CINSaT Center for Interdisciplinary Nanostructure Science and Technology

Newsletter 2/2018

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 in 2018, which is now the fifth one in a row after the rebirth of this publication body of CINSaT. Many thanks to all of you who contributed to these newsletters with exciting reports and to the editorial board for preparing again in a nicely looking format major results and events from CINSaT.

Very recently, since November, 2018, CINSaT got a new executive manager, Ms. Nina Felgen, who has a diploma degree in Nano Science and will have her PhD examination beginning of 2019. She is now responsible for all administrative and managing issues of CINSaT following Dr. Dennis Holzinger, who worked for CINSaT for the last 3 years in an excellent way. He will now focus fully on science but will be still available with his advice and has already pre-organized the next large CINSaT event, i.e. the CINSaT spring colloquium in Friedrichroda (see announcement in this issue). I wish Dennis all the best for his scientific career and I want gratefully thank him on behalf of all members for his great support of CINSaT. I wish also the new executive manager all the best for a good start. This newsletter gives already a good impression for a successful takeover because she was now already responsible for this edition of the newsletter.

In this issue, we have again in all categories highlights, which are reported. Starting with Education: While last year students from Kassel reported about their stay in our partner University of Jyväskylä (Finland, see NL 1/2017), several students from Jyväskylä attended courses at our University in summer this year. Their impressions and fun they had during their stay, are recorded on page 5. Subsequently, the VDE (Verein der Elektrotechnik Elektronik und Informationstechnik e.V.) group at University of Kassel introduce themselves and looking for students being interested in this topic and want to get in contact with industry, and we have a short report about the second pupils CINSaT seminar taking place during the summer semester.

In Highlights, member Dr. André Knie from the physics institute report about new insights of electron emission from ionic matters by using the free electron laser facility at DESY (Hamburg) and member Prof. Arno Müller together with Mostafa Aakhte (MSc Physics), both from the institute of biology, report about new results towards the realization of a versatile platform for beam shaping in Light Sheet Microscopy.

Three new research projects have been funded, which are briefly reported. Priv. Doz. Dr. Mohamed Benyoucef (physics institute, INA) starts a new cooperated DFG project with TU Berlin (Prof. Dr. Stefan Reitzenstein) related to deterministic photon sources for fiber-based quantum communication. A related large cooperated research project Q.Link.X, which is dealing with the realization of a quantum network, is funded by the BMBF. Two sub-projects will be performed by the members Priv. Doz. Dr. Mohamed Benyoucef and Prof. Dr. C. Popov (both physics, INA). All those projects are strengthening the CINSaT priority topic “Quantum Technology”. Member Prof. Dr. Peter Lehmann together with M.Sc. Lucie Hüser (both from electrical engineering) got a new DFG project funded dealing with the investigation of near-field assisted short-coherent interference microscopy.

A great success was also the approval of the new research focus project SMolBits within the excellence initiative LOEWE of the state of Hesse, coordinated by myself. Here, 7 CINSaT members get a financial support for 4 years to establish a new quantum technology platform based on molecular quantum bits as an alternative approach for the realization of quantum computers. 4.4 Mio € are spent for exploring this idea and for the preparation of a DFG-funded collaborative Research Center (CRC).

Three CINSaT members will introduce themselves. These are Prof. Dr. Monika Stengl (biology), Prof. Dr. Kilian Singer (physics) and Prof. Dr. Bernd Witzigmann (electrical engineering).

Reports about several events are attached, which took place in the last 6 months. This includes the last autumn colloquium, the day of Hesse (Hessentag) and the campus festival of the university. There are also two main announcements, which you should recognize: The next spring colloquium in March 2019 and the day of physics, end of January, 2019. Finally, you should not miss the nano art.

Unfortunately, to the very last point, I regret that I have to inform you about a very surprising and sad issue. Our well-known colleague and chairman of the scientific advisory board, Prof. Dr. Markus-Christian Amann (WSI, TU Munich) died recently without warning due to a very unlikely but deadly accident at his home in Munich. Our memories and thoughts are with him and his wife.

The year 2018 was quite event- and successful as reflected in this newsletter. Nevertheless, I am sure that 2019 will be at least as exciting because also fundamental changes in CINSaT are in view. A few indications to it are already given in the reports from the committees.

After enjoying reading this issue, I wish you peaceful Christmas holidays and a happy new year.

Enjoy the reading of this issue.

Johann Peter Reithmaier

General

Latest information from the CINSaT management

Here, we are reporting about public informations from the committee meetings, which can be of general interest for all members as well as for interesting readers.

(a) Steering Committee

We had in September 25th, 2018 our last meeting. The next one will be on December 20th of this year, which will be reported in the next newsletter. The following issues can be reported:

- A new distinguished colleague for the Scientific Advisory Board could be won: Prof. Dr. Efrat Lifshitz, RBNI, Technion, Israel. She is chemist and is well known in nano science of different disciplines.
- The list of members for the Scientific Advisory Board was sent to the president waiting for approval. The list consists of:
    - Prof. Dr. Markus-Christian Amann (WSI, TU Munich, electrical eng.) †
    - Prof. Dr. Hans-Joachim Freund (Fritz-Haber-Institut of MPG, Berlin, chemical physics)
    - Prof. Dr. Andreas Offenhäuser (Research Center Jülich, biology)
    - Prof. Dr. Efrat Lifshitz (RBNI, Technion, chemist)
- Prof. Kusserow got a deputy professorship at TU Darmstadt. His membership will be still kept alive. However, he has to give back his responsibility for the “Photonics” research focus.
- The CINSaT excecutive manager position has to be re-occupied (decision of president). This position is now fully linked to CINSaT and is paid by its own account.

(b) Research Coordination Committee

- Due to time restrictions of the members of the research coordination committee, no meeting tooks place within the last half year. However, the members gave their inputs for the organization of the autumn meeting.
- For some research focus topics new responsible people were selectred and approved by the CINSaT member meeting (see below).

(c) Member Meeting

The last member meeting took place on November 7th, 2018.

The members approved the following research focus topics and responsible people:

- 3D Nanostructures (Prof. Dr. Hartmut Hillmer, electrical engineering)
- Biosensing (Prof. Dr. Arno Müller, biology)
- Photonics (Prof. Dr. Peter Lehmann, electrical engineering)
- Chiral Systems (Prof. Dr. Thomas Baumert, physics)
- Quantum Technology (Prof. Dr. Kilian Singer, physics)
- Nanostructures in natural sciences, engineering sciences and arts (Professor Dr. Bernhard Middendorf, civil eng., Prof. Dr. Thomas Niendorf, mechanical engineering)

Three new colleagues applied for membership (Prof. Dr. Angelika Brückner-Foit, mechanical eng., Prof. Dr.-Ing. Hans-Peter Heim, civil eng., Prof. Dr. Georg Mayer, biology). They will present their research field in the CINSaT spring meeting.

Education

ERASMUS program Jyväskylä

We are Julia ("Vicky") and Suvi-Tuuli a physics bachelor student and a nano-chemistry master student from Jyväskylä, Finland. Vicky is on her fifth semester and did her fourth semester at the University of Kassel as Erasmus student and Suvi-Tuuli is on the second semester of her master program and did her first one in Kassel. Vicky had an idea to do her exchange period in Germany and when professor Fuhrmann-Lieker visited our university and told us about Kassel, she had already practically packed her bags and bought the tickets to go. Suvi-Tuuli was recommended to go by a professor as she finished her bachelor studies a bit early and having wanted to always do that, she was immediately on board.

Picture of Julia and Suvi-Tuuli.

We arrived in Kassel in April 2018 together with Henri, another Finnish nanochemistry student, and orientation week started already the day after our arrival. The first night was interesting, as due to some miscommunication, we only had one room ready for us, instead of 3 (there was another, so all 3 of us Finnish students ended up having a sleepover in Suvi's room. On orientation week we mainly got to know all the other international students and had some excursions to Herkules and Göttingen. We really enjoyed the orientation week and it was a great beginning for all the interesting events that the University of Kassel offers for both local and international students.

For studies, Vicky took a couple of physics courses and one from mathematics. ''I was kind of surprised how nice people were, for example one course which was supposed to be in German, was held in English instead. I was prepared to do a lot of self-studying, so I was glad it turned out that way.'' Suvi took mainly chemistry and physics courses as well as an internship in the group of physical chemistry. '' The internship was honestly the best thing studywise I did in Kassel. I got to work as a real scientist with very professional people in an inspiring environment and I feel like I learned immensely from that experience.''

Studying in general was quite different from what we are used to in Finland. For example with exercises, in Kassel you need certain percentage of exercise points just to get to exam. In Finland most of courses we have exercises too, but they are mostly optional, of course it's highly recommended to do them. You can participate exams without doing any exercise, but if you do them, you gain some extra points for your exam and it's easier to get better grades that way. Another big difference was the length and the type of the exams. In Finland we have almost always four hours for one written exam, but in Kassel just two. ''Honestly I was quite in a hurry with my two hours.'' Vicky describes her experience with the exams. Suvi also encountered new things with the exams. In Finland we rarely have oral exams and Suvi had had none before visiting Germany, so the first one was quite nerve-wrecking for her.

Group picture during summer activities.

We also participated in a buddy program on the natural science faculty. ''The buddy program started a bit too late for my buddy to actually help me with practical matters like German bureaucracy and getting to know the faculty. Instead I got a nice friend to hang out with and also got to know the local culture'', Vicky describes. Suvi-Tuuli also feels like she made a good friend and learned a lot of the German education system.

We spent a great four months in Kassel, getting to know locals and other international students. We had a blast and really would recommend Kassel for other students. We really miss the city and the people. And for you studying in Kassel, we would say: ''Go for exchange, there's quite big risk that it's going to be the best time of your life!''

VDE University Group Kassel

The VDE University Group Kassel is the student organisation of the VDE Regional Association Kassel. The VDE University Group offers all students interested in the areas of Electrical Engineering, Communications, Computer Science, Medical Engineering and Nanotechnology at the University Kassel a networking platform to connect with other students, companies and research facilities.

With our Regulars' Table every month, numerous events, technical talks and field trips, we want to bring students with same interest together and provide a friendly environment to discuss and learn more about different themes.

We also offer our members contacts to companies and research facilities to help them build a network for the professional future. We are part of a bigger network and are in contact with many other universities groups in Germany and Europe. We meet with them in various fairs and conventions such as the Young Engineers Seminar in Brussels or the Hannover Messe.

If you want to get to know our group and become a member, just send us an E-Mail or come to our Regulars' Table on the first Thursday of every month.

Contact

VDE Hochschulgruppe Kassel

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Visit of the Technik Museum in Kassel.

Christmas Party of the VDE University Group Kassel.

Group picture of the VDE University Group Kassel.

CINSaT hosts interdisciplinary seminar event for pupils

Due to the positive experiences that CINSaT had made last year with the first-time hosting a seminar event for pupils of the Upper Secondary level focusing on the MINT subjects, it quickly became clear that a reissue of the event was desirable for both sides. After the program was set, 25 pupils and their teachers from the private boarding school Solling made their way to the working groups of the CINSaT again this year. An important foundation for the future continuation of the seminar is the close contact with Dr. Frank Hubenthal, who was a longtime member of the CINSaT before his time as a teacher.

The aim of the seminar is to broaden the students' horizon with current research topics from the world of nanostructures. At the same time, however, insights into the laboratory work as well as the close cooperation between the classical disciplines such as biology, chemistry and physics are to be imparted since these are an indispensable part of today's research landscape. The program included a total of three 30 min lectures in the fields of experimental physics, biology and technical physics, each of which was accompanied by a laboratory tour of the department's staff. This gave the students a very detailed picture of some of the basic research taking place at CINSaT.

At the beginning, Dr. Holzinger gave an insight into the world of magnetic nanostructures, which in addition to the widely known hard disk technology, have meanwhile also found their way into new developments in the field of medical diagnostics. Subsequently, Prof. Stengl from the Department of Animal Physiology presented in an impressive way the functioning of sensory organs as well as the body's own temporal timing, such as, for example, in the perception of pain. The event was rounded off with an overview lecture by CINSaT speaker Prof. Reithmaier on nanostructures and their application in the field of laser structures and telecommunications.

The audience listening to the exciting talks given by Prof. Dr. Johann Peter Reithmaier (left) and Prof. Dr. Monika Stengl (right).

Research Highlights

Symmetry breakdown of electron emission

Limits of dipole approximation shown for the first time in sequential photoionization. In a study carried out at FERMI in Italy and recently published in Nature Communications, a team of international scientists demonstrate for the first time a significant symmetry breakdown of electron emission in ionic matter. The results have significant implications for a range of experiments, especially at free-electron laser (FEL) facilities.

When matter absorbs light of a sufficiently short wavelength or at high enough intensity, it can emit electrons. This process of electron ejection is known as photoionization and is an important basis for many experiments that investigate the electronic structure of atoms, and the structural and chemical information of molecules. When lots of 'light-particles' known as photons, are available during a very short time frame, multiple electrons may be emitted in quick succession, providing even more information about the way light and matter interact with another. In this way, the spectroscopic study of ionic matter has been revolutionized by FELs over the past few years.

Generally, it is assumed that for photons with long wavelengths in relation to the absorbing site, the interplay between photon and electron can be described as dipole interaction. However, for very short wavelengths and several other conditions, this assumption starts to break down since the momentum of the photon can distort electron emission patterns in its propagation direction.
Just like a cork or boat will only bob up and down vertically on the ocean on gentle, shallow waves with a long wavelength, but will then also be moved forward in the direction of the waves once they are of shorter wavelength, so the momentum of the photon can steer the movement of the electrons under certain conditions.

As modern free-electron laser facilities such as European XFEL begin to harness the power of X-rays with ultra-high intensity and very short wavelengths for spectroscopy and scattering experiments, a complete and accurate understanding of electron emission, including the propagation direction of the light, will be essential to be able to interpret results correctly.

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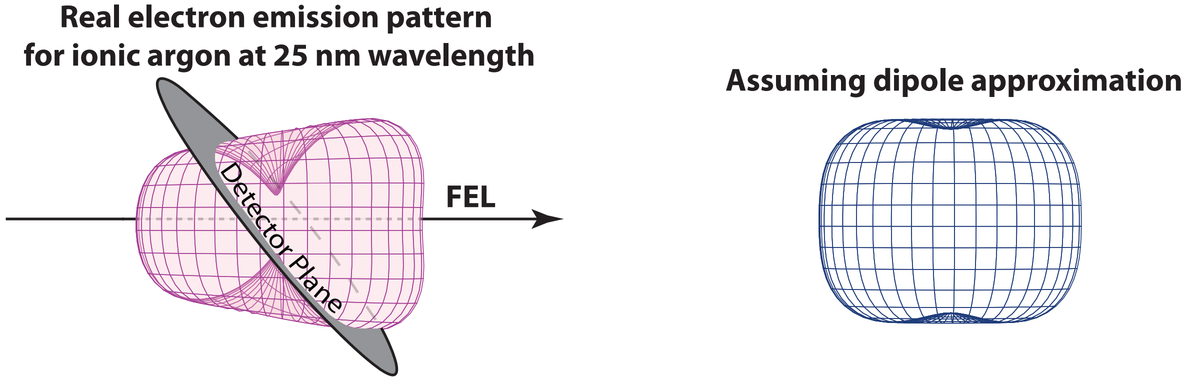
Original article:
Symmetry breakdown of electron emission in extreme ultraviolet photoionization of argon.
M. Ilchen et al., Nature Communications 9, 4659 (2018).

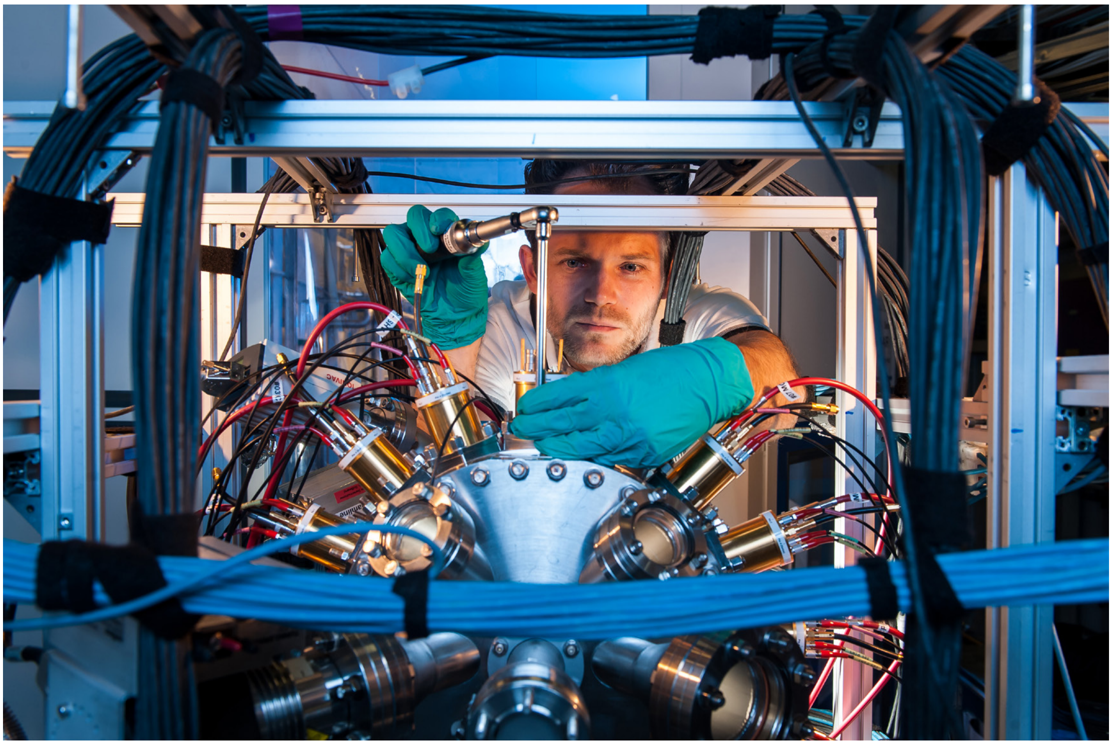
Link: https://doi.org/10.1038/s41467-018-07152-7



Non-dipole (left) and dipole (right) electron emission patterns.

Now, for the first time, an international research team led by scientists from European XFEL, DESY and the University of Kassel, have shown experimentally that so-called non-dipole effects can play an important role in sequential electron emission even at wavelengths that are commonly assumed to be symmetrical in distribution. The specially designed study, done using ultra-intense X-ray pulses at the free-electron laser FERMI in Italy, investigated the sequential emission of electrons from gaseous argon around 25 nm photon wavelength. This particular configuration allows for a "zoomed view" into the relevance of non-dipole effects and showed a significant symmetry breakdown of electron emission for neutral and also subsequently created ionic matter.

The findings, published in November 2018 in Nature Communications, have broad implications for future experiments on the fundamentals of photoemission from atoms and molecules at high intensities, applications in condensed matter physics, as well as astrophysical phenomena. Furthermore, time-resolved experiments with short-pulse light sources such as FELs are capable of monitoring the evolution of matter dissociating into ionic fragments which are subsequently further ionized in order to investigate their chemical and structural property changes on their natural time scale of femtoseconds to picoseconds. The altered symmetry signature of the electrons, as demonstrated in the current study, can therefore be decisive for correct interpretation of several kinds of time-resolved experiments. The Small Quantum Systems (SQS) instrument at European XFEL, which starts operation at the end of 2018, has been designed to routinely capture such non-dipole effects.



Lead author Dr. Markus Ilchen working at the instrument. Copyright European XFEL.

A Versatile Platform for beam shaping in Light Sheet Microscopy

Over more than 100 years, the common fruit fly (*Drosophila melanogaster*) represents one of the best genetic model organisms in biological research. The high level of evolutionary conservation of human genes in *Drosophila* (>75% of disease related genes are also found in the fly) makes the fly an outstanding model to study the function of disease-related genes. We use *Drosophila* embryos to study how a monolayer of cells is transformed into a three-layered tissue. This research is highly dependent on the observation of cells in the living embryo at a high resolution.

The overall aim of our project is to design and build a microscope with high spatio-temporal resolution based on a selective plane illumination microscopy platform (SPIM; aka light sheet microscope). SPIM is based on optical sectioning by illuminating the sample with a thin light sheet orthogonal to the detection axis (Fig. 1a). The sectioning capability in SPIM is defined by the thickness of the light sheet. A key area of the SPIM research is produce an optimal light sheet which covers a large field of view and provides a high spatial resolution. Different methods, including specific spatial beam structures (e.g. Bessel-, Airy-, Gaussian beams) or tiling methods, have been advised that help to address this problem, but these are often difficult to apply for biologists with little training in optics or physics.

To produce optimized light sheets for specific biological applications we have developed a software called Structured SPIM (SSPIM), which provides an open-source, user-friendly and compact toolbox for beam shaping that can generate digital patterns for a wide range of structures for shaping optical beams [1]. SSPIM can produce Gaussian, Bessel and Airy beams (Fig. 1b-i) by simple control of a Spatial Light Modulator (SLM). SSPIM is also able to instruct patterns for incoherent and coherent array beam formation and beam tiling (Fig. 2) [2]. SSPIM provides a key component of our current development of a dual-view tiling OpenSPIM system with which we will be able to record the whole functional 3D image of dynamic cell behaviours in *Drosophila* gastrulation at subcellular resolution.

Reference:

[1] Aakhte, Mostafa and Akhlaghi, Ehsan A. and Müller, H. -Arno J., (2018) “SSPIM: a beam shaping toolbox for structured selective plane illumination microscopy”, Scientific Reports 8, 10067.

[2] https://github.com/aakhtemostafa/SSPIM

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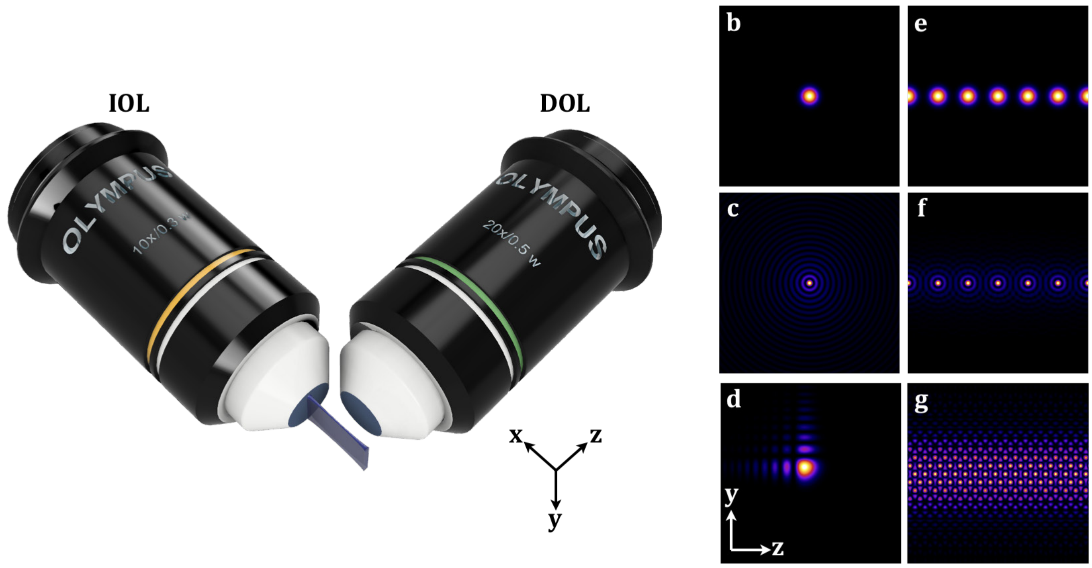


Figure 1. Schematic of the SPIM and example of illumination beams. (a) Schematic of a conventional SPIM system: the illumination objective lens (IOL) excites a thin sheet (x-y plane); the emitted light is collected with the detection objective lens (DOL) in the orthogonal direction (z axis). (b, c) Transverse intensity of single Gaussian and Bessel with radial symmetry and (d) 2D Airy beams with asymmetrical profile. (e-g) For increased resolution, SSPIM informs the generation of Gaussian (e) and Bessel (f) array beams and Lattice beams (g).

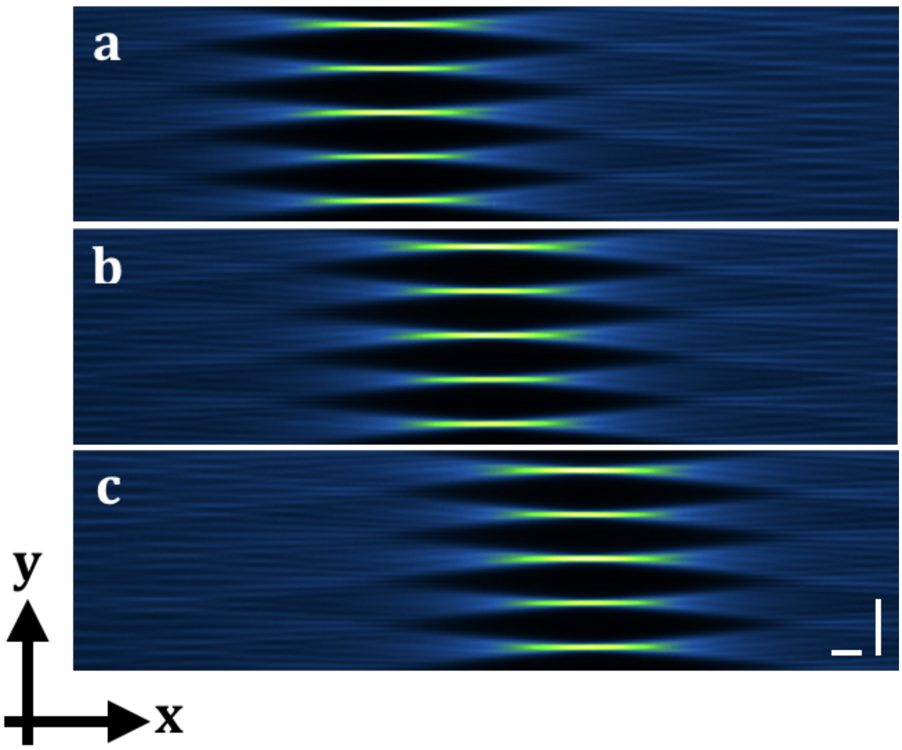
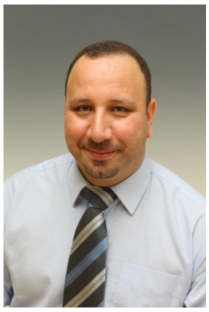


Figure 2. Tiling method. (a-c) show the measured intensity profile of a tiled Gaussian array beam through a dye solution. Beam propagation is in the x direction. Scale bars: 40 μm.

New Projects

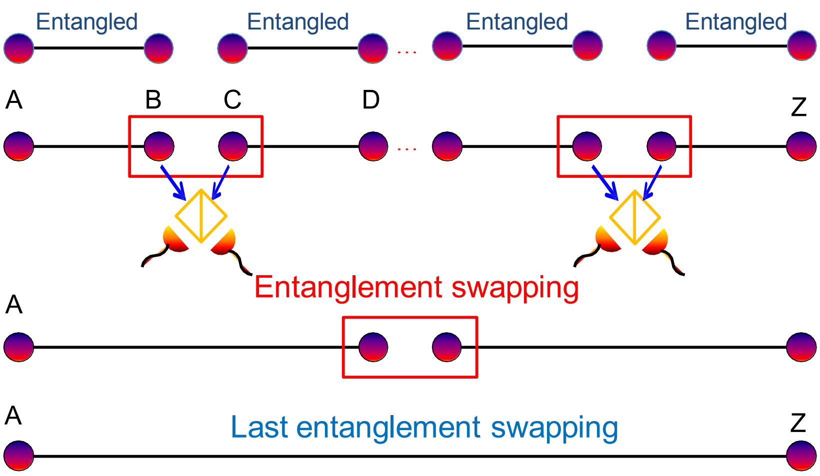
BMBF Project - Quantum Link Extension (Q.Link.X)



Data security and secure communication are becoming increasingly important. Quantum communication uses quantum states to transmit information, which cannot be copied due to fundamental laws of quantum physics. Direct point-to-point quantum communication in standard telecom optical fibers using quantum key distribution is limited to about few 100s km because of the exponential increase of photon losses with the channel length. The aim of the project is to enable long-distance secure quantum communication using quantum repeaters.

The BMBF is funding a joint project for fast and secure quantum communication „Quantum Link Extension“ (Q.Link.X) with a total of 14.8 million euros over the next three years. The Institute for Nanostructure Technology and Analytics (INA) of the University of Kassel is involved with two working groups of Priv.-Doz. Dr. Mohamed Benyoucef (Nano Optics Group) and apl. Prof. Dr. Cyril Popov (Nano Diamond Group).

Due to the low interaction with the environment, photons are ideally suited to transport quantum information over long-distances. Sharing these photons over long-distances through glass fiber requires sources of single-photons and entangled photons operating at telecom wavelengths, in particular the 1.55 µm telecom C-band, which offers the lowest attenuation losses in silica fibers. InP-based single quantum dots (QDs) are one of the possible candidates to reach the telecom spectral window of 1.55 µm. The goal of the subproject "InP-based quantum dot structures" of the Nano Optics Group led by Priv.-Doz. Dr. M. Benyoucef is realization of bright single QDs that emit single-photons and entangled photon pairs at 1.55 µm (telecom -C-band). In particular, the project will focus on in-situ control and optimization of the optical and structural properties of single QDs via epitaxial growth as well as integration of quantum emitters in more complex photonic structures, e.g., in microcavities for strong light emission and pin / Schottky diode structures for spin manipulation. The work will be performed in close collaboration with other project partners.



Fiber-based quantum repeaters for long-distance quantum communication

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Color centers in diamond have the advantages of long quantum coherence times of electron and nuclear spins in combination with efficient optical transitions as an interface to photons for the transfer of quantum information. The interface to photons is ensured either by a combination of microwave and optical transitions (NV centers) or by purely optical spin control (SiV centers). Diamond as solid-state platform offers the advantage of integration „on-chip“ with photonic elements for the targeted enhancement of the spin-light interaction. The aim of the diamond subproject of the Nano Diamond Group led by apl. Prof. Dr. C. Popov is the realization of diamond photonic structures (nanopillars, photonic crystals, waveguides) using electron beam lithography and reactive ion etching. All these structures will be coupled with color centers to increase the photon collection efficiency. The integration of the photonic structures with electrodes and antennas will allow for coherent manipulation and efficient readout of the spin state. The structures will serve as spin-photon interfaces as well as components of quantum memory for investigations by project partners.

The University of Kassel is among the 24 partners who are involved in the Q.Link.X network to explore the key technology of quantum repeaters.

Link to BMBF Project: https: //www.forschung-it-sicherheit-kommunikationssysteme.de/projekte/q-link.x

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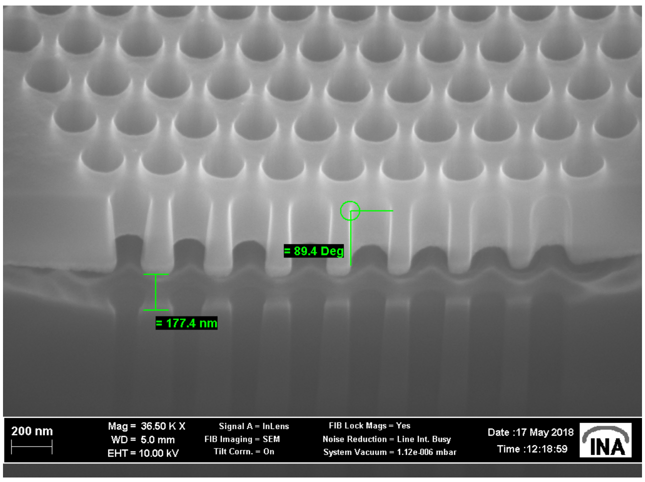


Planarized nanocrystalline diamond photonic crystal slab

Further information

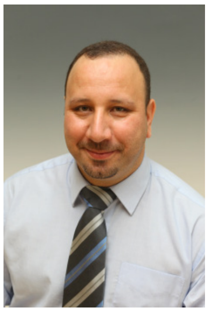
Website: http://tp.ina-kassel.de/index.php/nano_diamond_eng.html

DFG-Project - Development of deterministic quantum-light sources from InP-based quantum dots in the telecom c-band (DeLiCom)

The German Research Foundation (DFG) awarded a three-year research grant to Priv.-Doz. Dr. Mohamed Benyoucef (Nano Optics Group, INA, University of Kassel) and Prof. Dr. Stephan Reitzenstein (Optoelectronics and Quantum Devices, TU Berlin) for a new joint research project on “Development of deterministic quantum-light sources from InP-based quantum dots in the telecom c-band”.

Semiconductor quantum dots (QDs) have been proven to be excellent quantum emitters. Previously, twin photons have mostly been generated non-deterministically using parametric down conversion sources, which suffering from low efficiencies. Source emitting pairs of identical time-correlated photons represents a versatile resource with applications in quantum optics and biology. Likewise, for applications in quantum technology, in particular for long-distance quantum communication, generation of light states at telecom c-band is of great interest to establish low-loss quantum links in optical networks for secure data transmission.

This project focuses on generation of non-classical light at telecom c-band wavelengths (1.55 µm) from InP-based single QDs, which are deterministically integrated into photonic microstructures for enhanced photon outcoupling and emission control. Project addresses three main challenges: control of the electronic structure, enhancement of photon extraction efficiency for study on optically-generated quantum light states, and electrically-driven single-photon emission. With respect to twin-photons, we aim at using the degenerate biexciton-exciton cascade to generate time-correlated photon pairs. The output of the proposed research will significantly advance the state of knowledge on quantum light emission at telecom wavelengths and will open up exciting prospects for single- and twin-photon sources for fiber-based quantum communication and non-linear spectroscopy.



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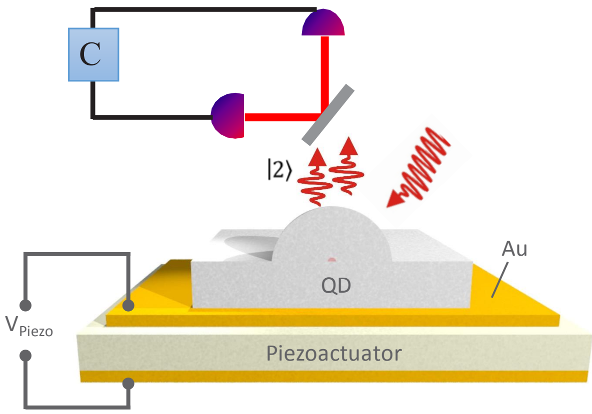

Schematic illustration for generation of twin photons under optical excitation

Near-Field Assisted Short-Coherent Interference Microscopy for 3D Measurement of Submicron Structures

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An important field of research of the measurement technology group lies on the development and characterization of novel microscopic sensors, which measure 3D topographies of submicrometer structures. The project "Near-field assisted low-coherence interference microscopy for 3D measurement of sub-micrometer structures" recently granted by the DFG studies the mechanisms of near-field assisted super-resolution in interference microscopes utilizing transparent microspheres. It is well known that optical microscopy is restricted by Abbe's diffraction limit due to the effect that two laterally shifted points on an object can only be separated by a far-field microscopic measuring device, if their distance is at least in the range of half the wavelength of the illuminating light.

A method with high potential to overcome the resolution limit in far-field microscopy without the labeling needed in fluorescence microscopy is called near-field assisted microscopy, which utilizes so called superlenses. Transparent microspheres are placed on the surface of the measuring object and transfer near-field information to a conventional far-field imaging device. This effect is commonly explained with "Photonic Nanojets", which show a sub-wavelength intensity distribution in the near-field of the microsphere. How super-resolution occurs in the far-field is still not conclusively explained in literature. For example, the role of evanescent waves is still unclear, as it is generally excluded [1], but simulations show their effect on Photonic Nanojets for small microspheres in [2].

In an immersion microsphere assisted system structures in the range of 50 nm were laterally resolved [3]. Besides intensity also phase information is transferred to the far-field, what enables 3D measurement capabilities. Results of sub-resolution measurements with Linnik and Mirau interferometers clearly point out the use of near-field assisted microscopy in interferometric applications [4, 5, 6]. This was mainly shown for white-light or phase-shifting interferometers with numerical apertures in the middle range (0.3 to 0.6). Generally, it can be noticed that microsphere assisted systems for topographic measurements currently gain wide interest in research.

In our project we want to examine the effects of high numerical apertures (0.7 to 0.9) on the imaging and topographic measurement processes in interference microscopy. In the past years one focus of our research was the development of high-resolution interferometers and the examination of their applications as well as the analysis of interference signals. Based on this experience the following points will be addressed:

- Relevant mechanisms of the image formation process, especally the near-field/far-field transition that allows super-resolution with far-fieldimaging systems shall be investigated. A theoretical model regarding the phase transfer process in the microsphere shall be elaborated.
- Is the near-field assisted technique really a super-resolution method in the sense that it resolves 3D-structure dimensions, which cannot be resolved by conventional interference microscopes suffering from the Abbe resolution limit?
- The influence of the wavelength and the coherence length of the light source shall be examined. In terms of further improvement of the resolution the wavelength can be reduced, e.g. using blue LED illumination.
- Since the diameter and materials as well as the surrounding medium documented in literature differ in a wide range, a systematic categorization of the parameters of the microsphere measurements shall be done.

Currently, the signal transfer process through a microsphere is studied in order to obtain the near-field/far-field transition. This is done with FDTD (finite difference time domain) methods. Figure 1 shows the electric field distribution in the near-field through a microsphere with a plane wave illumination from below. To gain information about the imaging process, different study cases have been simulated. In all cases the field source is a plane wave from below with a wavelength of 500 nm. The microsphere used in a) and c) has a diameter of 9 µm and its material is SiO_2. In terms of a better visualization, a grating with a period of 500 nm (which would still be resolvable with an optical microscope) is assumed in b) and c).

The simulated near-field distributions show the strong influence of the microsphere on the resulting transmitted fields, which can be collected by an optical imaging system such as a microscope or an interference microscope enabling even phase imaging. Examining how these changes are influencing the optical resolution is part of the project.

Theoretical studies as well as measurements with a high NA Linnik-interferometer through Silica microspheres with wavelengths ranging from blue to green show significant changes of the measurement results.

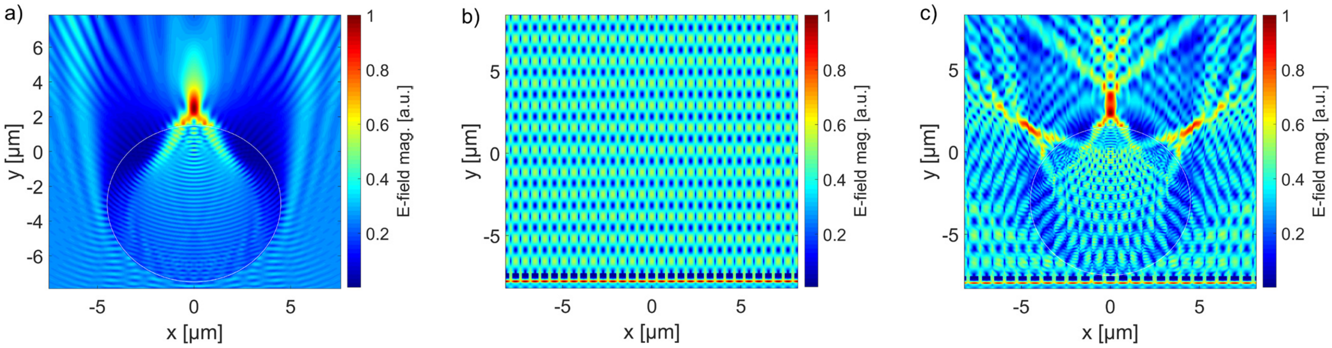

Figure 1 – Near-field distributions of different study cases. All cases assume illumination from below with a plane wave source (500 nm): a) Photonic nanojet behavior of the electric field transmitting through a microsphere; b) Electric field distribution with illumination through a grating; c) Electric field distribution with illumination through a grating and a microsphere placed above.

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New Coordinated Projects

LOEWE priority project SMolBits

The state of Hesse funds a new collaborative priority project in the frame of the state initiative for the development of scientific and economic excellence (LOEWE) entitled „Scalable Molecular Quantum Bits (SMolBits)“. The project, coordinated by Prof. Dr. Johann Peter Reithmaier, will start in January 2019 at the University of Kassel and will be funded for 4 years with about 4.4 Mio €. Seven CINSaT members (T. Baumert, M. Benyoucef, C. Koch, R. Pietschnig, J.P. Reithmaier, K. Singer, B. Witzigmann) from three disciplines (chemistry, physics and electrical engineering) are participating.

Since the theoretical work of Albert Einstein describing the photo effect and Max Planck‘s work describing the black body radiation, people have realized that many physical effects, even those far away from atomic properties, cannot be explained without quantum mechanical considerations. Also many applications nowadays benefit from quantum mechanical phenomena such as the control of emission wavelength of light emitting diodes and lasers. These size effects deals mainly with the discretization of possible electron states in artificial nanostructures and are similar to the sharp dark lines seen in atom gas absorption spectra. In the meantime, more advanced aspects of quantum physics is explored resulting in a 2nd generation of quantum mechanical applications. In this case, not only the discretization of energy states are considered but also non-classical correlations, such as entangled states. With this new generation of quantum mechanical instruments, one can think about using quantum mechanical principles for a new class of data storage and processing.

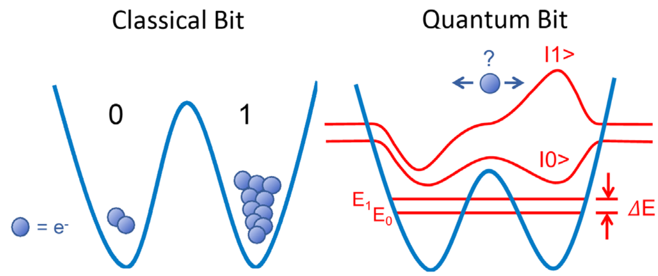

Fig. 1. Top left: Illustration of a classical bit defined by electrons charges localized in one of the potential wells. Only two values can be distinguished. A „1“ is here defined by a certain minimum charge on the right hand potential. Top right: Illustration of a quantum bit. The electron can tunnel between the two wells and can be at any position in between. This situation can be described by probability wave functions |0> as symmetric overlap of the two single well wave functions or |1> as antisymmetric overlap, respectively. These so-called entangled states can be distinguished by the energy splitting ΔE. However, these are only the most extreme cases. Also any superposition state Y = a |0> + b |1> is possible, which allow theoretically to store an infinite number of information in a single QuBit. Bottom: Cartoon addressing the consequence if one would transfer the strange behavior of entangled quantum states to a daily life situation.

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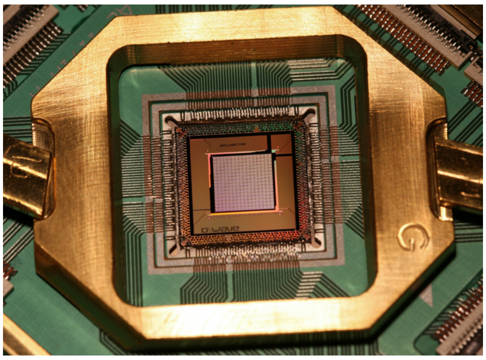
In figure 1, the main difference between a classical binary encoded memory and a quantum mechanically defined quantum bit is illustrated. In classical memory, e.g. the localized charge is used for the physical representation of the binary value „1“. Here, one can only distinguish between two values, „0“ or „1“. In contrast, a quantum bit can represent many different states (in theory an infinite number). A single electron confined in a double quantum well, as illustrated in the top right part of figure 1, can be represented in quantum mechanics by a wave function with phase and amplitude while the square of the absolute value of the wave function corresponds to the probability to find an electron at a certain position. The red line wavefunctions represent here the extreme cases of the combination of two single well wavefunctions. While the |0> state consists of an in-phase (symmetric) overlap, the |1> state consists of an anti-phase (anti-symmetric) overlap. However, also a combination of these two states are possible forming a superposition or entangled state, which is called quantum bit (QuBit). A QuBit can theoretically represent an infinite number of combinations and is a key component for the predicted power of quantum computers beyond conventional computers.

Very recently, big companies, such as Google, Microsoft and IBM, have started spending significant amounts of money on developing first demonstrations of quantum computing exceeding limits of classical computing. In figure 2, the approach at Google is illustrated. Their approach, as of many other groups, is based on superconducting chips (see left picture), which allow in the meantime the coupling of QuBits in the order of 100. The requests on control wiring and cooling down the whole system below 1 K is very demanding as can be seen in figure 2 (right panel). A scaling up of this approach to real practical complexities in the order of multiple thousands or millions of QuBits seems out of scope for the near future.



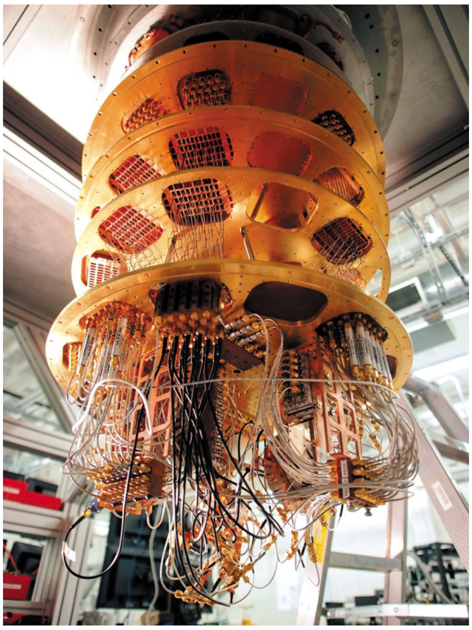


Fig. 2. Above, an optical microscope picture of a superconductive quantum chip from google. On the right, the external wiring in a quantum computer set-up, which will be penetrated in a large cryostat cooled down below 1 K (less than -272 °C).

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In the LOEWE priority project SMolBits a different and novel approach will be investigated, which addresses the scalability of quantum systems. Here, we want to utilize the nature's ability to reproduce identical quantum systems at the molecular level. In this project, we want to use lanthanoid complexes, as shown on the left of figure 3. The lanthanoid ion, marked in bright blue in figure 3, is embedded in a very rigid molecular cage to suppress vibrational excitations and is weakly linked to a linker molecule, which allows anchoring on functionalized solid surfaces. An optical transition of the core part of this lanthanoid complex works as a QuBit, which ideally can be identically reproduced. However, to address each of those QuBits, single molecules have to be localized on surfaces and connected to an optical network. In figure 3 (right), this is schematically illustrated based on a so-called photonic crystal nano-photonic platform. Here, the molecules are strongly coupled to optical nanocavities (i.e., areas with missing holes of the periodic structure), which are coupled themselves to each other by nano-photonic waveguides (not shown in the figure). The goal of the project after four years is to demonstrate for the first time the coherent optical coupling of two molecular QuBits on such a miniaturized nano-photonic chip and to understand the fundamental processes in such hybrid quantum systems.

To address these very challenging tasks, a unique interdisciplinary research consortium was built out of CINSaT members consisting of experts in chemical synthesis (Rudi Pietschnig), in ultra-short and coherent optical spectroscopy (Thomas Baumert), characterization of single molecules in ion traps (Kilian Singer), in semiconductor technologies and quantum optical characterization (Mohamed Benyoucef / Johann Peter Reithmaier), in computational photonics (Bernd Witzigmann) and quantum theory (Christiane Koch). To have these multiple expertise at one place is very unique in Germany as well as worldwide. Therefore, if the consortium will succeed in this 4-years project, it has a large potential to apply successfully for a collaborative research center (Sonderforschungsbereich) of the German Science Foundation and to establish „Quantum Technologies" as a long-term new focused research topic at the University.

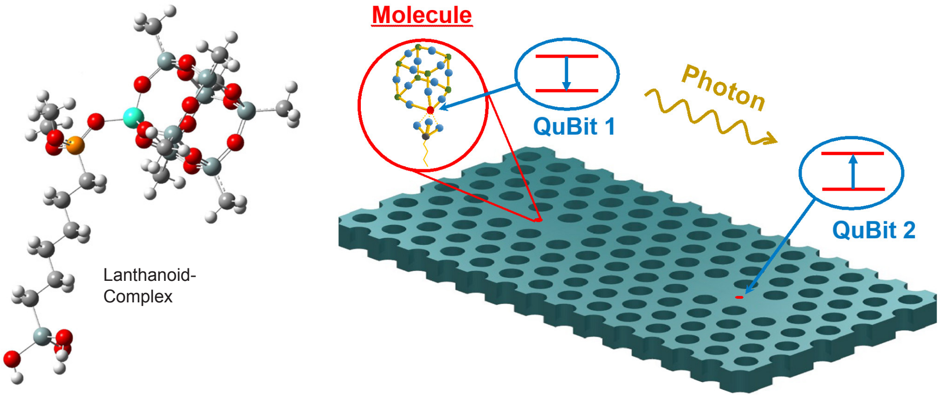
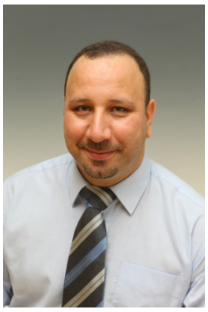


Fig. 3. On the left, schematic illustration of molecule complex consisting of a Lanthanoid atom (bright blue ball) embedded in a stiff carbon based cage to suppress vibrational states and combined with a linker molecule for surface immobilization; On the right a simplified schematic picture of molecules (red dots) placed in the centers of optical nanocavities made of a nanostructured semiconductor membrane. Each single molecule acts as a quantum bit, which are optically coupled to each other by photons. For simplicity, the optical waveguides coupling the nanocavities are not shown.



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Research Groups

Animal Physiology - Faculty 10

Prof. Dr. Monika Stengl is head of Animal Physiology/Neuroethology at the Department of Biology, at the Univ. of Kassel. She studied Biology at the Univ. of Würzburg, Germany. Her Diploma degree she finished in the laboratory of Prof. Dr. M. Heisenberg, where she searched for neuronal mechanisms of osmotropotaxis in flies with intracellular recordings. With a stipend she went to the Center of Insect Sciences in Tucson Arizona to join the group of Prof. Dr. J. G. Hildebrand. She earned her Ph.D. in 1990 at the Department of Molecular and Cellular Biology at the University of Arizona working on olfactory transduction in the hawkmoth *Manduca sexta*. For her PhD thesis work she obtained the international Don Tucker award. After a postdoc at the Arizona Research Labs in Tucson, at the end of 1990 she went back to Germany to the University of Konstanz. With her own DFG-payed position and grant financing her research in circadian rhythms she collaborated with the groups of Profs. Drs. W. Rathmayer and H. Markl. Starting 1992 as research assistant at the University of Regensburg she habilitated in the Department of Prof. Dr. H. Altner. There, her lab investigated circadian pacemakers and olfactory transduction in different insect species. For her postdoctoral work in olfactory transduction she was awarded with the international Takasago award. After an assistant professor position at the Univ. of Marburg, starting in 1998, in 2007 she became an associate professor at the Univ. of Kassel.

Her scientific interest centers at understanding the neuronal basis of natural behavior in insects. Her lab compares neuronal mechanisms of more genetically programmed with mainly stimulus-elicited behaviors, working with olfactory receptor neurons and neuropeptidergic circadian pacemaker networks in different insect species. Her research focuses on the mechanisms of rhythm generation at multiple timescales in neuronal networks and single neuropeptidergic circadian pacemaker neurons as basis of genetically determined behavior. Interdisciplinary projects within CINSaT include a cooperation with Prof. Dr. C. Popov at the Dep. of Technical Physics. Ultrananocrystalline diamond (UNCD) films are employed to strongly attach primary cell cultures of insect neurons to allow for physiological analysis in calcium imaging studies combined with immunocytochemistry. Three publications resulted from this fruitful collaboration. In a cooperation with the group of Prof. Dr. A. Ehresmann at the Department of Experimental Physics IV an automated light stimulation setup was developed to investigate the circadian light input pathway from the cockroach compound eye to the circadian pacemaker center. A common publication about the time-dependent regulation of wavelength sensitivity in the cockroach eye is currently in preparation. In a collaboration with Prof. Dr. M. Garcia we develop new tools for the analysis of large electrophysiological data sets. We are currently writing our first common publication. Finally, we cooperate with the group of Prof. Dr. F. Herberg, Department of Biochemistry employing different cAMP / cGMP analogs and engineered FRET sensors for the study of pheromone-dependent ion channels.

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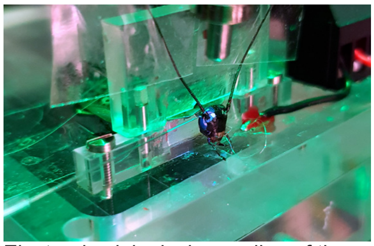
The animal physiology group members in Juli 2018.



Electrophysiological recording of the compound eye of the Madeira cockroach. A pulse of UV light triggers an electrical response in the eye. On the left side is the steel electrode.

Light-Matter-Interaction - Faculty 10

Prof. Dr. Kilian Singer is the head of Experimental Physics I / Light-Matter-Interaction and a member of CINSaT since 2016. The research focus of his group is to further quantum technologies, in particular by the manipulation of atoms and ions at the nanoscale. This is highlighted by the development of an atomic nanoassembler, the exploitation of Rydberg atoms for quantum detection of chirality, the investigation of the Kibble-Zurek mechanism thought to be involved in the formation of the early universe and also the development of the single atom heat engine. The latter was ranked by Physics World to be among the top ten publications of the year 2016. The single atom heat engine can be seen as the first experimentally-realised thermal machine or heat engine operating truly at the nanoscale, with the potential of reaching the deep quantum regime. The special feature of this engine is that it can exploit the time-averaged definition of temperature which replaces the common ensemble-average under ergodic system evolution. In terms of quantum thermal machines, the research group is performing pioneering experiments in the field of thermodynamics towards the quantum regime. Prof. Singer has also predicted a boost in efficiency of single ion heat engines when driven with non-thermal baths.

He is also leading a research network funded by the Volkswagen-foundation focusing on the deterministic generation of color centres in diamond through the extraction of single laser cooled ions from an ion trap. This project aims at the realization of scalable quantum information processing with color centres at room temperature via deterministic single-ion implantation. A second Volkswagen-foundation project, also led by Prof. Singer, focusses on the realization of quantum memories and quantum sensors based on color centres. This project depends on the collaborators within CINSaT, namely the groups of Prof. Cyril Popov, Prof. Johann Peter Reithmaier and Prof. Christiane Koch.

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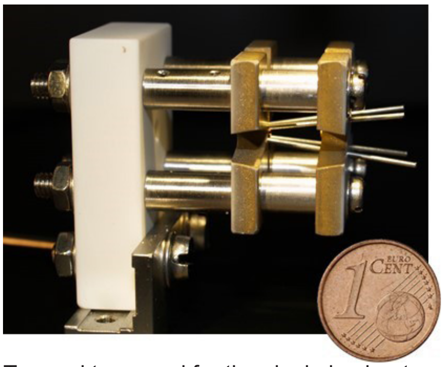

Tapered trap used for the single ion heat engine, prior to mounting in the experimental setup. The euro cent is to assist with visualising the scale.

Professor Singer and his group in Kassel

Computational Electronics and Photonics - Faculty 16

Photonics is the science of controlling light for a multitude of applications, such as information technology, materials processing, metrology, and lighting. The Computational Electronics and Photonics Group (CEP) develops theoretical models for photonic components and systems. Our work combines aspects of applied mathematics, physics, electrical engineering and computer science. This has led to multi-physics simulation codes for carrier transport, light-matter interaction and electromagnetic waves in semiconductor devices.

The area of solid state lighting continues to be an active research field. III-nitride based light emitting diodes (LEDs) have become light sources with external quantum efficiencies of close to 70%, lifetimes of several 10‘000 hours and excellent color control. With detailed numerical calculations and comparison to experiment, our group contributes to the research on visible light emitters within this material system. We have developed a consistent model for describing the efficiency droop, which is the reduction of the internal quantum efficiency at rising current densities. By deriving an extended description of the Auger process, and developing a realistic model for dopant activation, a broad set of experiments on efficiency droop can be explained consistently, with Auger model parameters derived from first principles. Currently, we apply this model to ultraviolet III-nitride LEDs.

Photonic sensing is another field of research within the CEP group. This involves the interaction of electromagnetic waves with the sample. In collaboration with experimental partners at IHP Frankfurt, Oder and University of Osnabrück we are developing CMOS based Terahertz sensors for characterizing the conformational state of proteins. The fundamental question is how to control THz waves so that a sensor can detect modifications in the protein conformation and its hydration shell. In order to benefit from the capabilities of the CMOS technology, semiconductior based plasmonic subwavelength resonators are designed by our group. By selective deposition of proteins on the sensor suface, and maximum interaction with the THz wave, maximum sensitivities are predicted by our model.

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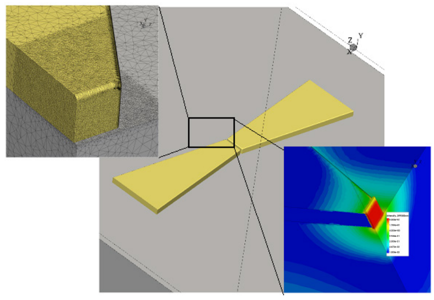
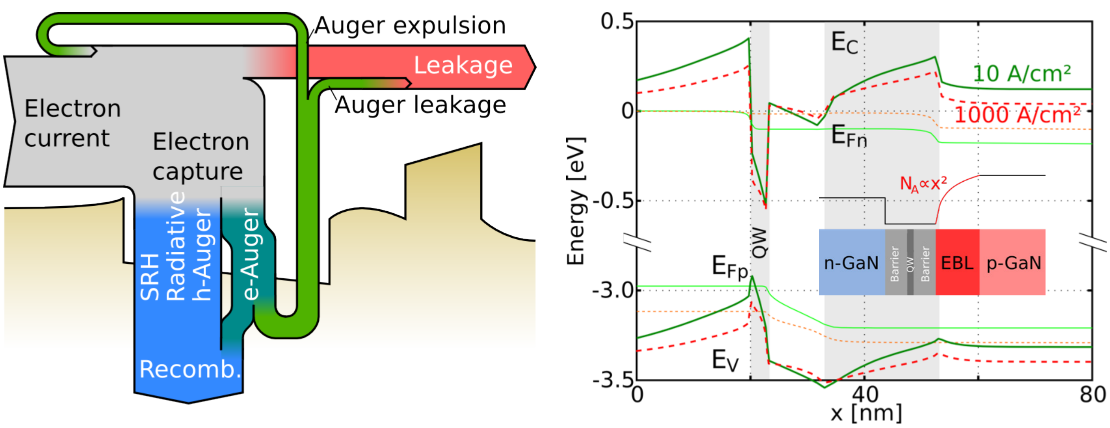


Electromagnetic simulation of a germanium (Ge) THz sensing structure with plasmonic field enhancement of 10‘000 in the gap between the resonator arms.



Left: schematic of electron current in a quantum well LED, including a leakage component from Auger recombination.
Right: band diagram of a blue quantum well (QW) LED at different currents, showing the reduction of electron barrier with increasing current due to nonideal doping.

Latest Reports

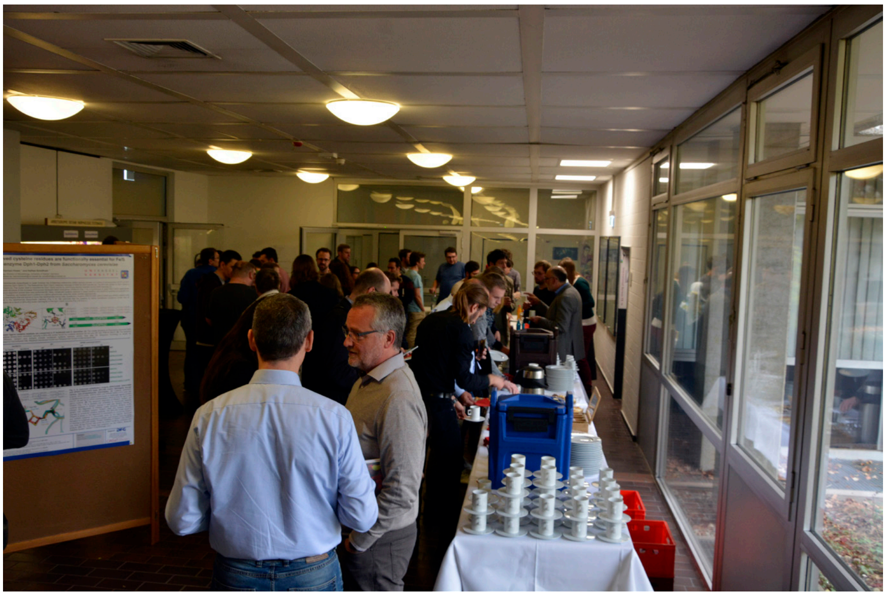
Autumn colloquium

This year's CINSaT Autumn Colloquium continues to thrill and attracts many professors, academic staff and students to the lecture hall. On Wednesday, 24.10.2018, the annual autumn colloquium of the CINSaT took place for the first time in the renovated lecture hall 282 at the Heinrich-Plett-Straße of the University of Kassel. Numerous professors, doctoral students, as well as undergraduate and graduate students from various disciplines waited excitedly for the lectures of the guest speakers. The autumn colloquium, which is open to all who are interested, offers not only the opportunity to listen to interesting topics on current nanotechnology research, but also to inform themselves about the current research contents of the CINSaT during the poster session. The opening of the event took place on behalf of CINSaT speaker Prof. Dr. Johann Peter Reithmaier by the board member Prof. Dr. Bernd Witzigmann, who welcomed the auditorium warmly.

The beginning of the lecture series was made by Prof. Dr. Johann Plank from the Technical University of Munich who in his lecture „Polycarboxylates (PCE) Superplasticizers and Their Impact on the Micro and Nano Structure of Concrete" very vividly explained the effects of various additives based on polycarboxylates and their effects on the micro- and nanostructure of the individual phases in concrete, as well as the associated changes e.g. in the mechanical properties. Following this, Prof. Dr. Philip Russel from the Max Planck Institute for the Physics of Light in Erlangen captivated the audience with his exciting lecture „Ultimate light-matter control in glass-fiber crystals". The presentation was accompanied vividly with videos.

After a half-hour coffee break, which was used not only to get to know each other, but also for the first review of the posters, the second part of the lecture series followed, Assoc. Prof. Dr. Jussi Toppari from the Nanoscience Center of the partner university in Jyväskylä (Finland) presented his lecture entitled „Chemistry of Vacuum: Manipulating Chemistry with a Vacuum Light Field".

The poster session following the lectures achieved a new record with 52 posters. The foyer in front of lecture hall 282 offered not only enough space for the numerous poster contributions, but also for extensive scientific discussions and the exchange of information on current research content within the CINSaT. The catering of the Studentenwerk of the University of Kassel provided again for the well-being during the event. The interdisciplinary cooperation within the CINSaT has been pronounced through cross-working-group poster contributions or related posters of the research consortium PhosMOrg (Phosphoregulation of Biomolecules: from Mechanisms to Organisms).



First discussions during the coffee break

The conclusion of the event was the presentation of the poster prizes awarded by this year's jury - consisting of CINSaT members Prof. Dr. Jörg H. Kleinschmidt, Prof. Dr. Markus Maniak, Prof. Dr. Thomas Niendorf and Dr. Arne Senftleben - for the three best poster contributions (1st prize tablet, 2nd prize retro gaming console, 3rd prize external hard drive). The jury emphasized the high scientific quality of the posters.

Rico Huhnstock won the 1st prize this year with the poster „Exploring the static and dynamic behavior of spherical exchange-biased Janus particels as a new tool for microfluidic biointeraction screening". Second place went to Uh-Myong Ha & Kristijan Krekic this year with their poster „Highly fluorescent triangle shaped PMMA nanoparticles". The third place was awarded to Sabine Pautz with the poster „Biochemical Characterization of Microtubule-Associated Serine / Threonine Kinases".

Due to the high number of participants, both in the audience as well as the poster contributions, and the thematically balanced lectures of the guest speakers, the CINSaT Autumn Colloquium was again a complete success.

Exciting discussions during the poster session

Group photo of the members of the poster jury, award winners and CINSaT speaker

CINSaT present at the Hessentag 2018 in Korbach

With mostly sunny weather and summery temperatures, this year's Hessentag in Korbach once again provided an ideal opportunity for visitors to gain insights into the diverse and interdisciplinary research topics at currently going on at CINSaT. At the same time, the scientists showed a great deal of commitment to the interested visitors in the wide range of courses offered at the University of Kassel and their references to nanotechnology.

The CINSaT was once again present at the booth of the science campaign „Hessen Schafft Wissen“ together with the numerous research projects of ProLOEWE - LandesOffensive zur Entwicklung Wissenschaftlich-ökonomischer Ekzellenz. The Hessentag is a unique format from the state of Hessen to make science accessible to the public and to communicate in an understandable language. For this purpose, many experiments and exhibits were prepared to astonish the visitors. The scientists were thus able to prove that the image of science has changed significantly in recent years and that science communication has meanwhile become an important element.

In addition to exciting experiments, a visit to the CINSaT booth offered the opportunity to gain insights into the diverse and sometimes internationally unique study programs - such as the Nanostructure Science study program - at the University of Kassel, the latter being largely supported by CINSaT's established research areas. The close intertwining of interdisciplinary cooperation is particularly impressive, using the example of the previously funded LOEWE project ELCH - Electron Dynamics of Chiral Systems - from which an own research focus „Chiral Systems" has grown and recently merged into a DFG Collaborative Research Center. The current research activities of the Collaborative Research Center on the topic of chirality were discussed i.a. using 3D models on the topic of handedness, the variable odor properties of molecules of the same chemical composition and the uniform direction of rotation in screw housings illustrated.

Especially the experiments with liquid nitrogen, the influence of magnetic liquids by magnetic fields and the replica of an atomic force microscope with LEGO Mindstorms for the elucidation of nanostructures were perceived as spectacular and attractive. For the latter, numerous children and adolescents who had already gained initial experience in the programming of such systems at school or privately could also be enthusiastic.

CINSaT presents itself at this year's Campus Festival of the University of Kassel

The campus festival of the University of Kassel - which celebrated its three-year anniversary this year - once again provided an ideal opportunity for CINSaT to give interested citizens from the region insights into research and study opportunities in the field of nanotechnology at the University of Kassel. In addition to information material on the scientific center itself and the CINSaT-supported bachelor and master programs Nanoscience, the CINSaT has also shown exhibitions on core topics of nanotechnology. These range from a LEGO Mindstorms replica of a scanning probe microscope, models of DNA molecules and the so-called football molecule „Buckminster Fullerene“ to magnetic nanostructures, such as those found in hard disks, or the influence of magnetic fields on magnetic material. In the latter case, the visitors were able to experience that, for example, the toner material of laser printers is magnetic. The campus festival was once again a successful event to bring the work of CINSaT closer to the public.

Announcements

Spring Colloquium 2019

CINSaT cordially invites all members and their staff to take part in the internal spring colloquium, taking place from Tuesday, the 7th to Friday, the 8th of March 2019 in the Ahorn Berghotel in Friedirchroda. All participants (except the members) have to submit a contribution in form of a poster or talk.

The talks held during the colloquium will be organized by the CINSaT main topic speakers and the management. On the one hand, the keynote speakers will make individual inquiries regarding the presentation of a lecture to the CINSaT members and their staff. On the other hand, you are also welcome to make inquiries regarding a presentation to the main topic speakers or the management:

- 3dimensional Nanostructures (Prof. H. Hillmer)
- Biosensing (Prof. A. Müller)
- Photonics (Prof. P. Lehmann)
- Chiral Systems (Prof T. Baumert)
- Quantum Technology (Prof. K. Singer)
- Nanostructures in natural sciences, engineering sciences and the arts (Prof. B. Middendorf, Prof. T. Niendorf)

For registration, please send an E-Mail to Nina Felgen including the following information:

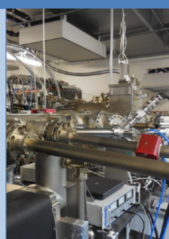
- Name of participamnts
- (Preliminary) Title of the contribution
- Information, if you stay over night or only can attend one day

The deadline for the registration is Wednesday, 19th December 2018. The preliminary schedule will be delivered after the registration deadline has expired. We expect the colloquium to start at 9:30 a.m. (07.03.2019)and end at 5:00 p.m (08.03.2018).

Note that all participants have to arrange their own travel, which is not funded by CINSaT.

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

Participants of the CINSaT Spring Colloquium 2018

Ab 10:00	**Experimente zum Anschauen und Mitmachen** … die verblüffen, … die Spaß machen, … die begeistern, … die Physik greifbar machen **Gesprächsangebote mit Physikerinnen**	
10:30 Hörsaal 298	**Begrüßung:** Prof. Dr. Rainer Finkeldey, Präsident Universität Kassel Prof. Dr. Thomas Baumert, Institutsdirektor Universität Kassel **Vortrag:** **„Bauteile für ein Quanteninternet: Quantenschnittstellen zwischen Licht und Materie“** Prof. Dr. Tracy Northup, Universität Innsbruck	PHYSIK KASSEL 
Stündlich	**Laborführungen** Reinraum, Femtosekundenspekroskopie, Quantensensing, Astromoleküle im Labor, Forschung und Lehre in der Physikdidaktik, Physik der Extreme 12:30, 13:30, 14:30, 15:30 (Anmeldung am Infopoint im Foyer)	

Die Cafeteria am Standort ist von 10-17 Uhr für Sie geöffnet.

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: Backside of a HFCVD grown nanocrystalline diamond film

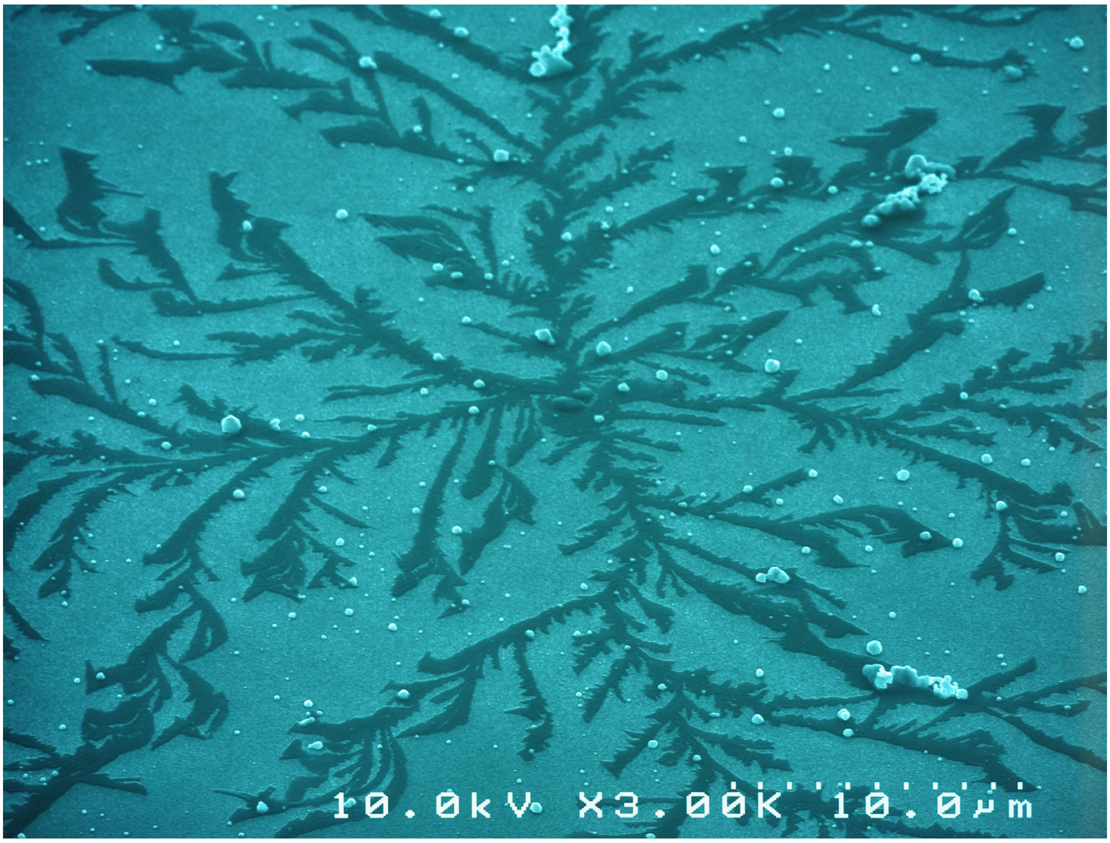


photo: A. Schmidt, AG Reithmaier/Popov; Nano Diamond Group

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

Imprint

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print:
viaprinto
Martin-Luther-King-Weg 30a
48155 Münster

Responsible according to the press law (german: ViSdPR):
CINSaT executive board,
University of Kassel