carried out by M.Sc. Andreea Tomiţa and B.Sc. Jendrik Gördes (AGE) who covered the shape-designed polymer particles, fabricated by Uh-Myong, with magnetic layers with specific characteristics and devised a method for their magnetic characterization.

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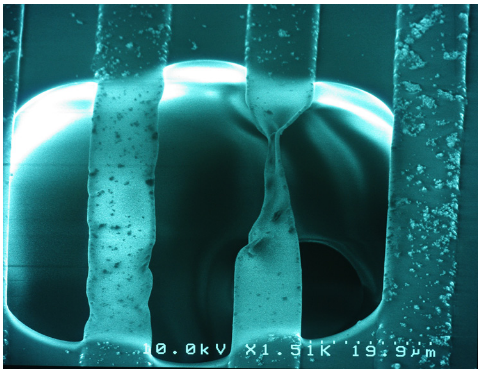
Since this is an ongoing research, additional cooperation with other CINSaT group members are in progress and welcome.

Scientific purpose

The project focuses on fabricating imprinted particles with magnetic and fluorescent properties and functionalizable surface that can be delivered within a magnetic transport system where the importance of shape, magnetic content and distribution is studied. The structures are created with the Reversal Imprint technique (RIMP), adequately adapted for the experimental purposes by Uh-Myong Ha, where the polymer is spin-coated over the stamp, this being a more efficient way to avoid defects, especially since the polymer is doped with the magnetic nanoparticles synthesized by Kristijan Krekić within a ligand matrix. The resulting particles are characterized magnetically and topologically by Andreea Tomița and then added to the magnetic environment for transportation.

The characteristics of the newly created particles make them efficient to use in dynamics studies due to their shape variety and in sensor applications because of the ligand's luminescent properties. Using the properties of rare earth metal complexes and the high precision of nanoimprint lithography it is possible to fabricate highly tailored particles for directed transport over a magnetically patterned substrate. The long-term goal of this cooperation is the fabrication of a transport/sensor system in which the magnetic and fluorescent guest-host particles with specific shapes will enable further research and bring improvements for lab-on-a-chip types of devices.



SEM-image of Eu_2O_3 implemented AMONIL microfibers.

Metal-organic coordination polymers under UV light (366 nm). Color variation based upon different metals or their combinations: Europium (red), Terbium (green) and Yttrium (blue).

Project team members (from left to right): Jendrik Gördes, Andreea Tomița, Uh-Myong Ha, Kristijan Krekić and Burhan Kaban.

Mechanisms of protein-insertion into biomembranes

New DFG funded research project

The biophysics department led by Prof. Dr. Jörg H. Kleinschmidt investigates biological machines responsible for the insertion of membrane proteins into biological membranes.

Biomembranes separate cells and cell organelles from their environment and preserve their structural integrity. Gram-negative bacteria and various cell organelles of eukaryotic cells are enclosed by two membranes, an inner and an outer membrane. Membranes are phospholipid bilayers that contain integral and peripheral proteins. While the bilayer imposes a hydrophobic barrier against the arbitrary diffusion of solutes, integral proteins, also called transmembrane proteins, span the bilayer and are essential for transport of nutrients and other metabolic solutes across membranes as well as for signaling events from one side of the membrane to the other. Based on the structure of their transmembrane domains, transmembrane proteins can be divided into two classes: α-helical and ß-barrel membrane proteins. Typically, the diameters of the transmembrane domains are a few nanometers.

In pioneering work, Kleinschmidt et al. previously demonstrated that ß-barrel membrane proteins insert into membranes via a highly concerted mechanism, in which folding of secondary and tertiary structure are synchronized and coupled to membrane insertion. In cells, folding and insertion of membrane proteins is facilitated by molecular chaperones that prevent misfolding and by a machinery that catalyzes folding and insertion. How this machinery works is not well understood, but the machines are essential for membrane biogenesis and cell growth. For outer membrane proteins in bacteria and mitochondria of eukaryotic cells, the ß-barrel assembly machinery (BAM) complex is vital. While the main function of BAM complexes is evolutionarily conserved, the composition and structure of the BAM complex varies. Structural differences between BAM-complexes of bacteria and BAM complexes of cell organelles of eukaryotic cells can potentially be exploited to design new classes of antibiotics, for example against the multi-drug resistant bacteria in hospitals (also known as superbugs).

To explore the function and mechanisms of several proteins of the BAM complex of bacteria, the biophysics team of the University of Kassel uses a combination of molecular biology, biochemistry and spectroscopy. Site-directed fluorescence quenching, site-directed fluorescence energy transfer and sited-directed electron spin resonance spectroscopy provide details not only on structure, thermodynamics and kinetics of interactions but also on the location and sequence of intra- and intermolecular interactions in protein folding events.

In February 2017, a new DFG funded project (340.000,- €) has started to explore the roles of the two essential proteins, BamA and BamD, in membrane insertion and folding of ß-barrel membrane proteins.

reference: public relations department University of Kassel

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http://www.membranproteine.net

http://www.uni-kassel.de/fb10/institute/biologie/fachgebiete/biophysik/home.html

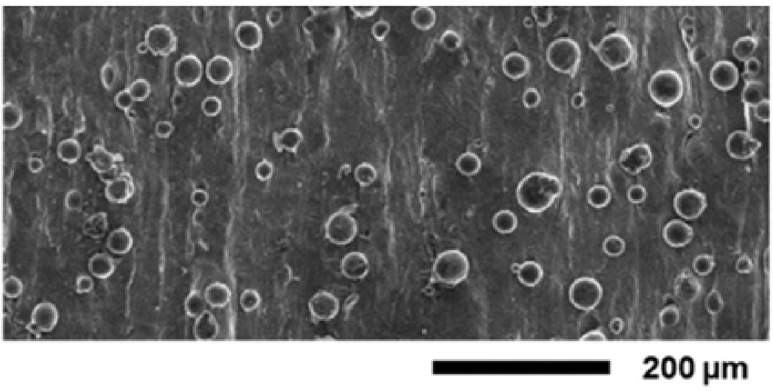
New Coordinated Projects
PROTON

The project „Process-integrated manufacturing of tribological stressed surfaces (PROTON)" headed by Prof. Dr. Angelika Brücknet-Foit is conducted with the participation of two CINSaT members.

Additive manufacturing (AM) enables for production of structures and components of unprecedented complexity solely from CAD-data. Structures to be directly employed in application are manufactured layer by layer from a powder bed. For local melting of metallic powders high-power energy sources such as lasers are employed (Selective Laser Melting, SLM). Current limitations linked to AM processes such as porosity and surface roughness demand post-process treatments with respect to robust applications in numerous fields.

In the framework of the PROTON project surface conditions will be established by AM that allow for direct use of the components under tribological loading conditions, i.e., dry and lubricated contact under superimposed mechanical loading. Optimized wear resistance and/or lubrication are essential for obtaining robust surfaces. The key is to develop new approaches for process integrated surface and microstructure design, respectively. The materials in focus will be steels. Surfaces manufactured will be thoroughly tested by appropriate loadings.

In order to reach the ambitious goals of the project, an interdisciplinary research team has agreed to collaborate on the topic. Besides groups from the faculty of mechanical engineering, members of CINSaT will contribute by bringing in their expertise in the fields of surface modification by femto-second laser (Prof. Baumert) and topology characterization by advanced techniques (Prof. Lehmann). Process and material design for AM will be the topic in focus of the group of Prof. Niendorf.



Rough surface of an additively processed steel. In the framework of the PROTON project surfaces will be tailored for robust application under tribological load.

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PhosMOrg

„PhosMOrg: Phosphoregulation of Biomolecules – from Mechanisms to Organisms“ is a joined research project coordinated by Prof. Dr. Raffael Schaffrath under participation of four further CINSaT members.

Life of all organisms critically depends on proteins and other biomolecules. Their modification by addition or removal of phosphates (phosphorylation/dephosphorylation) constitutes an important means for cells to regulate processes as vital as growth, division or morphogenesis (Fig. 1). Phosphomodifications are also crucial for synthesis of complex biominerals including highly ordered silicate skeletons of diatoms (Fig. 1). Phosphorylation by dedicated enzymes (protein kinases) can alter the charge or conformation of the modified protein thereby changing its biological activity. Therefore, protein kinases represent molecular 'on/off' switches that orchestrate chemical signals with proper cellular behaviour (Fig. 1). Accordingly, improper phosphorylation due to kinase defects can lead to severe human diseases including cancer, neuropathies or chronic inflammation. To study phosphotransfer and kinase mechanisms at the molecular level and to better understand how phosphorylation controls biological output (intracellular signalling, morphogenesis of complex biological patterns, Fig. 1), PhosMOrg has teamed-up CINSaT members (Fig. 2) with interdisciplinary expertise in kinase biology (Herberg, Müller, Schaffrath), nanochemistry (Fuhrmann-Lieker) and biomolecular modelling (Garcia).

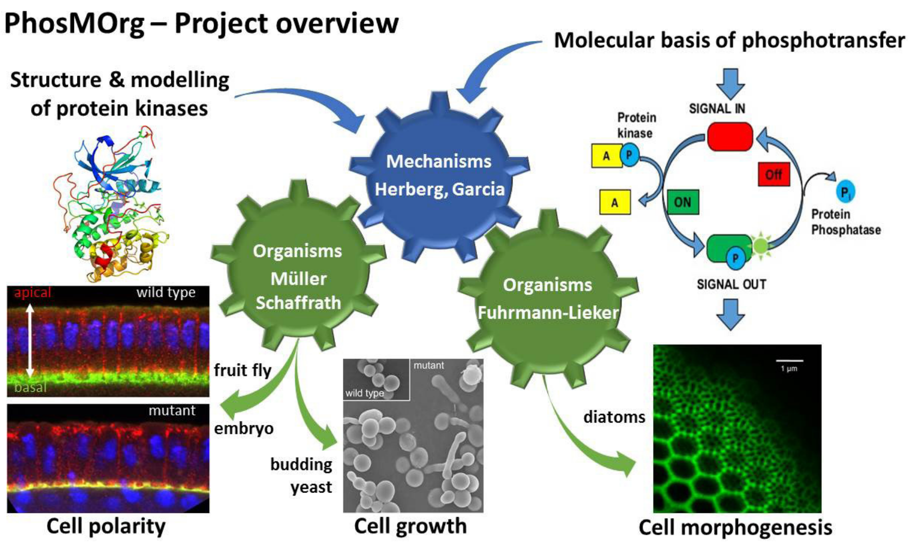

Fig. 1: PhosMOrg overview and principle. Phosphoregulation of protein function and cell behavior involves signal (in/out) transduction that changes protein activity by 'on/off' phosphorylation switches (protein kinases and phosphatase; A: ATP; P: phosphate; scheme on top, left). PhosMOrg addresses processes as diverse as formation of polarized epithelial cell layers in fly embryos (cell polarity, bottom left), yeast budding (cell growth, bottom middle) and exoskeleton synthesis in diatoms (cell morphogenesis, bottom right). 'Mutant' refers to defects in fly MAST kinase or yeast casein kinase. Micrographs are from the Müller, Schaffrath and Fuhrmann-Lieker groups. Blue and green gear-wheels denote consortium members' main expertise (mechanism vs. organism).

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Using a unique combination of in vivo, in vitro and in silico methods, PhosMOrg aims to:

- study phosphate transfer from the donor ATP to target molecules
- determine the molecular mechanisms of protein kinase regulation
- model how phosphorylation affects protein conformation and function
- investigate how phosphorylation instructs cell shape and polarity
- examine how phosphotransfer controls RNA modification and gene expression
- study how phosphorylation allows biomimetic design of nano-objects

PhosMOrg will recruit an excellent cohort of PhD students (1 per member) in order to advance our understanding of phosphoregulation (Herberg, Garcia) during morphogenesis (Müller, Fuhrmann-Lieker) and cell growth (Schaffrath) and to provide a nucleus for a new collaborative research unit (DFG-Forschergruppe).

Further information:
Website: http://www.uni-kassel.de/fb10/institute/phosmorg (under construction)

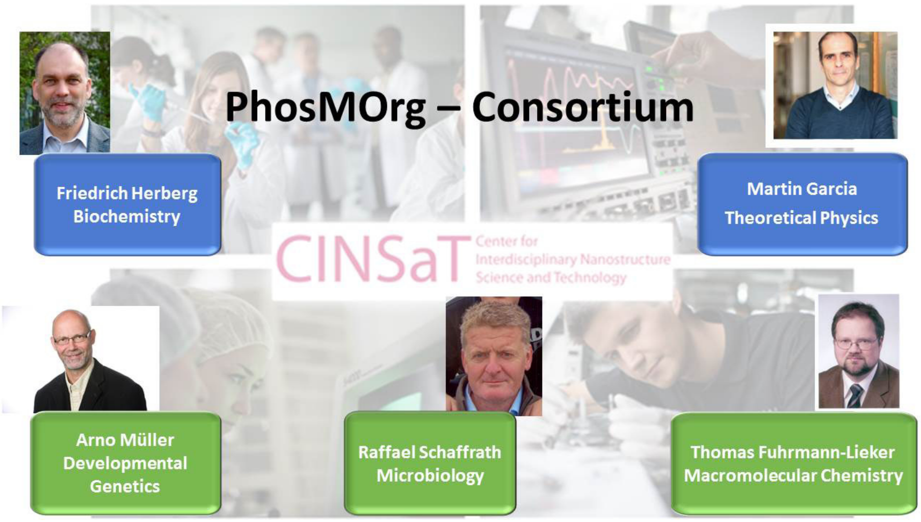

Fig. 2: PhosMOrg consortium. Blue & green boxes highlight the expertise of individual members (mechanisms vs. organisms). PhosMOrg coordination: Prof. Schaffrath (substitute: Prof. Herberg).

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New Members

Laboratory Astrophysics - Faculty 10

One of the most surprising discoveries of twentieth-century astrophysics was the omnipresence of molecules found in giant interstellar clouds, the home of stars and their accompanying planetary systems. Predominantly of organic origin, interstellar molecules bear witness to chemical evolution as a general theme and suggest the formation of life as a universal and likely scenario in space. In the context, nano-sized dust particles play a crucial role in astro-chemistry. Expelled from stellar atmospheres, they can act as catalysts of a complex interstellar chemistry, featuring molecular growth which finally leads to the formation of pre-biotic molecules. The advent of new Terahertz- and Infrared-telescopes of breathtaking sensitivity and angular resolution offers a closer and detailed look at stellar environments where dust particles and molecules are formed. The interplay of gas phase and solid phase chemistry is encoded in the spectra of stars, planetary systems and interstellar clouds. It is the role of laboratory astrophysics to decipher astrophysical spectra by means of laboratory studies. Another focus of interest are chiral molecules which are studied by Terahertz- and Infrared-spectroscopy. The structure and dynamics of chiral molecules in the gas-phase are of fundamental interest. Particularly, the tunneling behavior of chiral molecules as a function of rotational-vibrational excitation is under investigation using narrow-band phase-stabilized infrared lasers and THz-multiplier chains.

Prof. Dr. Thomas Giesen studied physics at the University of Cologne where he received his PhD in 1992. He was awarded a stipend of the Max-Kade foundation and started his postdoctoral research on small carbon clusters at the University of California, Berkeley. In 1994, he returned to the University of Cologne where he conducted gas-phase infrared laser spectroscopy experiments of carbon chains, e.g., linear C_8 and C_{10}, and other carbon containing molecules of astrophysical relevance. After his habilitation at the University of Cologne in 2001 he accepted an offer as Interim Professor and Chair of the Physical Chemistry Department at the University Wuppertal. From 2004 – 2014 he was Co-PI of the European FP6 projects "Molecular Universe" and "QUASAAR" and the DFG CRC "Conditions and Impact of Star Formation". He is Co-Investigator of the Herschel satellite programs HEXOS and PRISMAS and member of the executive committee of the European Task Force for Laboratory Astrophysics (EFTLA). In 2003 he received the Sir Thompson Memorial Award and in 2007 the Albertus-Magnus-Teaching Award. From 2009 to 2012 he held a position as adjunct professor at the University of Cologne, and since 2012 he is professor for experimental physics at the University of Kassel. Prof. Giesen is member of the CINSaT since 2015, where he and his team contribute to high precision THz- and IR-spectroscopy on chiral molecules and to investigations on astrophysical molecules that form nanoparticles.

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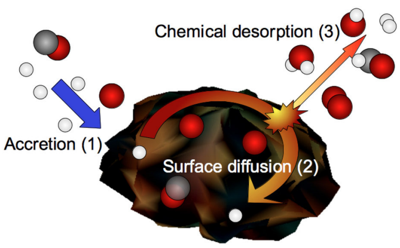
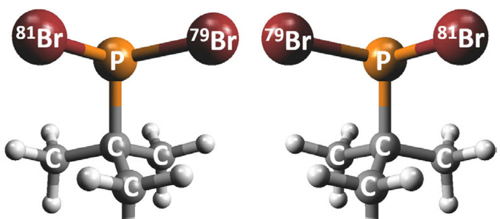
Prof. Giesen at IRAM 30 m telescope.



Surface chemistry on nano-sized dust particle.(Adapted by permission from Macmillan Publishers Ltd: Dulieu et al., Scientific Reports 3, 1338 (2013), copyright 2013))



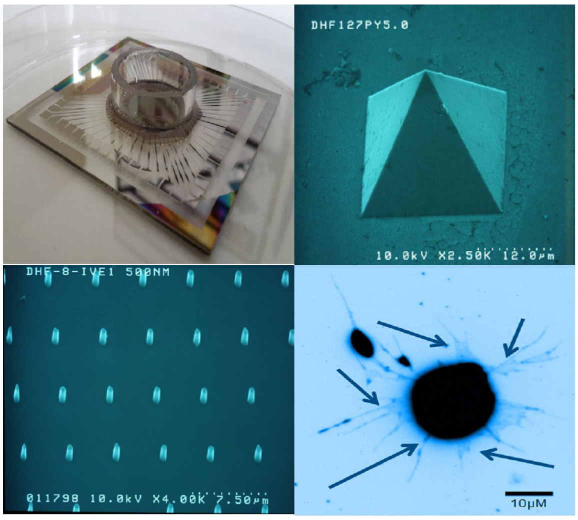
Tert-butyl dibromophosphane: The main isotopologue t-BuPBr^{79}Br^{81} is chiral.

Nano Diamond - Faculty 10

PD Dr. habil Cyril Popov has received his M.Sc. in Chemical Engineering in 1990 and PhD in 1994 from the University of Chemical Technology and Metallurgy, Sofia, Bulgaria. In the period between 1995-1997, he was a postdoc at the National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan, and at the Central Laboratory of Photoprocesses, Bulgarian Academy of Sciences, Sofia, working on preparation and investigation of novel materials in the ternary system B-C-N. In 1998, he joined the Institute of Nanostructure Technologies and Analytics (INA), University of Kassel, where at the present he is leader of the Nano Diamond Group. For almost 15 years, His research interests cover deposition, characterization and applications of nano- and ultrananocrystalline diamond films.

Diamond is a material with excellent mechanical, optical, thermal, electronic, and chemical properties, which make it of potential interest for a wide spectrum of applications. In the CINSaT research focus "Biosensing" the cooperation with the Dept. of Animal Physiology (Prof. Stengl) aims at the development of diamond-based platforms for long-term growth and investigation of neurons relying on their fast and strong attachment on modified ultrananocrystalline diamond surfaces. Together with the Group of Biotechnology, Dept. of Biochemistry (Dr. Pavlidis) such surfaces are functionalized with enzymes for realization of continuous flow biocatalytic systems.

Another group of projects of Cyril Popov addresses the CINSaT research focus "Photonics". The cooperation with Dept. of Experimental Physics I, Light-Matter Interaction (Prof. Singer) is directed to the preparation of diamond nanopillars and AFM tips with deterministically incorporated color centers to serve as quantum coins and nano-sensors. The design and fabrication of diamond photonic crystals is supported by the Dept. of Computational Electronics and Photonics (Prof. Witzigmann) with simulations of the structures. Further projects will be dedicated to the investigation of diamond as material for plasmonic applications together with the Dept. of Nanophotonics (Prof. Kusserow) and the coating with diamond films of novel alloys based on Ti or Fe for bio-applications prepared by additive manufacturing by the Dept. of Metallic Materials (Prof. Niendorf).



Nano diamond structures.

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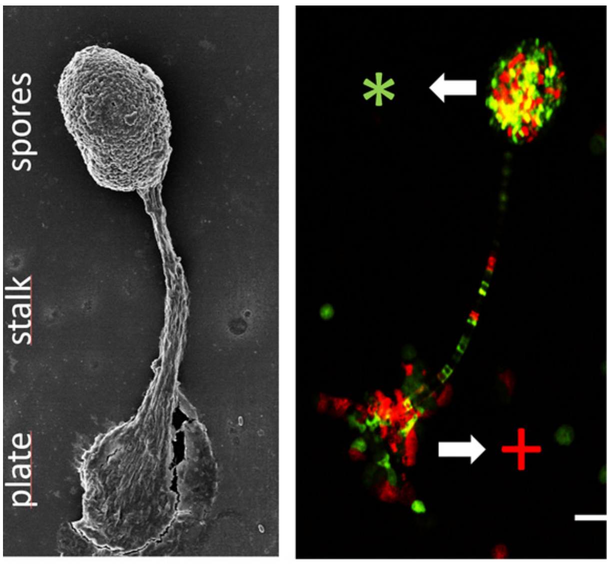
Research Groups

Cell Biology - Faculty 10

Professor Dr. Markus Maniak was one of the founding members of CINSaT, teaming up with colleagues from chemistry, physics and engineering to initiate interdisciplinary projects back in July 2000. From the following 5-6 years of work, a couple of publications arose, ranging from the improvement of optical resolution in light microscopy over techniques to reveal the inner structure of cells for the scanning electron microscope to the production of light-emitting diatoms and their use as photonic crystals.

The past ten years witnessed a shift to more genuine biological questions that were solved in international and local (with Prof. Herberg) collaborations. One focus was the development of hybrid proteins tools to perform micro- and nanomanipulations within living cells. To achieve this goal, fine tuning by molecular biology techniques was needed to arrive at the most effective protein dosage and highly localized cellular action. A rather early but nonetheless spectacular success was the destruction of the cell's actin-cytoskeleton surrounding a specific organelle, the endosome, with sub- 100 nanometres precision.

In parallel, the present focus of Prof. Maniak's laboratory is the elucidation of the lipid metabolism in the amoeba Dictyostelium. Now, the path of a fatty acid can be followed with high precision from uptake through the endosomal membrane over transfer to the endoplasmic reticulum and transient storage in lipid droplets to degradation in peroxisomes. The key enzymes mediating the biochemical conversions were characterized using gene knock-out mutants. The group currently also aims at understanding the transport of proteins from one organelle to the other at highest possible resolution using individually positioned cysteine amino acids as sensors for their biochemical environment. Finally, it came as an evolutionary surprise that Dictyostelium cells which carry fat-reserves are not resistant to starvation (like all other known organisms are) but are rather eliminated during development and thus do not appear in the next generation (see Figure). Current collaborative projects within the CINSaT include analyzing features of nanoparticles fabricated via imprint lithography (with Prof. Hillmer) and the infiltration of hollow micro-cylinders with optically active materials (with Prof. Kusserow).



Left: Scanning electron micrograph of a Dictyostelium fruiting body assembled from 100,000 cells after starvation. Right: The cells that have fat reserves (red) predominate in the dead (+) basal plate, whereas most of the green cells form surviving (*) spore cells. The size of the whole structure is about 500 μm.

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Nanophotonics - Faculty 10

The Nanophotonics group was established in 2014 as a junior professorship in FB 16 Electrical Engineering/Computer Science and is part of the Institute of Nanostructure Technologies and Analytics. Current research activities are focused on the interaction of optical waves with nanostructures and on new materials for nano-optics. Additionally, the required technological processes and characterization methods are developed and improved.

Periodic patterns, like photonic crystals, are implemented for filter applications with spectral or polarization selectivity. A new technology to structure dielectric materials based on temporally shaped fs-laser pulses is investigated with the group of Thomas Baumert. This method is not only unaffected by surface charge build-up but also provides structure dimensions below the diffraction limit with aspect ratios up to 25:1. In another research topic, vertical emitting laser devices (VCSEL) with new design approaches are developed. One goal is to improve the emission by utilizing more active volume and optimizing the overlap with a laser mode. This can be achieved, e.g., with a thin film stack having varying layer thicknesses that distributes the resonant cavity. As active material several options, like colloidal quantum dots, are tested.

The third area of research is focused on finding, studying and modifying new materials for nano-optical applications. Similar to the significance of Silicon for microelectronics, Gold is the mostly used material in plasmonics. But new materials with tailored properties can help to widen the spectrum of nano-optical devices. The desired optical properties are achieved by either high doping of materials (e.g. GaN, Diamond) or "diluting" metals (e.g. ZrN). In all areas a strong collaboration in CINSaT, most notably with the groups of Hartmut Hillmer, Bernd Witzigmann, Thomas Fuhrmann-Lieker, Markus Maniak, Thomas Baumert, and Cyril Popov, as well as with external partners (e.g., NTU Singapore) is existing. Research is accompanied by lectures, seminars and lab work on optics, technology, characterization methods, and nanophotonics. In most teaching activities and thesis works other members of CINSaT are involved, which proves to be very fruitful for students and teachers alike.

Photo of the Nanophotonics group.

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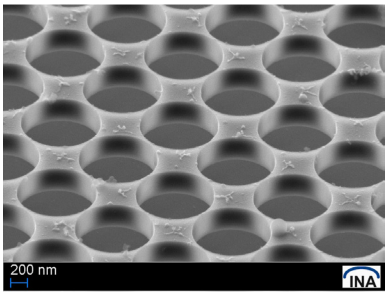
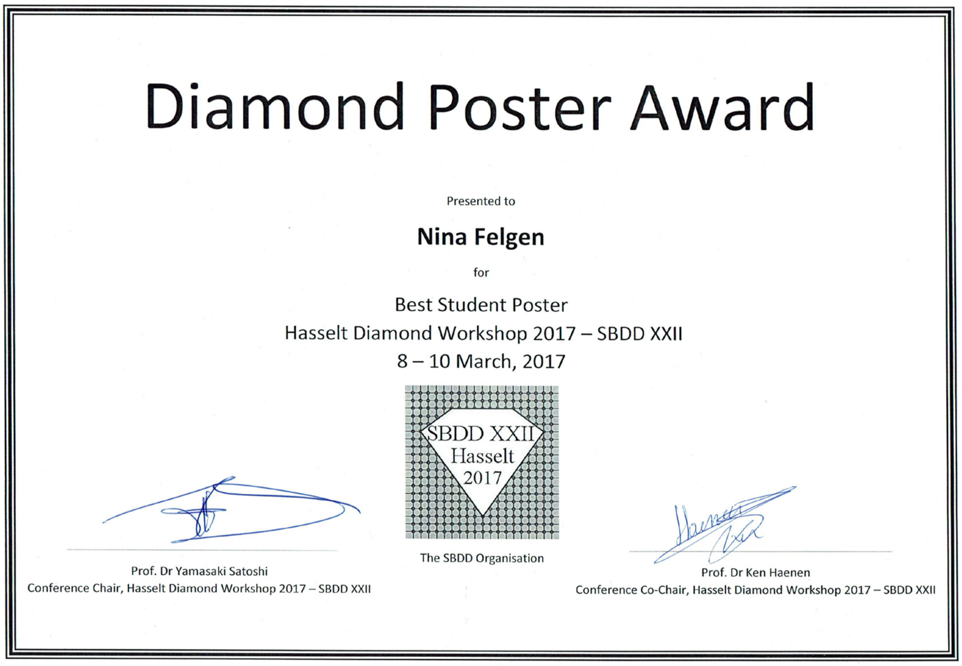


Scanning electron microscope image of a photonic crystal.

Awards

Diamond Poster Award for Nina Felgen

Nina Felgen won the Diamond Poster Award at the Hasselt Diamond Workshop 2017 (SBDD XXII, 8-10 March 2017, Hasselt, Belgium) for the poster „Fabrication and characterization of diamond photonic structures“ with co-authors Friedhard Römer and Bernd Witzigmann (Department of Computational Electronics and Photonics, CINSaT, University of Kassel), Boris Naydenov and Fedor Jelezko (Institute of Quantum Optics, University of Ulm), and Johann Peter Reithmaier and Cyril Popov (Institute of Nanostructure Technologies and Analytics, CINSaT, University of Kassel). The poster was selected by the international jury from 97 posters presented by participants from 24 countries.



Diamond Poster Award

Presented to

Nina Felgen

for

Best Student Poster
Hasselt Diamond Workshop 2017 – SBDD XXII
8 – 10 March, 2017

SBDD XXII
Hasselt
2017

The SBDD Organisation

Prof. Dr Yamasaki Satoshi
Conference Chair, Hasselt Diamond Workshop 2017 – SBDD XXII

Prof. Dr Ken Haenen
Conference Co-Chair, Hasselt Diamond Workshop 2017 – SBDD XXII

Latest Reports

Spring colloquium

On February 15/16, 2017, the time for the annual CINSaT spring colloquium being held at the Ahorn Berghotel in Friedrichroda had come. Following previous years' trend, a pleasantly high amount of participants with about 80 researchers could be welcomed and, therefore, emphasized once more the center's positive development over the last 15 years. The event began with a warm welcome speech given by CINSaT spokesman Prof. Dr. Johann Peter Reithmaier followed by a short overview about the history, the current organizational structure as well as recent activities within the CINSaT. Background of the given presentation was the participation of Prof. Dr. Dr. h.c. Volker Mosbrugger, general manager of the Senckenberg Gesellschaft für Naturforschung (SGN) and first-time external speaker at the spring colloquium, who caught the audience's attention by giving an impressive overview of Senckenberg's research activities. Both presentations served as an occasion for getting to know each other, scientific exchange and the planning of a possible strategic collaboration of the two institutes.

In addition to four lecture sessions being introduced and hosted by the respective spokesmen and presenting CINSaT's focus areas, the varied program was enhanced by the introduction of CINSaT membership applicants Prof. Dr. Christiane Koch (Department of Quantum Dynamics and Control), Prof. Arno Müller (Department of Developmental Genetics), and Prof. Dr. Peter Lehmann (Department of Measurement Technology). In the course of the focus sessions, the scientific staff of the participating departments gave striking insights into latest research outcomes from the world of nanostructures. It was shown that the interdisciplinary collaboration between the different departments provided a strong fundament for the achieved results.

Prof. Dr. Dr. h.c. Volker Mosbrugger

Conference room in which the CINSaT focus sessions took place.

The interdisciplinary collaboration was once again proved by the high number of five interdisciplinary joint projects with the involvement of CINSaT members being supported by the funding lines "Zukunft", "Aufbau Graduiertenprogramme" and "Brücken" in the context of Kassel University's further profiling. The research topics of the granted projects' were showcased in illustrative presentations within a separate session.

In order to intensify the scientific exchange, the program was round out by an evening poster session. The numerous research activities within the CINSaT focus area framework were displayed in a total of 45 posters, with no limits concerning people's creativity in visual representation, e.g., by showing footage of their results on tablets. Thus, this year's poster session – being the first time an open-end event – provided a strong medium for future collaboration planning.

Scientific exchange between the participants during the Thursday evening poster session.

Group photos of the participants.

Announcements

Autumn colloquium 2017

CINSaT cordially invites you to join the annual autumn colloquium, which takes place on **Wednesday, the 25th of October 2017**, between 13:00-18:00 at the lecture hall 100, Campus Heinrich-Plett-Straße. The spirit of the colloquium is to provide current research issues within the interdisciplinary framework of nanostructure science to a broad audience in order to find a common language for research.

The program is organized in a way that invited external speakers were chosen to represent current and future activities within the scope of CINSaT's scientific key topics. The event is completed by a poster session in which the participators have the opportunity to hold scientific discussions and informal exchanges about current activities within the CINSaT. Note that the physical well-being of the participants is ensured.

We are pleased to welcome you to the colloquium and look forward for your participation!

Autumn Colloquium
Location: HPS, HS100

October
25^{th} 2017
$13^{\underline{00}}$-$18^{\underline{00}}$

Impressions of the CINSaT autumn colloquium 2016.

Events

Hessentag 2017

11.06.-12.06.2017

CINSaT will be part of the Hessentag 2017 exhibition in Rüsselsheim and introduce visitors to its future vision of nanotechnology, to the center's research infrastructure as well as to the possibilities of bachelor and master programs in Kassel.

photo: www.ruesselsheim.de/hessentag2017

Campusfest 2017

29.06.2017, 15:00 to 21:00

CINSaT will introduce its interdisciplinary approach of nanosciences supported by practical examples and artistic visualization of selected research highlights.

photo: Press and Public Relations Office, University of Kassel, Studio Blåfield

Student Representatives - Events

Freshman Orientation 9.10.-13.10.2017

To give a proper introduction to the numerous students of the faculty, we need tutors from every department. You might remember your first steps at Kassel University and want to share your knowledge with the next generation. Then feel free to contact us.

University Elections 20.06.-22.06.2017

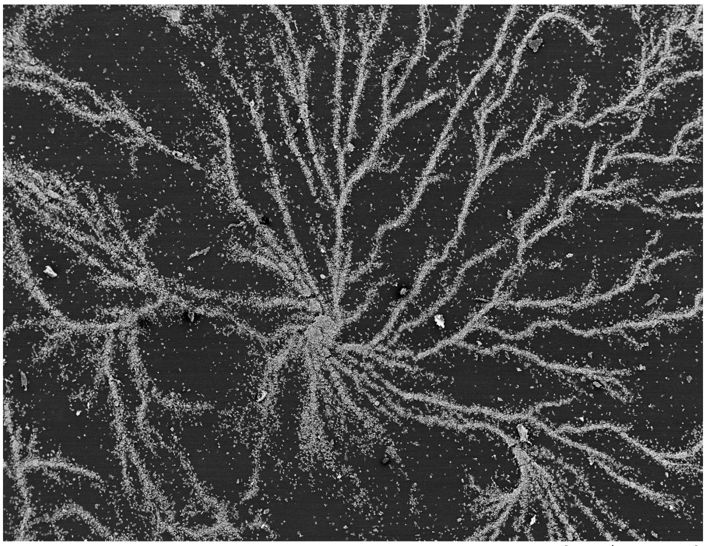
Each day from 09:30 to 15:00

Summer Party 14.06.2017

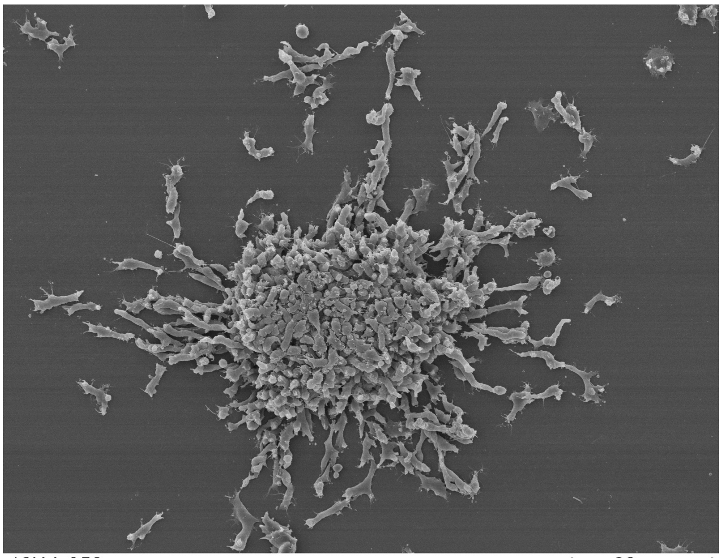
Nano arts

In this section, artistically appealing images from the CINSaT groups will be presented. If you obtained any kind of visually appealing and fascinating data during your experiments with focus on micro- and nanometer length scales, you are cordially invited to submit your contribution to the editors.

In this edition: Aggregating amoebas from the *Dictyostelium discoideum* species



1 mm



10kV, 350x, 60 µm

photo: AG Maniak, Cell Biology

photo: Campus Heinrich-Plett-Straße, Press and Public Relations Office University of Kassel, Studio Blåfield

Imprint

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