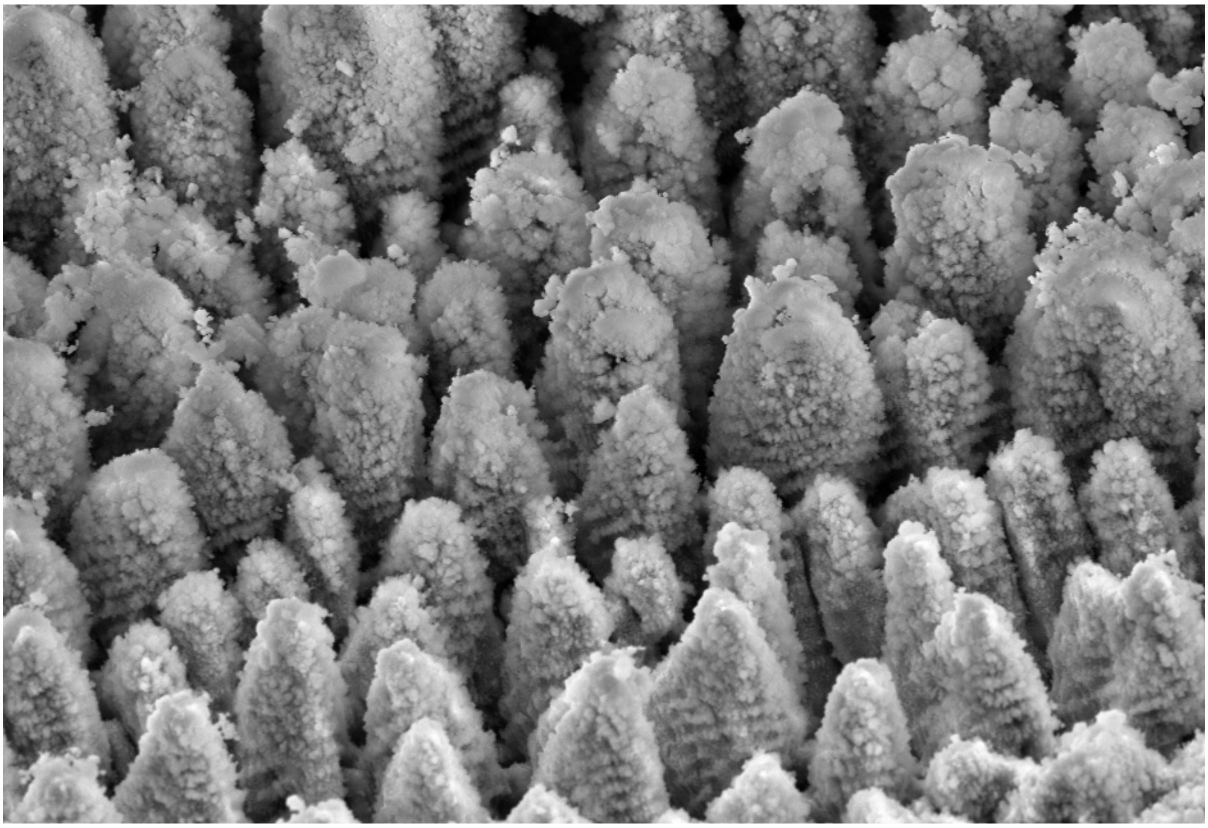
CINSaT Center for Interdisciplinary Nanostructure Science and Technology

Newsletter No. 18 (July 2025)



UNIKASSEL VERSITÄT

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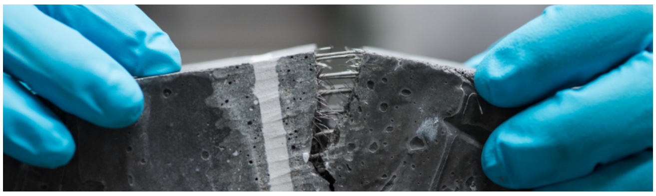

Cover Image
Spike structures adorned with nanostructures produced on crystalline Silicon orientation <111> with 1035 nm wavelength and 400 fs pulse duration (images taken by Group of Prof. Florian Baron).

Preface

Dear Readers of the CINSaT Newsletter,

Welcome to the first issue of the CINSaT Newsletter in 2025. This year has already brought many changes for CINSaT, most notably, you're reading these lines from me for the first time, rather than from Prof. Johann Peter Reithmaier, who has written this introduction for the past eight years. At the CINSaT General Assembly on March 5, 2025, Prof. Dr. Johann Peter Reithmaier stepped down as spokesperson of CINSaT. He had been a member of CINSaT since 2005 and played a key role in shaping its development. Since May 13, 2016, he led the center as spokesperson with great dedication, promoting interdisciplinary collaboration in nanostructure research at our university over many years. I would like to express my deep gratitude for his longstanding commitment and leadership.
I was honored to be elected as the new spokesperson of CINSaT and would like to take this opportunity to briefly introduce myself. I have been a member of CINSaT since 2022 and have been actively involved ever since. I have held the Chair of Physical Chemistry of Nanomaterials at the University of Kassel since October 2021. I studied chemistry and earned my Ph.D. with honors in 2011 from the University of Erlangen under the supervision of Prof. Dr. Andreas Hirsch. After working as Deputy Executive Director in the Cluster of Excellence Engineering of Advanced Materials, I joined the group of Prof. Jonathan Coleman at Trinity College Dublin in 2012 with a research fellowship from the German Research Foundation (DFG). In 2015, I returned to Germany and began leading an Emmy Noether independent research group at Heidelberg University in 2016. My research focuses on liquid-phase exfoliation, the size control and modification of nanosheets, and the development of hybrid materials. Already during my time in Erlangen, I became enthusiastic about inter- and transdisciplinary research—an approach I am now eager to strengthen further in my new role as spokesperson of CINSaT. I look forward to continuing our work together and to supporting the excellent and diverse research activities within CINSaT.
The content of this newsletter, as usual, is provided by our members. In the New Projects section, you will find a report by Prof. Wenwen Song on the DFG-funded project "White and Dark", which investigates fatigue damage mechanisms in safety-relevant industrial components using high-end characterization methods, numerical modelling, and large-scale diffraction techniques, among others. The project is a collaboration between several universities and institutes. Prof. Mohamed Benyoucef and Prof. Cyril Popov report on the new joint research project "Quantenrepeater.Net (QR.N)", funded by the Federal Ministry of Research, Technology and Space. The project aims to identify suitable hardware platforms for scalable quantum communication. In their respective sub-projects, Prof. Benyoucef aims to realize quantum emitters in resonators operating at the telecom C-band, while Prof. Popov explores the integration of color centers in diamond with nanophotonic structures.
In the Research Highlights section, you will find a report by Prof. Hartmut Hillmer on the new size upscaling of MEMS smart glass for personalized lighting and energy management in buildings. Another report features a publication by Prof. Camilo Florian Baron on the efficiency of temporal Airy pulses in thin glass dicing. Prof. Florian Baron joined CINSaT in 2024 and will present his research in the New Member section. There, you will also find the introduction of Prof. Benoit Merle, who joined CINSaT in 2025. In the Latest Report section, you will find coverage of this year's spring colloquium and an engaging special lecture delivered by an international guest. This section also includes a report on a special issue of the scientific journal Advanced Quantum Technologies, entitled "Photonic Quantum Technologies", edited by Prof. Mohamed Benyoucef.

As always, I hope you enjoy reading this issue!

New Projects
White n Dark

Identification of the formation mechanisms of white etching cracks and fine granular dark areas during fatigue loading – parallels and differences

Safety-relevant components in industrial sectors such as transportation, energy and construction are frequently exposed to cyclic loading [1]. For the reliable design and construction, extensive knowledge and understanding of the material's fatigue behavior is essential [2]. Inproper component design can lead to catastrophic consequences such as economic damage or, much more fatal, danger to human life [3]. This emphasizes the significance of our new German Research Foundation (German: Deutsche Forschungsgemeinschaft, DFG) funded Forschungsgruppe project (FOR 5701), in which the fatigue damage mechanisms in terms of white etching cracks (WEC/ WEA) and fine granular dark areas (FGA) will be comprehensively understood through high-end characterization methods, numerical modelling, large-facility diffraction techniques and controlled fatigue testing under diverse environments. This mechanistic insight will assist in designing damage-tolerant materials for promoting sustainable energy transition.

The project is a collaboration between RPTU Kaiserslautern, RWTH Aachen, TU Darmstadt, IFOS GmbH (Institut für Oberflächen- und Schichtanalytik) and the University of Kassel. It is organized into eight sub projects, consisting of professors, postdoctoral researchers and PhD candidates with expertise in material science, mechanics, analytical techniques and simulation. The research department 'Granularity of Structural Information in Materials Engineering (GWS)' at University of Kassel, led by Prof. Wenwen Song, aims to investigate the formation mechanism of the two phenomena (WEC/WEA and FGA), and crack initiation and propagation in steels with variable carbon concentrations and hardness in the subproject TP4 in FOR 5701. Multiscale characterization by scanning electron microscopy (SEM), transmission electron microscopy (TEM), atom probe tomography (APT) and synchrotron X-ray computed tomography (SR-CT) as well as in situ fatigue tests will be integrated to gain a comprehensive understanding of the complex mechanisms. Moreover, the influence of hydrogen migration, variable mean stress and temperatures will be investigated. The mechanical and analytical results serve as interactions for simulations in other sub-projects to enhance the overall comprehension. The DFG is funding the project with 4.5 million euros over the next four years. After successful completion of the project, a second funding period of another four years of intensive research is planned.

Rolling element bearings are exposed to rolling contact fatigue (RCF) [4] during their lifetime in e.g. wind turbines. Although components are used in accordance with industry recommendations, failure can occur significantly earlier than predicted by design. One specific failure mode, which is less understood than failure related to lubrication problems, can arise already at 5 – 10 % of the calculated rating life [5]. By analyzing the microstructure of failed bearings, it has been revealed that this failure correlates with the initiation of internal cracks around microstructural inhomogeneities. These cracks appear white when treated with a contrast agent and observed in a light optical microscope (LOM), hence the designation white etching crack (WEC) [6]. The branching of WEC's to a network is also known as white etching area (WEA) and can be seen in Figure 1 a) [7]. Results obtained by SEM for the area of investigations are shown in higher magnification as an Image Quality (IQ) map in Figure 1 b) and as an Inverse Pole Figure (IPF) map in Figure 1 c). Grains with sizes below 250nm are demonstrated in the latter, highlighting the above-mentioned grain refinement.

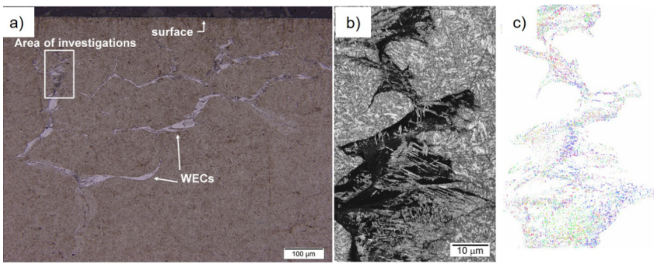

Figure 1: a) LOM micrograph of WECs in 100Cr6 bearing steel, b) IQ map and c) IPF map of bcc grains in altered region with grain size <250 nm by Šmeļova et al. [7]

Another damaging mechanism can be found in high-strength steels or titanium alloys, that are exposed to tension-compression loading or rotating bending with stress amplitudes below a conventional fatigue limit. Surpassing 10^7 loading cycles during their lifetime, failure occurs in a regime, which is known as Very High Cycle Fatigue (VHCF) [8]. In contrast to surface crack initiation, which is the dominant mechanism for larger stress amplitudes, a unique feature can be observed on the fracture surface. Due to its visual appearance, as seen in Figure 2 a) [9], it is called “fish-eye” [10].

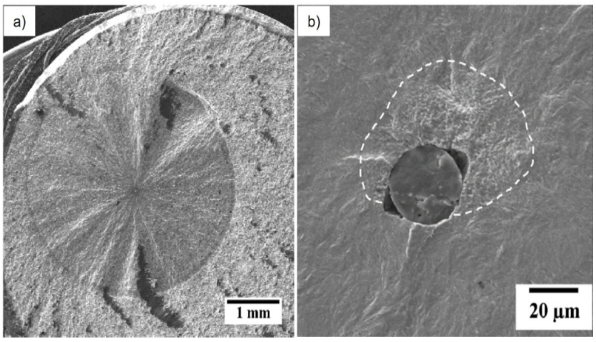

Figure 2: a) fish-eye formation on the fracture surface and b) internal crack initiation at a non-metallic inclusion and FGA formation in 50CrMo4 tempered steel by Giertler et al. [9]

In its center, a material defect like a non-metallic inclusion or pore is always present. Investigations by SEM have shown that a fine granular area (FGA) forms in the immediate vicinity of the defect [11], see the white circle in Figure 2 b) [9]. This same area appears dark when observed through the bright-field of a LOM [12]. The formation of the FGA plays a crucial role in samples with internal failure, as it accounts for more than 95 % of the total fatigue life [13].

Several models and hypotheses have been postulated for the crack initiation, grain refinement and crack propagation regarding both WEC/WEA and FGA, but still the mechanisms have not yet been conclusively clarified. The main objectives of FOR 5701 are to understand these mechanisms and to identify the analogies between the two phenomena. Knowledge about the chronological sequence of crack initiation and grain refinement is mandatory for proper component design and lifetime prediction. Based on the results of the project, new material concepts will be developed to improve bearing steels in wind turbines and other applications. By reducing the demand for maintenance and resources, these developments will make a significant contribution to sustainability.

Further Information

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BMFTR - Joint Research Project: Quantenrepeater.Net (QR.N)

Reports on IT sabotage, espionage, and cyberattacks are increasingly common. Quantum networks promise a new level of security, vital for protecting free societies and critical infrastructure. Central to these networks are quantum repeaters, enabling secure long-distance communication and forming the backbone of quantum-secure IT systems. They will also be essential for linking future quantum computers to secure networks.

In the newly launched joint research project “Quantenrepeater.Net (QR.N),” is funded by the Federal Ministry of Research, Technology and Space (BMFTR) and started in January 2025. The project involves 42 partners from academia and industry who are working to advance quantum networks and demonstrate quantum repeaters outside the laboratory. A key focus is on identifying suitable hardware platforms for scalable quantum communication. Promising candidates include individual atoms and ions, semiconductor structures, color centers in diamond, and rare-earth-doped systems. To enable efficient quantum networking, quantum states must be generated with high fidelity, temporarily stored, and transmitted with minimal loss. The project will also explore cross-platform protocols and hybrid systems.

The Institute of Nanostructure Technology and Analytics (INA) at the University of Kassel is involved in the project with two working groups, each focusing on a distinct material platform for the development of quantum repeater technologies. The first sub-project, titled "Telecom C-band InP-based Quantum Dot Structures and Quantum Dot Molecules," is led by Prof. Dr. Mohamed Benyoucef and targets the realization of quantum emitters in resonators operating in the telecom C-band. The second sub-project, "Diamond-based Photonic Nanostructures with Coupled Color Centers," is headed by apl. Prof. Dr. Cyril Popov and explores the integration of color centers in diamond with nanophotonic structures.

The sub-project "Telecom C-band InP-based Quantum Dot Structures and Quantum Dot Molecules" pursues the following key objectives:

- Epitaxial growth via molecular beam epitaxy (MBE) and comprehensive optical characterization of InP-based quantum dots (QDs) and quantum dot molecules (QDMs) emitting in the telecom C-band.
- Nanostructuring and integration of QDs and QDMs into microresonator architectures.
- Demonstration of bright emission with negligible fine-structure splitting (FSS), enabling their use as efficient single-photon sources and entangled photon-pair emitters, as well as for fiber coupling.
- Implementation of doping-controlled QDs and QDMs as rechargeable platforms for spin manipulation and quantum memory applications.

These research activities are conducted in close collaboration with partner groups in Berlin (HUB, TUB), Dortmund, Hanover, Munich (TUM), and Stuttgart.

The group of apl. Prof. Dr. Cyril Popov (Diamond Quantum Nanotechnology) will exploit the unique properties of the color centers in diamond. These point defects in the crystal lattice are composed of a foreign atom (N, Si, Ge, Sn) adjacent to one or more vacancies, and possess exceptional optical and spin properties, namely long quantum coherence times of electron and nuclear spins even at room temperature in combination with efficient optical transitions as an interface to photons for the transfer of quantum information. Diamond as a solid-state platform offers the advantage of integration „on-chip“ with photonic elements for the targeted enhancement of the spin-light interaction. The goal of the project is the fabrication of diamond membranes and diamond photonic structures (such as 1D and 2D photonic crystals, and waveguides) using reactive ion etching and electron beam lithography. These structures will be coupled with color centers to increase the photon collection efficiency and applied as components for realization of demonstrators of quantum repeater nodes and fragments by project partners in Karlsruhe, Ulm, Berlin (HUB) and Stuttgart.

Further Information

[Quantenrepeater.Net (QR.N)]

Website: [Quantum Nano Photonics]

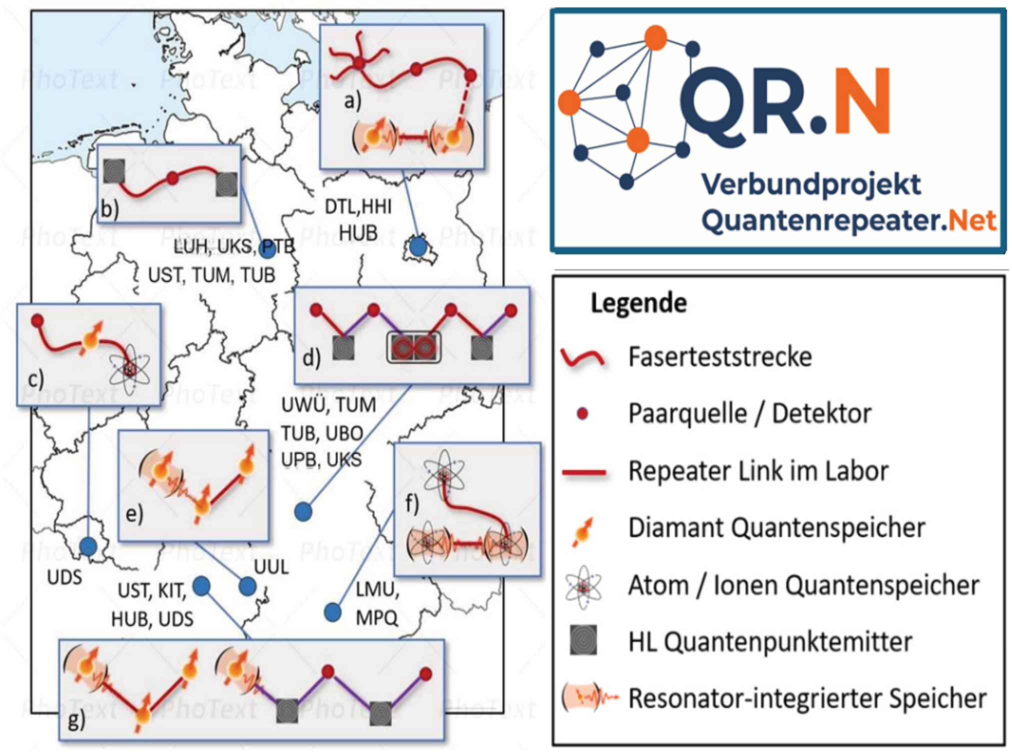
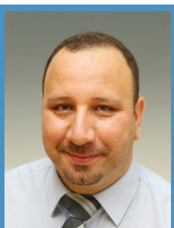


Fig. 1. Planned quantum repeater test tracks in Project QR.N



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Research Highlights

Use of Temporal Airy Pulses in Laser Dicing Technology

In a recent study published in Zeitschrift für Physikalische Chemie, researchers from the University of Kassel and the University of Craiova demonstrated a novel approach to precision glass cutting using temporally shaped femtosecond laser pulses, known as Temporal Airy Pulses (TAPs). By comparing three pulse types—standard bandwidth-limited (BWL) pulses, positively dispersed TAPs (TAP^+), and negatively dispersed TAPs (TAP^-)—the team investigated their effectiveness in scribing thin soda-lime glass for subsequent mechanical dicing. Using a Ti:sapphire laser system delivering 30 fs pulses at 785 nm, they inscribed lines under varying energies and scanning speeds with both medium (20×) and high (50×) magnification objectives. Post-inscription, the samples were broken using a custom four-point bending apparatus, allowing detailed analysis of edge quality and required breaking force. The results showed that TAP^+ pulses significantly outperformed the other types, producing deeper, cleaner, and more consistent ablation grooves with minimal collateral damage. These grooves acted as highly effective precursors for mechanical separation, requiring less force to break and yielding smoother fracture surfaces, particularly under tight focusing and low-energy conditions. This technique proved especially advantageous over traditional laser and mechanical cutting methods, offering enhanced precision and efficiency with less material loss and fewer defects. Given its scalability and compatibility with other dielectric materials, such as sapphire or semiconductors, TAP-based laser processing stands as a promising innovation for high-precision applications in microelectronics, optoelectronics, and advanced materials manufacturing.

Further Information

"Temporal airy pulses efficiency in thin glass dicing" Radu, Madalin-Stefan; Sarpe, Cristian; Ciobotea, Elena Ramela; Zielinski, Bastian; Constantinescu, Radu; Baumert, Thomas; Florian, Camilo.
Zeitschrift für Physikalische Chemie, 2024.
DOI: https://doi.org/10.1515/zpch-2024-0911

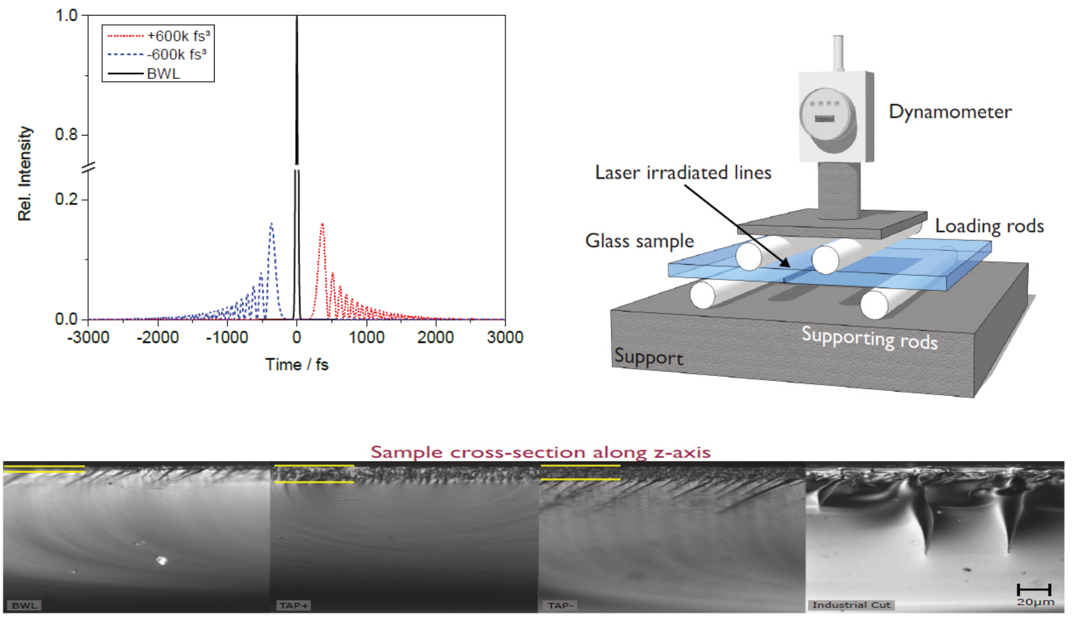

Figure 1: The plot contains the implemented pulses including temporal Airy pulses with positive and negative cubic phases (red and blue respectively) and in the center, the band-width limited pulse (BWL, in black). On the right, the scheme of the 4-point bending strength setup is displayed, where the laser treated, surfaces were diced measuring the force required. At the bottom, differential interferometric contrast optical microscopy images are included, highlighting in yellow the areas where the laser irradiation took place viewed transversely after the dicing process, displaying the resulting produced edges as well. For comparison, industrial cutting with a mechanical tool is also included on the right.

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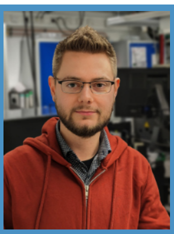

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Size upscaling of MEMS smart glass for lighting and energy management

Nowadays buildings consume the largest amount of primary energy only to cover lighting, heating and cooling. This is a major contribution to rapid global warming, rising sea level, and profound changes in ocean ecosystems by emitting massive amounts of CO_2. MEMS (micro-electro-mechanical system) micromirror arrays integrated between the double, triple or quadruple panes of insulation glazing can automatically steer and control daylight dynamically in rooms according to user requirements [1-6]. Recently we built our own large-scale lithography system and used it to up-scale the arrays to a module size of 71 cm × 128 cm containing about 15 million individual micromirrors. The MEMS arrays are mounted into double glazing window modules in Ar atmosphere. To the best of our knowledge this is the largest and fastest switching smart glass revealing also the lowest power consumption in international comparison [1]. A single micromirror is composed of three main parts: planarized anchor, curled hinge and micromirror blade. Within the multi-metal (Al,Cr) layers residual stress in the hinge area it is possible to obtain deflections of free standing micromirrors at angles of e.g. 130°, 120°, 110°, 100° or 90° without applied voltage. If an actuation voltage is applied between the metallic mirror plane and the FTO (fluorine-doped tin oxide) counter electrode, the micromirror can be held in different tilting angles. The whole window is subdivided into 28 subfields (4 columns × 7 rows) which can be addressed individually by individual actuation voltages. Thus, each subfield can reveal individual mirror orientations. Out of these almost unlimited number of scenarios, four specific ones have been selected and are depicted in Fig. 1. Our MEMS microshutters arrays with planarized metallic blades reveal an average power consumption of only 0.08 μW/cm^2, a modulation contrast of up to Tmax/Tmin = 7700 between the open and closed state.

Reliability studies are often performed as rapid aging tests, that means the system to be investigated is operated under high currents, at high temperatures, or high frequencies close to resonance, or exposed to hash environments, or a combination of some of these conditions. Our MEMS smart glass modules have been revealed to extreme environmental situations such as temperature changes; ultraviolet (UV), visible, or infrared (IR) radiation; mechanical vibrations and shocks. Our micromirror arrays for active light steering in smart windows are sealed in modules and protected in a noble gas atmosphere inside the insulation glazing (double glazing, triple glazing or quadruple glazing). The insulation glazing is filled with noble gas, since single-atomic gases exhibit the best thermal insulation properties next to vacuum. In such arrangements the micromirror arrays benefit enormously due to the absence of moisture and oxygen that could harm the metallic surfaces of the mirrors in the long term. Therefore, the remaining reliability issues which could cause material and structural failure are then limited to multiple movements, vibrations, mechanical shocks, sudden temperature variations, extreme temperatures, and UV radiation. In almost all cases in the experimental reliability experiments, MEMS micromirror arrays in double insulation glazing were used. Only the 1D vibration test is performed with just MEMS arrays on (10×10) cm^2 glass substrates (not mounted into modules), since a weight reduction was required to approach the high vibration frequencies of up to 7 kHz. The following experiments have been performed: (i) Simulating rapid aging due to fast movements, mechanical vibration tests with one or two degrees of freedom were performed (called 1D and 2D vibrations, in short). (ii) Material fatigue tests of the micromirrors have also been performed under electrostatic actuation at different frequencies for a long time. The MEMS micromirror arrays survived 53 billion of open-closed-open cycles, demonstrating sustainability and robustness of our MEMS technology. (iii) Solar irradiance in the UV was spectrally simulated by UV LED arrays using a choice of different UV wavelengths and was selected 10x higher than in extreme situations occurring in global big cities. Compared to visible LEDs, UV LEDs have much lower efficiencies which are approximately in the range of 2% at 350 nm and of 0.1% at 230 nm, Thus, UV LEDs are intense heat sources rather than efficient light sources. However, this heat was used to perform temperature cycles at the same time. A total cycle lasted 5 h 18 min, during which temperature rises from 21 °C to 52 °C and falls back to 21°. (iv) Additional faster multiple temperature cycles (between 0 °C and 80 °C without UV) have been performed to simulate the various thermal conditions in practice (during day and night period, sudden sun hiding behind dark clouds, during summer and winter and simulating sudden weather changes). (v) Full operability has been also shown at extreme temperatures of -80 °C and 120 °C. In all 5 cases electrostatic actuation tests and capacitance changes were measured to confirm functioning properly after the reliability tests. All studies already demonstrate a large operating temperature range fully sufficient for building, car, plane or ship applications and they reveal weather-, daytime- and season-independence in performance. In Fig. 3 the results are summarized. All the studies demonstrate weather-, daytime- and season-independence in performance of our MEMS micromirror smart glass. The MEMS micromirror arrays survived these tests without damage, seeming to reveal a long and stable maintenance free lifespan.

Finally, preliminary microwave transmission experiments show that the MEMS metal grid in combination with the FTO layer has even higher transmission than the FTO alone. Since all competitive smart glass technologies like electrochromic, liquid crystal or suspended particle technologies even need two transparent conductive oxide layers (such as FTO) this is a very promising result.

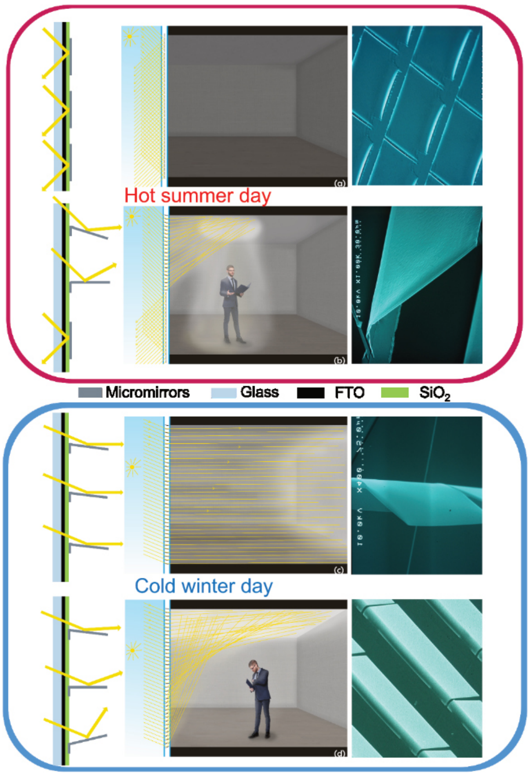
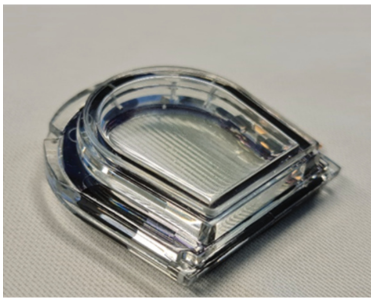


Fig. 1. The central row of diagrams illustrates a room equipped with a micromirror-array-based smart windows and scenarios with and without users in different seasons, demonstrating light steering and heat energy management. (a) Summer, no user present: solar radiation is blocked by reflecting outside that keeps the room cool and saves huge energy, (b) Summer, user present: illuminates by deflecting light towards ceiling above the user and saves energy by limiting the heat transfer with closed micromirror in the lower areas, (c) Winter, no user: acts as a radiation heater by using all solar infrared and visible radiation to heat up the room, (d) Winter, user present: complete solar radiation is reflected towards the ceiling. In the left column three corresponding micromirrors are depicted for each scenario and on the right row one SEM micrograph as an example is given for each scenario.

a)



b)

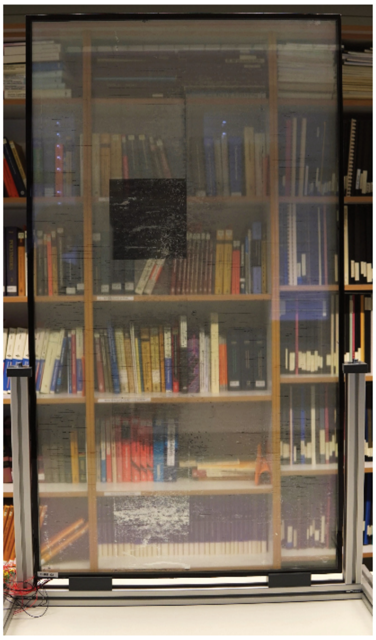


Fig. 2. MEMS micromirror array module housed as double using standard window module manufacturing process, in inert gas environment and sealed with butyl. (a) specially shaped small-scale module closing within 1μs at 80V for laser safety goggles (b) large-scale module of 71×128 cm2 closing within 30μs at 70 V in the center.

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Multiple permanent temperature cycles	Temperature range	Temperature cycle period	Duration (hours)	Remarks
	0 °C → 80 °C → 0 °C → ... (repeatedly)	1.5 h	225	Tested with mounted (housed module), no extreme UV exposure. With in situ C-V measurements.

Aging at extreme temperatures	Temperature (°C)	Temperature cycle period	Duration (hours)	Remarks
	+120	no cycle	30	Tested with mounted (housed module), no extreme UV exposure. With in situ C-V measurements.
	−80	no cycle	30	

Long-term rapid-aging/ Reliability test method	Frequency (Hz)	Duration (hours)	Open-close-open cycles	Remarks
1D Vibration	3278	36,122	not applicable	Forced oscillation on vibratory plate, external mechanical excitation, small amplitudes, sample tested
2D Vibration	60	200	not applicable	Forced oscillation on vibratory plate, external mechanical excitation, large amplitudes, mounted module tested
Vibration under electrostatic actuation	4000	3700	53 billion	Forced oscillation, internal electrostatic MEMS actuation, mounted module tested

Extreme UV exposure	Temperature cycles	Temperature cycle period	Duration (hours)	Remarks
UV	21 °C → 52 °C → 21 °C → ... (repeatedly)	5 h 18 min	1542	Aging under extreme UV solar spectrum. Tested with mounted (housed module). 10 times more intense than the most extreme situation occurring in big cities.

Fig. 3. Overview of different reliability studies and rapid aging tests performed for MEMS micromirror arrays.

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Further Information

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New Members
Prof. Dr. Camilo Florian Baron

Since summer 2024, Dr. Camilo Florian Baron, chair of the group of Extreme Light for Material Structures, became full CINSaT member.
Camilo Florian Baron obtained his doctorate in Nanosciences at the University of Barcelona, also working as a postdoctoral researcher fellow at the Institute of Optics from the Spanish National Research Council (CSIC) in Madrid, Spain, and the Center of Pulsed Lasers (CLPU) in Salamanca Spain, and at the Federal Institute for Materials Research and Testing (BAM), in Berlin, Germany. He was then a postdoctoral fellow at the Princeton Institute for the Science and Technology of Materials (PRISM), New Jersey, and a Marie Skłodowska-Curie Fellow at the Institute of Optics from the Spanish National Research Council (CSIC), in Madrid. His research area includes the interaction mechanisms between short and ultrashort laser pulses (ps and fs) with dielectrics, semiconductors and metals, both in the far and near field range. He has contributed to the development of laser-based additive and subtractive processes, including laser-induced forward transfer (LIFT) for printing viscous liquids and functional metal inks, and laser direct writing (LDW) for micro- and nanomachining of materials towards the functionalization for technological applications.

Extreme Light for Nanostructures
The Extreme Light for Nanostructures group bridges the gap between physics and engineering by using ultrashort laser pulses to modify material properties for applications across various fields, including optics, biology, medicine, tribology, and wetting.
Ultrashort laser pulses offer a powerful method for modifying nearly any material—metals, semiconductors, and dielectrics alike. Their key advantage lies in the ability to generate extremely high power peaks (in the GW-TW range) by depositing energy in materials during extremely short timescales, from picoseconds (10^{-12} s) to femtoseconds (10^{-15} s). This makes it possible to alter even transparent materials with high energy bandgaps. Our group exploits the legacy expertise from the Experimental Physics III laboratory to temporally shape ultrashort laser pulses using optical synthesizers. This allows us to precisely tailor the light to meet the specific demands for material processing, enabling nanometric modifications with unprecedented precision.

At ELiNa, these laser pulses are implemented to impulse the following research lines:

- **Nanomaterial processing laser direct write (LDW)**

Ultrashort laser pulses that are tightly focused can remove material from an irradiated surface and create micro- or nanometric modifications. Using an optical synthesizer to shape these laser pulses in time, enabling us to generate exceptionally narrow nanochannels, only 250 nm wide and 7 µm deep—far beyond previous capabilities with regular laser direct write systems. This technique can be used to gently perforate cell membranes with precision, allowing the cells to remain viable throughout the process, also to produce channels on glass for dicing it, reducing the necessary amount of force to break them. In combination with an additional spherical microsphere, nanometric modifications can be achieved by exploiting the near-field radiation for ultrahigh spatial resolution modifications.

- **Laser induced periodic surface structures (LIPSS)**

LIPSS are parallel lines formed on various materials using multiple ultrashort laser pulses. The orientation of these structures depends on the laser's polarization and the material's optical properties. Surface modification using LIPSS can alter characteristics such as reflectivity, wettability, and friction, due to both changes in surface structure and chemical alterations during laser processing. Ongoing research explores both the applications and origins of LIPSS.

- **Laser induced forwards transfer (LIFT)**

This technique is a laser-based printing method used to transfer functional materials. In this process, a laser is focused on a donor film, causing an interaction that propels the material forward, producing its deposition onto a receptor substrate. For liquids, the energy creates a micro explosion, forming a bubble that collapses and generates a thin liquid jet, which deposits a small droplet which size can reach just a few microns. The goal of the research is to improve the LIFT by using different functional fluids along with advanced pulse-shaping techniques to better control and optimize the transfer process, especially with transparent liquids, aiming towards reservoir-based donors rather than liquid thin films.

- **Laser induced breakdown spectroscopy (LIBS)**

Tightly focused ultrashort laser pulses can generate plasma in materials. As the plasma cools, ions and electrons recombine, emitting light patterns specific to the elements and molecules involved. This process is the basis for Laser-Induced Breakdown Spectroscopy (LIBS), which uses femtosecond laser pulses. The Experimental Physics Department at Kassel first demonstrated this technique in 2010, using a gated amplification system to detect only the relevant photons, avoiding interference from blackbody radiation. This system has been applied to investigate crack growth in metals and to distinguish between cancerous and healthy tissue in pathological samples using machine learning algorithms. Future research aims to explore depth-dependent laser-assisted surface chemistry for analyzing complex materials such as metallic alloys, battery electrodes, and biological samples.

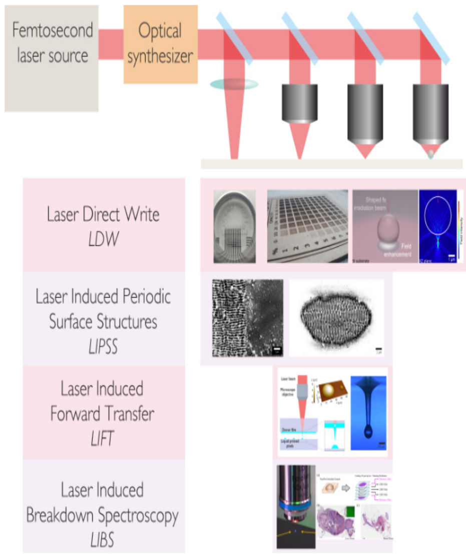


Figure 1: Research areas of the group of Extreme Light for Nanostructures from the Institute of Materials Engineering at FB15 and the Institute of Physics at FB10.

Prof. Dr.-Ing. habil. Benoit Merle

We are pleased to welcome Prof. Benoit Merle as a new member of CINSaT.

Prof. Merle recently joined the University of Kassel as the head of the Mechanical Behavior of Materials lab. He is an enthusiastic researcher in the field of nanomechanics, with a particular focus on nanoindentation and the mechanical testing of materials at the micro- and nanoscale. He earned both his PhD and habilitation in Materials Science from Friedrich-Alexander-University Erlangen-Nürnberg (FAU), following his engineering studies at École Centrale de Lyon and early career as an engineer at Siemens AG.

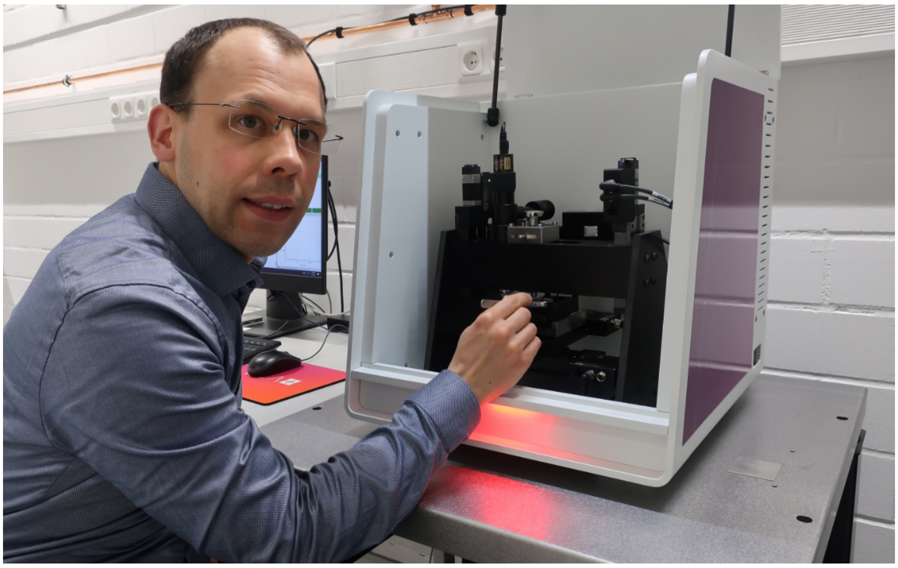
Prof. Merle is internationally known for his research on the mechanical behavior of ultrathin (<200 nm) metallic films, and for pioneering experimental methods in nanomechanics, including advanced nanoindentation and in situ nanomechanical testing in the SEM, TEM and AFM. His work has been recognized with several prestigious awards, including an ERC Starting Grant, the Masing Award from the German Materials Society (DGM), the Staedtler Foundation's Best PhD Award, and the Wolfgang Finkelnburg Award.

He maintains close research partnerships with Prof. George Pharr at Texas A&M and Prof. Dan Gianola at UCSB, where he has respectively been visiting scholar. Beyond his own research, Prof. Merle is committed to building strong scientific communities. He incepted and currently chairs the EU-COST network MecaNano, which connects over 500 researchers across Europe and supports early-career scientists, women in science, and researchers from Eastern Europe.

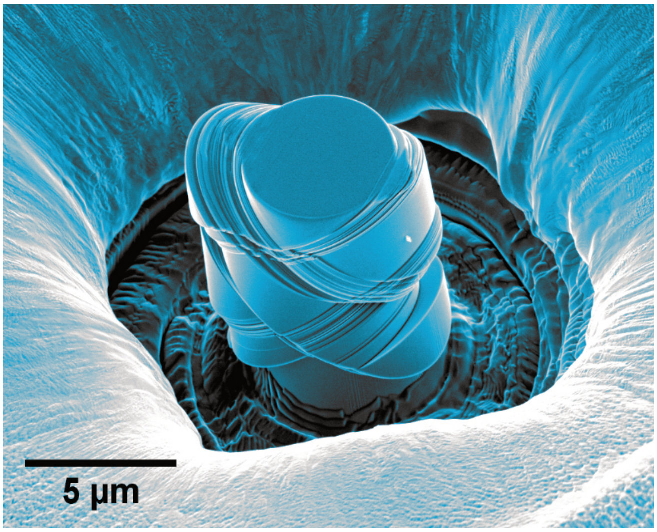
He is excited to engage with fellow CINSaT members and welcomes new collaborations, especially on projects involving the mechanical characterization of materials at small scales.

If you are developing materials sytems and are curious about how they deform at the nano- or microscale, do not hesitate to reach out - there's a lot we can explore together!

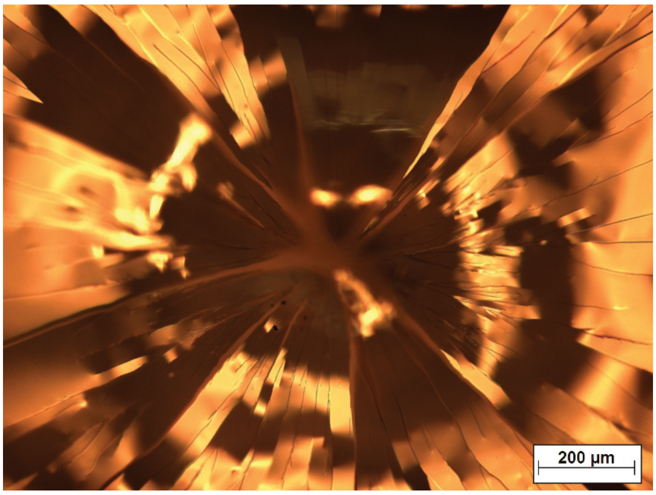
Information and contact: www.uni-kassel.de/go/mbm



Prof. Benoit Merle operating the iMicro nanoindenter at the University of Kassel.



Electron micrograph of a single-crystal brass micropillar undergoing multiple shear deformation after compression using the nanoindenter.



Shattered freestanding thin film following a punching experiment using the nanoindenter.

Latest Reports

CINSaT Spring Colloquium 2025

From March 13th to 14th, the CINSaT hosted the annual Spring Colloquium at the Berghotel Friedrichroda. A total of 80 participants attended, listening to over 15 scientific presentations that ranged from 10-minute general overviews of focal points to 20-minute focus talks on specific research findings. The poster session displayed approximately 45 posters, stimulating lively discussions among attendees. As organizers, we thank all the participants and contributors to this event and look forward to future activities and events to connect both people and research activities.

The first day began with the symbolic handover of responsibilities from Prof. Johann Peter Reithmaier to Prof. Claudia Backes, who was elected as the new speaker of CINSaT following Prof. Reithmaier's resignation just a week earlier. On behalf of all members, Prof. Backes expressed gratitude to Prof. Reithmaier for his tireless efforts in shaping CINSaT's future. Prof. Bernhard Middendorf chaired the first session on Nanomaterials, which included four presentations. After lunch, Prof. Müller led the Multiscale Bioimaging session, featuring two talks, followed by a special lecture from Prof. Thomas Fuhrmann-Lieker titled "Nanoscience or Nanosciences – The Interdisciplinary Discipline," based on his recent publication[1]. The talk sparked a lively discussion and a spontaneous survey among participants about the discipline they most identify with (results below). We were very proud to see that the majority of participants identified themselves as nanoscientists rather than members of their classical disciplines! Following this stimulating philosophical detour, Prof. Cyril Popov chaired the final lecture session of the day, which focused on Quantum Technologies. Eager for some fresh air, the participants took part in a 5 km hike through the surrounding forest. After dinner, all attendees gathered for the poster session, which led to productive discussions that often continued deep in the night.

The second day resumed the scientific talks, starting with the 3D Nanostructures session, chaired by focal point speaker Prof. Hartmut Hillmer, with four presentations. Prof. Peter Lehmann chaired the Photonics session, which also featured four talks. After lunch, individual focal point sessions took place, where the respective chairs discussed future endeavors within their areas of focus. These sessions culminated in a discussion among all participants, providing valuable insights for CINSaT's management and generating fresh ideas for improvement. After Prof. Backes gave the closing remarks, the Spring Colloquium 2025 came to an end. We hope all participants enjoyed the event and gained new knowledge!

[1]Fuhrmann-Lieker, T. Nanoscience or Nanosciences? - The Interdisciplinary Discipline. Nanoethics 18, 15 (2024). https://doi.org/10.1007/s11569-024-00464-7

Disciplines	%
Biology	8%
Chemistry	8%
Engineering	8%
Physics	10%
Nanoscience	54%
Others	15%

Figure 1: Passing the Torch – Former CINSaT speaker Prof. Reithmaier receives a gift in recognition of his contributions, presented by the new speaker, Prof. Backes

Figure 2: Group photo.

Figure 3: Audience of the 2025 spring colloquium.

Topical symposia at E-MRS organized by CINSaT members

At the 2025 E-MRS spring colloquium held in Strasbourg at May 26-30, topical symposia were organized by two CINSaT members. The E-MRS spring meeting is one of the two major conferences of the European Materials Research Society and offers on average 25 topical symposia. It is widely recognized as being of the highest international significance and is the greatest of its kind in Europe with about 2,500 attendees every year.

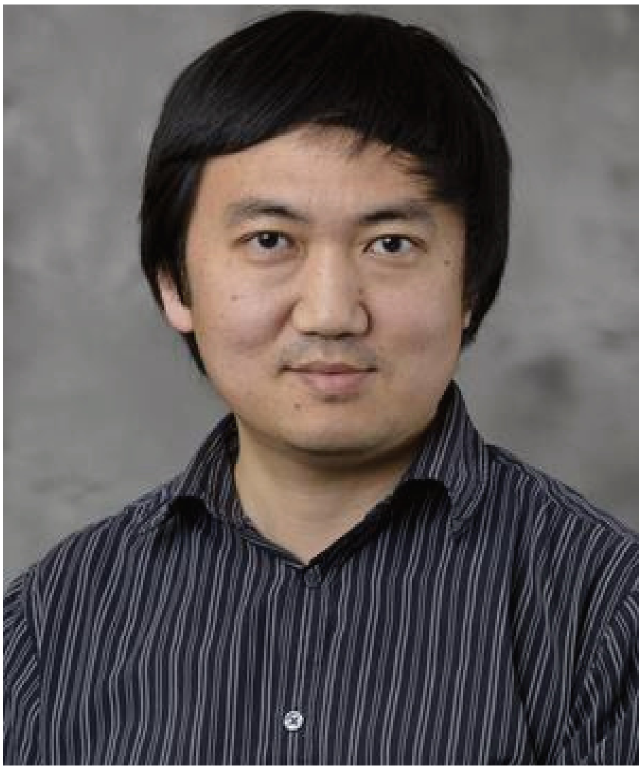
Prof. Claudia Backes, leader of the Physical Chemistry of Nanomaterials group, organized symposium C entitled “2D materials and beyond: tomorrow’s printable low-dimensional nanostructures and hybrids” together with three colleagues from Dublin, Manchester and Strasbourg. Focus of the symposium was on solution processing, printing & deposition, composite & hybrid formation, characterisation and applications of 2D nanomaterials as well as 1D and 0D systems. It brought together a lively community working on solution-processed nanomaterials for printed electronics from all over the world featuring 19 invited presentation.

Symposium O entitled “Laser-matter interaction for life and society: fundamental mechanisms and emerging applications”, organized by **Prof. Camilo Florian Baron**, leader of the Extreme Light for Nanostructures group, was equally successful. Prof. Camilo Florian Baron and his three organizer colleagues from Italy, Romania and France hosted an interdisciplinary scientific community working on laser materials processing and laser-matter interaction including 12 leading scientists as invited speakers. It covered the topics laser- and plasma-based materials synthesis, surface structuring and functionalization, 3D processing, additive manufacturing, process analytics and materials diagnostics with the special emphasis on the micro- and nanoscale.

At the 2025 Fall meeting taking place September 15-18 in Warsaw, Poland, **Prof. Jost Adam**, leader of the Computational Materials and Photonics group, is one of the organizers of the symposium E “Materials discovery, modeling, and characterization for sustainable energy applications”. We wish him all success and a wonderful event!!

Special Lecture by Prof. Dr. Yong Chen

On February 26, 2025, U.S. researcher Prof. Dr. Yong P. Chen visited CINSaT and delivered a one-hour lecture titled “Quantum Materials Meets Quantum Technologies”. Prof. Chen holds a bachelor’s degree in applied mathematics, a master’s from MIT, and a Ph.D. in electrical engineering from Princeton University, where he studied under Nobel laureate Daniel C. Tsui. After completing a postdoctoral fellowship at Rice University, he joined Purdue University, becoming a full professor in 2016 and later the director of the Purdue Quantum Science and Engineering Institute. Since early 2025, he has been the Director of the Center for Quantum Technologies at Purdue. Prof. Chen is also a principal investigator at Tohoku University in Japan and a Villum Investigator at Aarhus University in Denmark. With over 200 publications, his research covers quantum materials, devices, spintronics, and photonics. Approximately 50 researchers from CINSaT attended the lecture and engaged in an extended scientific discussion with Prof. Chen that continued well beyond the event's conclusion.



Special Issue on Photonic Quantum Technologies: Highlight

The miniaturization of photonic structures through advanced nanofabrication has opened new frontiers in photonic quantum systems, enabling breakthroughs in quantum computing, secure communication, quantum imaging, and metrology. These developments are reshaping experimental quantum physics and driving transformative technological innovation.

Earlier this year, we proudly published a **Special Issue on Recent Advances in Photonic Quantum Technologies** in the Journal of Advanced Quantum Technology. In celebration of 100 Years of Quantum Science and Technology, this issue compiles cutting-edge research and visionary perspectives that shape the current and future landscape of photonic quantum technologies.

The issue covers a wide range of quantum emitters, including ions, atoms, molecules, color centers, and artificial atoms, and highlights pioneering studies with both fundamental and practical applications. It addresses critical technical and conceptual challenges and proposes strategies for scalable quantum architecture. Additionally, it promotes interdisciplinary collaboration aimed at realizing practical and robust quantum technologies.

This special issue provides a comprehensive overview of recent developments in the field of photonic quantum systems, with a particular emphasis on hybrid integration strategies, cavity quantum electrodynamics (QED), and nanoscale light–matter interactions. Noteworthy achievements include the on-chip integration of entangled photon sources, the incorporation of color centers into nanophotonic architectures, and the fabrication of suspended transducers. The issue also explores single-photon emission at telecom wavelengths, molecule-based photon sources, the coupling of quantum emitters to plasmonic cavities, and the dynamics of coupled quantum systems.

This special issue features 20 contributions:

- **3 Perspectives**
- **4 Reviews**
- **13 Research Articles**

Collectively, these works reflect the rapid progress and interdisciplinary scope of the field, providing valuable insights into both fundamental phenomena and technological applications.

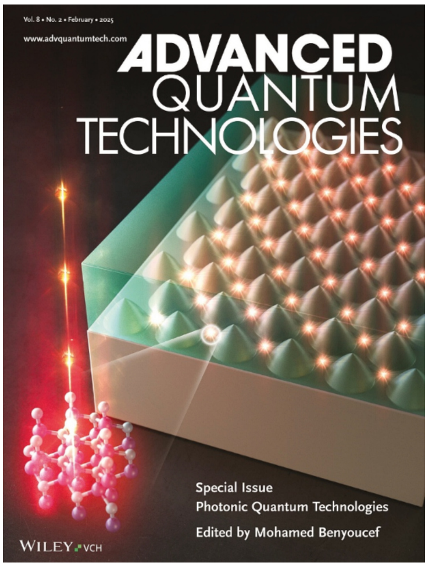
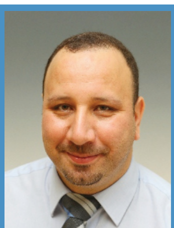


Figure 1: Cover image of the Special Issue.

Further Information

Website: Quantum Nano Photonics



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XPS-Workshop in Collaboration with ThermoFisher Scientific

CINSaT, in collaboration with ThermoFisher Scientific, organized a workshop to introduce students and researchers at the university to the possibilities of X-ray Photoelectron Spectroscopy (XPS). The event aimed to provide both theoretical insights and practical applications relevant to modern materials research. Experts Dr. Samir Mammadov and Dr. Yahya Zakaria gave a seminar on advanced methods for surface and materials analysis. They presented the capabilities of ThermoFisher's XPS instruments and discussed their applications in both academic and industrial contexts. In addition to XPS, related techniques such as UPS, ISS, REELS, Raman spectroscopy, and correlative imaging with SEM were introduced, highlighting their complementary roles in materials characterization. Participants were actively involved in discussing how these methods could be applied to their own research topics. A live demonstration of data analysis routines, including peak fitting and quantitative interpretation, helped illustrate the practical workflow and the importance of accurate evaluation in surface analysis. The workshop successfully combined foundational knowledge with hands-on insights, offering participants valuable tools for their scientific work.

Dr. Samir Mammadov from ThermoFisher Scientific introduces the audience to recent advancements in XPS technologies.

Announcements
CINSaT Alumni Database

The CINSaT opens a database to stay in touch with former members of the CINSaT related research groups.

For over 20 years, young researchers from CINSaT groups have been working to achieve their diplomas or PhDs. In a former issue, we reported on the meeting of the first cohort of nanoscience students, and it became clear that the former students are now established members of the scientific community in academia or industry. To follow up and facilitate exchange between former researchers we are happy to announce the start of the new alumni database. With this, former students and group members can enter their contact information to stay in touch with the CINSaT. Later on, a questionnaire will be send out to gather more information about the career path of our graduates.

We therefore ask every member of the CINSaT or member of a CINSaT research group to forward this information to any known graduate from a CINSaT research group of the University of Kassel. Please share this information:

https://www.uni-kassel.de/forschung/cinsat/alumni

Nano Arts

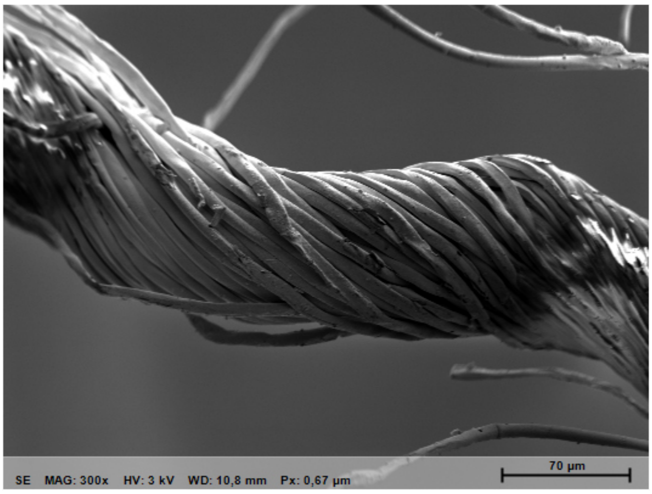

Figure 1: SEM image of a Cu coated lyocell fabric thread, laser irradiated, used as battery cathode (images taken by Group of Prof. Florian Baron).

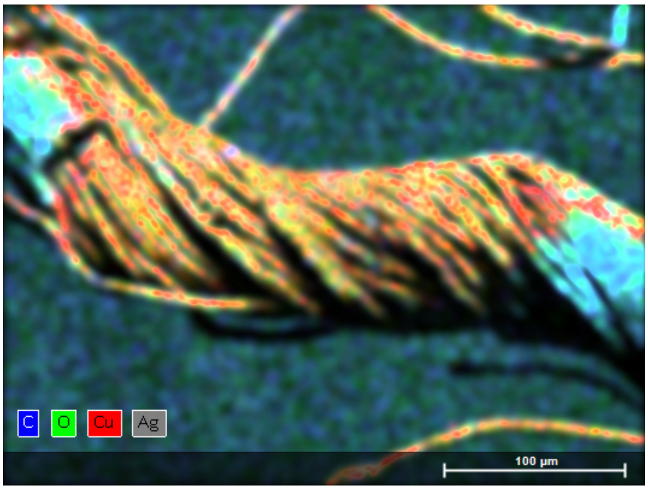

Figure 2: Corresponding EDX characterization highlighting the elements carbon, oxygen, copper and silver (images taken by Group of Prof. Florian Baron).

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

Imprint

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