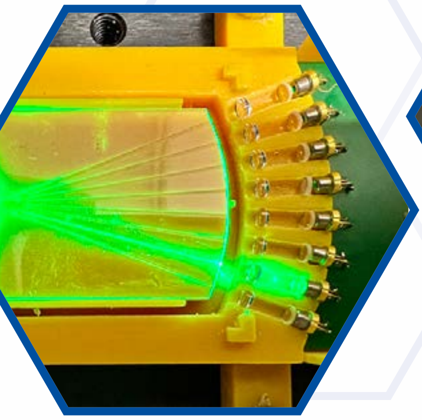
PhoenixD
Photonics · Optics · Engineering
Innovation Across Disciplines

Leibniz Universität Hannover

PhoenixD Magazine

News from the German Cluster of Excellence on Optics and Photonics



Volume 2

That's what we stand for

More than 120 scientists performing research on novel optical systems form the Cluster of Excellence PhoenixD (Photonics, Optics, and Engineering – Innovation Across Disciplines). Our interdisciplinary team comprises physicists, mechanical engineers, chemists, electrical engineers, computer scientists and mathematicians from Leibniz University Hannover and our partner institutions TU Braunschweig, Max Planck Institute for Gravitational Physics, and Laser Zentrum Hannover. Over the period of 2019 to 2025, we are receiving €52 million in funding from the Federal Government and the State of Lower Saxony via the German Research Foundation (DFG).

So far, we have established the Leibniz School of Optics & Photonics (LSO) as a new cross-disciplinary faculty for Optics & Photonics at Leibniz University Hannover. To further advance our interdisciplinary approach, the LSO now confers doctoral degrees both in science (Dr. rer. nat.) and in engineering (Dr.-Ing.).

In addition to our successful Master's Programme, we initiated the new Bachelor's Programme "Optical Technologies: Lasers and Photonics" in October 2022.

We have appointed five tenured professorships in optics so far, and five additional colleagues will join the team till 2025. Ranging from material science via simulation, optics design and manufacturing to applications of optical technologies such as phytophotonics or optical communication, the research topics of the new professors complement and expand the broad interdisciplinary expertise of the PhoenixD community.

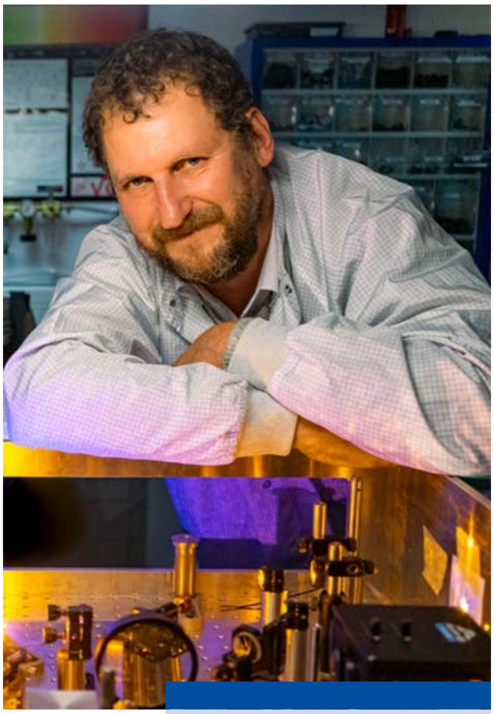
Our current efforts for further strengthening Hannover as the leading location for interdisciplinary research on optics and photonics in Germany include:

- Construct our new research building, the OPTICUM – Optics University Center and Campus, in the Science Area 30X in Hannover-Marienwerder by 2026, and put it into operation.
- Set up a manufacturing grid of production systems for the fabrication of optical components and their assembly into optical systems as an automatized research workshop in the new OPTICUM building.
- Establish a multi-scale, multi-modal simulation platform for the simulation of optical materials, components and systems, based on the digital twin concept.
- Develop production technologies for novel types of integrated optical systems based on glass, polymers or semiconductors, using innovative adaptive optical materials and nanostructures.
- Monitor and adjust the production processes in real-time with high-precision in-line measurement technology, and connect these to the simulation platform and the manufacturing grid.
- Support the creation of spin-off companies emerging from the PhoenixD network.

Learn more about us and visit our website:
https://www.phoenixd.uni-hannover.de

Leibniz Universität Hannover
LASER ZENTRUM HANNOVER e.V.
Technische Universität Braunschweig
DFG Deutsche Forschungsgemeinschaft German Research Foundation

The foundations of the digital revolution, which has dominated our lives ever since, were laid in 1947. This was when scientists in the USA invented the first bipolar junction transistor. Transistors allow electrical currents to control another current. Many transistors make up an integrated circuit, and over the decades it has been possible to fit billions of transistors onto a small chip. Processors are made in semiconductor fabs. Any paying customer can submit their own processor architecture in a standardised format and receive the finished silicon chips in large quantities.



Uwe Morgner

Spokesperson PhoenixD

Half a century later, photonics launched the second digital revolution. Travelling at the speed of light, photons have a wide bandwidth and minimal energy loss, making them both fast at transferring data and highly energy efficient. When light switches light, the process is much more complicated than with electrons, but has much greater potential in the long term. In our PhoenixD, we are working on the photonics fab of the future, where precisely integrated optical nonlinear structures made of materials such as glass, plastic, diamond, semiconductors, and nanoparticles, produced by various interconnected processes such as 3D printing, coating, laser structuring, lithography, etc., will be investigated.

Our large-scale manufacturing equipment and know-how are currently spread across the various institutes and campuses. The vision of the second funding period of PhoenixD envisages the integration of the manufacturing modalities into an internationally unique transdisciplinary optics foundry.

This photonics factory will be at the heart of our new building. From 2026, we will be working in our OPTICUM directly next to the Laser Zentrum Hannover e.V. in Marienwerder. On this new Hannover Optics Campus, we will combine fundamental university research and practice-oriented international education with industry-related research and already existing technology centres, where many optics and laser technology companies, both small and large, are optimally networked.

Electronics is great – photonics is the future.

Uwe Morgner

Uwe Morgner

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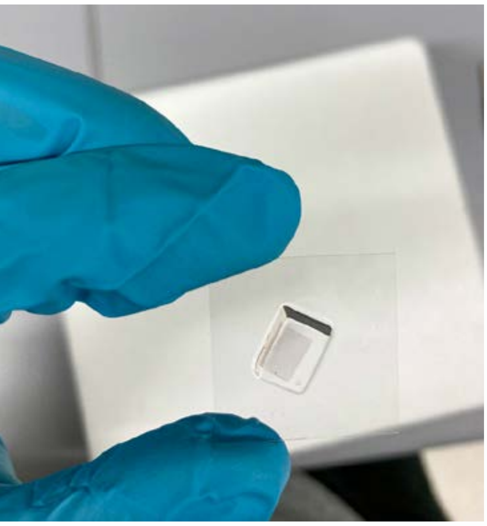

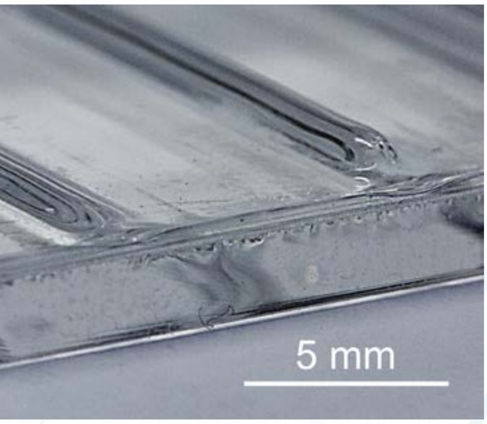

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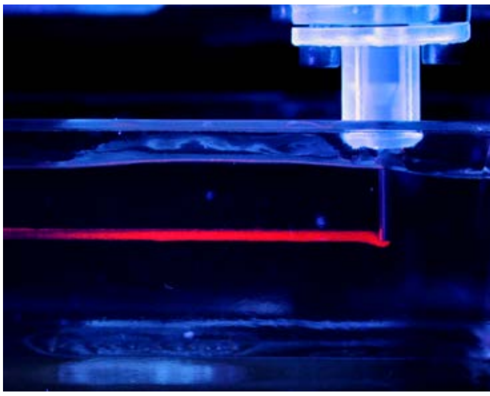
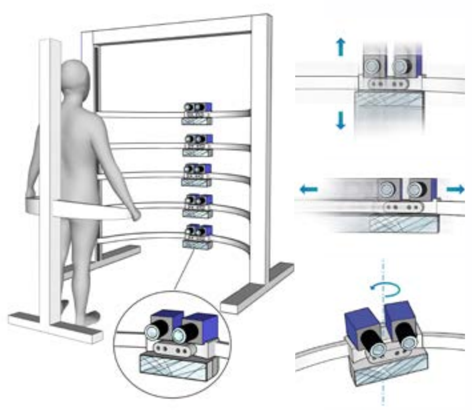
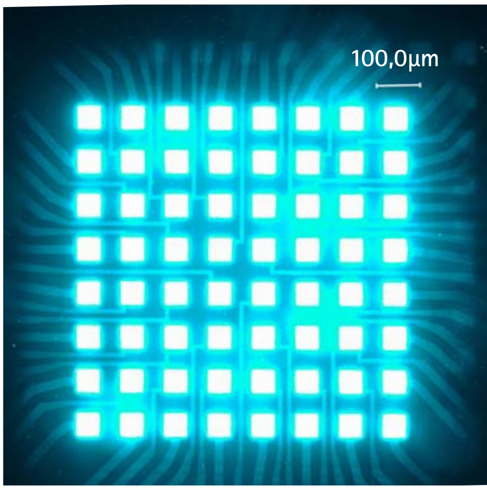






PhoenixD sad to announce death of Pioneer Prof. Dr. Peter Behrens

Prof. Dr. Peter Behrens, a leading member of PhoenixD from the very beginning, passed away at the age of 65 after a brief but serious illness in January 2023. He played a major role in the conception of the Cluster of Excellence PhoenixD. As a Cluster board member, he was responsible for the PhoenixD Research School, an institution promoting young scientists, until the spring of 2022. He also contributed his expertise to developing the new Bachelor's degree programme Optical Technologies: Lasers and Photonics.

Peter Behrens had a chair in Inorganic Chemistry at Leibniz University Hannover from 1998. He was a member of the executive board and director of the Institute of Inorganic Chemistry.

The Inorganic Solid State and Materials Chemistry working group he headed was concerned, among other things, with the controlled synthesis of metal-organic frameworks (MOFs) under mild conditions. These inorganic-organic hybrid materials were modelled using computational chemistry. Behrens' group also researched the functionalisation of solid surfaces, for example, to develop drug-releasing implant coatings.

Peter Behrens was involved in various research networks at LUH, such as the Lower Saxony Centre for Biomedical Engineering, Implant Research and Development (NIFE), the Laboratory for Nano and Quantum Engineering (LNQE) and several Clusters of Excellence. For example, he was a member of the Cluster of Excellence Rebirth from 2007, the Cluster of Excellence Hearing4All from 2012 and the Cluster of Excellence PhoenixD from 2019.

From the start, he was part of the planning team of PhoenixD, preparing the application, building up the PhoenixD community, and giving PhoenixD its name by adding the "D" for Disciplines.

As a board member, he was responsible for setting up the PhoenixD Research School and the accompanying continuing education programme for doctoral students from the various institutes involved in the cluster.

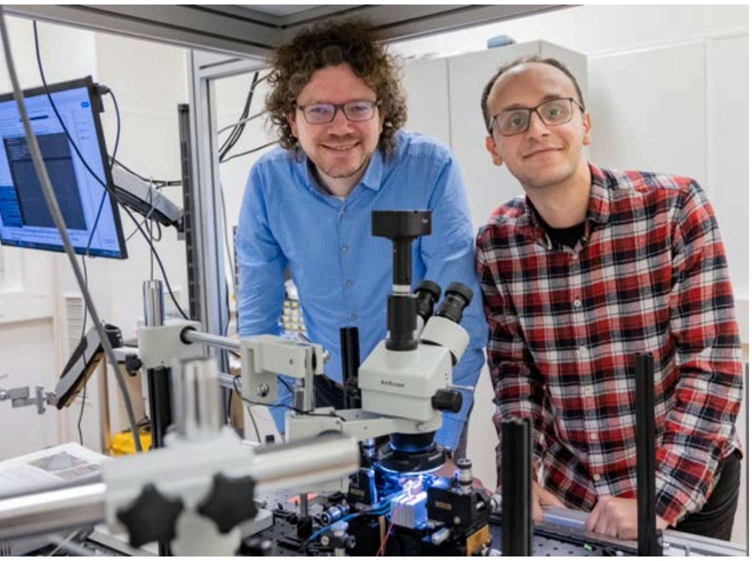
In addition, he was extraordinarily committed to university teaching and the interdisciplinary training of PhD students. The promotion of women in male-dominated natural science subjects was his particular concern.

During his long professional career, he supported numerous organisations. Among others, he was a member of the Fraunhofer Institute for Silicate Research, the German Institute for Rubber Technology and the Braunschweig Academy of Science.

The entire PhoenixD team regrets this loss. His scientific and strategically significant contributions and his open and cordial nature are much missed.

Research Cooperation with TÜV NORD into Tap-Proof Satellite Communication

PhoenixD board member Michael Kues (left) has entered a cooperation agreement with TÜV NORD GROUP on the joint development of a highly integrated quantum light source with a new protocol for generating and exchanging so-called quantum keys (QKD - Quantum Key Distribution). Using the latest technology, tap-proof satellite communication with a range of more than 1,000 kilometres should be possible. The QKD method is based on quantum light sources that can emit "entangled" photon pairs. The importance of research into such photon pairs was recognised by the Nobel Prize in Physics in 2022. Moreover, a quantum light source can be used to set up an eavesdropping-proof communication link: As soon as someone tries to eavesdrop on the connection protected by QKD, this is detected due to the "entanglement" of the quantum keys used. "Currently, there are no stable, efficient and integrated light sources with advanced protocols for this," says Kues. TÜV NORD e.V. and TÜV Hannover/Sachsen-Anhalt e.V., two shareholders of the TÜV NORD Group, will support the project over three to four years with an annual grant of €100,000. The partners want to build a functioning QKD demonstrator during this time. "To achieve our goal, we have identified several issues related to heat transfer, filter placement and coupling efficiency that we will address in the project," says Muhamed Sewidan (right), a PhD student involved in the research project. "An important task of universities is the transfer of knowledge and technology," says Kues, and emphasises: "With such cooperation projects, doctoral students gain insight into industrial manufacturing and can thus pursue new approaches in research." PhD student Sewidan will conduct experiments on the design of the light source in the laser laboratory at Leibniz University's Institute of Photonics (IOP) and continue his research at Alter Technology's Seville and Glasgow sites. Alter Technology will then take over the product development.



Materials Researchers acquire new X-Ray Photoelectron Spectrometer

At Leibniz University Hannover (LUH), scientists have inaugurated a new X-ray photoelectron spectrometer (XPS) in the Laboratory of Nano and Quantum Engineering. The Swedish physicist Kai Siegbahn once received a Nobel Prize for developing experimental investigation methods using such a device. Today, the large-scale device is primarily used for the chemical analysis of various surfaces, from soft matter such as polymers to inorganic solids such as semiconductors and metals. It enables researchers to determine the elemental composition of the surface as well as the chemical environment of the respective elements. "The highly sensitive XPS device works non-destructively in the top five nanometres of a sample", says PhoenixD member Dirk Dorfs from the Institute of Physical Chemistry and Electrochemistry. He goes on to say that the acquired spectrometer offers Auger electron spectroscopy, ultraviolet photoelectron spectroscopy, and an argon cluster gun for ablating the sample surface, which is especially useful for soft samples. It also has a heatable sample chamber. Important materials that the device can characterise are metal-organic frameworks (MOFs) and colloidal nanocrystals. "The comprehensive investigation of these new materials is necessary in many cases," says PhoenixD board member Nadja-C. Bigall, lead applicant for the new device. "This is the only way we can understand why the respective materials have corresponding properties, which is imperative for applications in optics and photonics, for example." Investigating and developing new materials is an essential building block for optics and photonics research.

The Institute of Physical Chemistry and Electrochemistry and the Institute of Inorganic Chemistry operate the €1.19 million facility. The federal government and the state of Lower Saxony financed the new XPS in equal parts. Scientists and industry can carry out their own measurements, or commission them from the two institutes.

PhoenixD team present itself at IdeenExpo 2022

A 24-member team from PhoenixD presented the Cluster of Excellence at the IdeenExpo in Hannover from 2 to 10 July 2022. For nine days, the Hannover Exhibition Centre became one big technology show. Over an area of some 100,000 square metres, more than 280 exhibitors introduced schoolchildren to the wide range of vocational opportunities in the STEM areas of science, technology, engineering, and mathematics, thereby setting a new record: More than 425,000 visitors flocked to Europe's largest youth event for technology and science.
PhoenixD set up its "Photo(ns) Box" on the joint stand of Leibniz University Hannover, providing information on the light phenomenon fluorescence. **(1)** More than 5,000 young people took up the chance to take home an unusual black light photo of themselves and their friends. On the picture, a QR code supplied details of the new bachelor's degree programme Optical Technologies: Lasers and Photonics.
The new bachelor's programme was also the topic of Stage Seven for two days. **(2)** Here, PhoenixD spokesperson Uwe Morgner presented a current research project with PhoenixD member Bernhard Roth and his doctoral student Anatoly Kukk: a skin cancer scanner using light-based technologies. Again, the young audience showed no fear of contact and willingly put their arms at the disposal of a painless scan.
(3) Lower Saxony's State Secretary for Science and Culture, Dr. Sabine Johannsen, visited the PhoenixD stand. **(4)** And Uwe Morgner also used the fair to present the first PhoenixD magazine to Björn Thümler, at that time Lower Saxony's Minister for Science and Culture.
The event is organised by the IdeenExpo GmbH, whose shareholders are Norddeutsche Wirtschaftsholding GmbH (for the Union Niedersachsen Metall), IHK Projekte Hannover GmbH (for the Hannover Chamber of Industry and Commerce), and Dienstleistungsgesellschaft der Norddeutschen Wirtschaft GmbH (for the Lower Saxony Business Associations) and the State of Lower Saxony.

Leibniz Lab team work with more than 2,000 pupils after the Covid break

Leibniz University Hannover has a successful outreach programme for pupils from grades 4 to 13, the Leibniz Lab. Their vans carry many experiments in the natural sciences, mathematics, engineering and technology, including optical experiments with light, lenses and mirrors. Teachers can book Leibniz Lab to visit their school in the city and region of Hannover. University students then drive a van with the pre-booked experiments, and work with the classes. The service is free of charge for the schools – and very popular. After the Covid break, the demand by schools is increasing rapidly again. The team visited 92 classes between September 2021 and March 2023. In total, they worked with 2,015 pupils at 45 different schools. PhoenixD actively supports this success story by providing a second van. In 2019, shortly before the Covid lockdown, the cluster financed a second van, a Volkswagen Crafter, and new exterior coatings depicting laser beams, lab equipment and the PhoenixD logo for the two Leibniz Lab vans.

First large-scale Facility for Integrated Optical Systems set up in House of Optics

PhoenixD has installed the first significant element in its planned production line for integrated optical systems: The Challenger 650 large-scale nsm Norbert Schläfli AG machine has moved into the House of Optics (far right). First, two large trucks, a crane and half a dozen men had to work hard for about two hours. Then the machine, weighing around five tonnes, was in its new place on the Welfengarten campus. The Challenger 650 is a high-precision, multifunctional printing and coating system that enables the development of printed electronics and other printed devices. The large-scale machine can process flexible and rigid substrates to an accuracy of fewer than 10 microns. By using this innovative machine in research and development as well as in pilot and production applications, PhoenixD scientists can realise optical and electronic functionalities in a single manufacturing device. The arrival of the machine thus marks a milestone in developing an integrated production line for fully integrated optical systems.

PhoenixD Researchers talk about their work in a podcast

PhoenixD spokesperson Uwe Morgner (left), research associate Dr. Oliver Melchert (centre) and doctoral student Stephanie Willms (right) gave an insight into their research work in the 15th episode of the German podcast series "Exzellent erklärt – Spitzenforschung für alle" (Excellently explained – top research for all). In the episode "Computer Simulations - Using Models to gain knowledge in Optics", the three scientists use computers to calculate physical laws so precisely that their predictions complement practical experiments, and in some cases make them redundant. In addition to experimentation and theory, this "third pillar" of science is becoming increasingly important as computing capacities grow. Since September 2021, the podcast has regularly reported on the work of the research collaborations funded under the Excellence Strategy of the German federal and state governments. Ten science communicators from various clusters of excellence, including PhoenixD's Sonja Smalian, jointly developed the concept to make cutting-edge research visible and tangible for everyone. In each episode, podcaster Larissa Vassilian (centre, on-screen) talks to the scientists of a particular Cluster of Excellence about their research. The common goal is to inform a broad public about current topics and working methods in research.

Morgner succeeds Overmeyer on the LZH Board

The Laser Zentrum Hannover e.V. (LZH) has appointed PhoenixD spokesman Uwe Morgner (left) to its board. He succeeds PhoenixD board member Ludger Overmeyer (right), who is leaving the LZH board. The LZH is an independent non-profit research institute and cooperation partner of PhoenixD. The spokesperson of the five-member board is PhoenixD member Stefan Kaierle. Other board members are PhoenixD member Dietmar Kracht, Volker Schmidt (Chairman of LZH's Industrial Advisory Board), and Lena Bennefeld. Bennefeld succeeded Klaus Ulbrich, who is retiring. At the same time, there is also a change in LZH's Scientific Directorate. Morgner takes over the chair from Overmeyer, who remains a member of the Directorate.

Interview with Roberto Osellame:

"Integrated photonics will be a game changer in many applications"

Sonja Smalian

Roberto Osellame is a Director of Research at the Institute for Photonics and Nanotechnologies of the CNR in Milan, Italy. There, he uses ultrafast lasers as a manufacturing tool to produce devices based on photonic circuits and microfluidic channels. In spring 2023, the physicist and electronic engineer joined PhoenixD's International Advisory Committee. In the interview, he provides an outlook on upcoming megatrends in optics and photonics and how universities could promote spin-off companies.

Roberto Osellame, a new member of PhoenixD's International Advisory Committee, stands in front of the entrance to Leibniz University's main building.

Theodore Maiman invented the laser more than 60 years ago. Since then, optics and photonics have delivered plenty of new applications and provided internet access 24/7. Therefore, optics and photonics are generally perceived as a ripe technology with little more potential for innovation.

Roberto Osellame: It's true: You can find lasers everywhere. Optics and photonics are so standard nowadays with the widespread use of smartphones and the worldwide internet that people do not give enough recognition to their importance compared to other technologies. But that should not obscure the fact that optics and photonics are one of the critical technologies of our century.

Could you explain why?

Osellame: Light covers a broad spectrum, and each frequency offers dedicated applications, from astronomical observations to the investigation of nanoscale-sized molecules. Exploiting nonlinear optical effects, you can even move between very different parts of the spectrum; for example, X-rays can be produced by shining ultrashort infrared light pulses in suitable materials. And most importantly, in an era of communication: Light is the most powerful information carrier. It's simply incredible what you can do with light. And we have yet to explore all the possibilities.

Where do you still see growth opportunities?

Osellame: Concerning industrial applications, laser manufacturing and light-matter interaction will continue to grow. Lasers are unique manufacturing tools because they are contactless and can modify nearly any material, even diamonds. That is counterintuitive for an intangible tool. By the way, Germany is probably leading in the research and applications of laser manufacturing and the fabrication of optical components.

And, when looking beyond Europe?

Osellame: China has grown a lot in the last ten years with many very focused investments from the government. However, a broader photonic ecosystem exists in Europe and the Western world. In the near future, another rising field is optical communication. I am thinking of cloud computing, which also encompasses supercomputers and quantum computers. There is a very high demand for the continuous transmission of vast amounts of data.

And light-based technologies provide the missing link in this development?

Osellame: Indeed. Light is a good, or the only way to provide large bandwidths and high-speed communication even in short interconnections. And with integrated photonic chips on the rise, information might be transmitted with less energy consumption and heat dissipation than with classic electrical cables.

What opportunities for scalability do you see in optical technologies?

Osellame: The best way for scalability is integrated photonics. That will be a game changer in most photonic applications with multiple advantages. For example, you can scale up the complexity of the device on the one hand, but you also gain in stability because you rely on a monolithic substrate. You also gain portability, which is vital for real-world applications. I combined integrated photonics with telescopes in my lab to do stellar interferometry and exoplanet search. Having something integrated which is compact, stable, and can sustain a very long acquisition time without recalibration is very important.

Qualities that are also required for quantum photonics.

Osellame: That's another vast trend. In quantum communication, photons are the most suitable carrier of information. It is also possible to encode an entirely new protocol to transmit data securely so that no one can decrypt the information. Quantum computing and quantum sensing are red-hot topics for the future. And photonics and optics can play a significant role in these fields.

What makes them so versatile?

Osellame: We can manipulate photons at room temperature and keep their quantum properties. They do not need a vacuum or freezers. So, they're convenient for sensors, and there's a considerable global effort to build a photonic quantum computer.

Will patents be an adequate method to protect research findings?

Osellame: Patents are essential for universities and research centres to generate some return on investment. But patents should only protect those research findings leading to a business venture. That might be a spin-off company or existing companies already interested in licensing it.

Mr. Osellame, you founded your spin-off about a year ago.

Osellame: I found a young postdoc willing to become the CEO and take all the burden of doing this. Finding the right person is critical. So, if you don't have the right person, it is difficult to decide to move in this direction.

So, offering entrepreneurship courses to PhD students is not a successful approach to promoting more spin-off companies to turn universities' research activities into companies?

Osellame: Yes, this is important, but it is not enough. We must remember that being a scientist and running a company are different jobs. Even if you have invented the technology, exploiting it requires a different language. Therefore, it's best if young people start spin-off companies rather than senior researchers. Suppose there are PhD students or postdocs interested in running a business. In that case, they should complement their technical skills with some courses in entrepreneurship and thus become exposed to business cases. It would be even better to do secondments in start-up companies so that they understand what is involved.

With a talent shortage, the industry offers good job opportunities to university graduates. PhD students and postdocs are usually interested in something other than starting a spin-off company.

Osellame: Of course, the numbers cannot be huge, but you can have a programme where you progressively select the most talented or the most committed, and then you can offer different levels of training to them. But that's only one side of the story. Young founders need additional support so that their businesses can take off.

Do you mean incubators connected to the university?

Osellame: Yes. Researchers can continue to use the university's equipment and have offices on campus. Enough to start their business. At my university, we established an incubator, which seems very useful. At pitch contests, the young entrepreneurs can win sums like €30,000 to build prototypes, hire personnel and so on.

It seems we will see quite a few innovations in the upcoming years. How should researchers address these broad topics ahead?

Osellame: We have reached a point where making photonic devices is becoming quite complex. Research teams must involve different disciplines to accomplish fundamental advances in the field. What I like about the idea of forming a cluster is the approach of gathering all the different disciplines in one place. In the academic world, there is much talk about transdisciplinary departments to break up the traditional scheme of separated physics and chemistry departments. But most of the time, it's just talking and evolution on paper, which doesn't work.

What works instead?

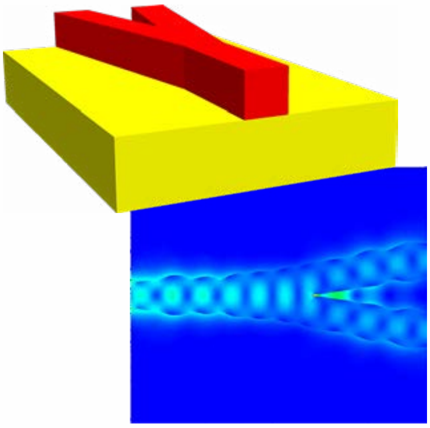
Osellame: If you have a building and the researchers sit close to each other and meet at the coffee machine. That's the moment when interdisciplinary research becomes a reality. I look forward to seeing the PhoenixD team move into the new OPTICUM.

Spotlights on PhoenixD

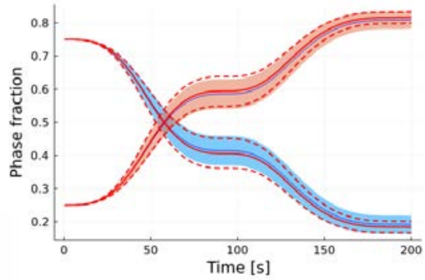
Modern optical technologies have little in common with the traditional grinding and polishing of lenses. Nowadays, optics and photonics are core technologies with interfaces to almost all areas of engineering and science. Light serves as a tool and as material in many ways. Optical systems generate, manipulate, transmit and detect light. Physicists calculate light and optical phenomena. Chemists develop new materials that make optical systems lighter or provide them with new functions. Mechanical engineers transfer manufacturing techniques from microelectronics or 3D printing technology to optical production. Today, optical technologies are inconceivable without digital technologies. Mathematicians and computer scientists are, therefore, in demand for the development of new algorithms for the optimization of optical systems.

Sven Beuchler
optics simulation

Consisting of applied mathematicians, my group develops and analyses efficient numerical algorithms for light propagation with lasers. This research will provide PhoenixD with simulation tools on chip-size scales.



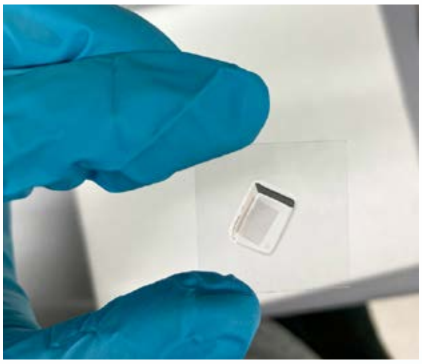
3D shape optimization of an optical device (top), optimal deformation (bottom).



Evolution of the expectation plus/ minus the standard deviation of volume fractions during phase transformations.

I work on continuum mechanical models for optical components. We focus on efficient high-fidelity simulations in order to more accurately design new devices. It is a pleasure to interact and cooperate with researchers from various disciplines within PhoenixD.

Philipp Junker
opto-mechanical simulation



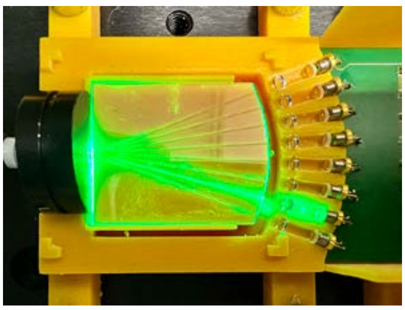
Soft photonic sensors fabricated via two photon photoreduction for analyte detection.

As an interdisciplinary researcher working in biophotonics, I develop photonic solutions that can be applied for sensing and cell manipulation. This research brings the technologies developed within PhoenixD towards applications in biology and medicine.

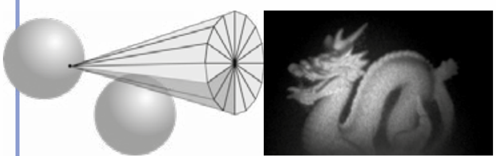
Maria Leilani Torres
biophotonics

Keno Pflieger
assembly

I design and manufacture flexographically printed waveguides and integrate optical functionality into electrical circuit boards. This requires expertise in both optical and electrical systems. Our cutting-edge printing technologies help create efficient and cost-effective solutions.



Printed waveguides.



Our triangulation approach enables us to conduct fast occlusion computations, which can increase both the accuracy and runtime speed by discarding occluded parts of the wavefront from the hologram computation.

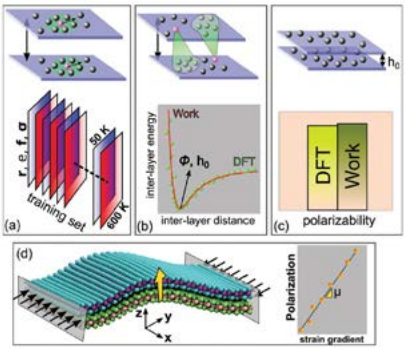
Holography is an emerging topic in displays and metrology. As experts on computer graphics, we develop fast and accurate algorithms to compute light properties. Within PhoenixD we apply these using real world data for the verification of physical models and prototyping.

Sascha Fricke
holography

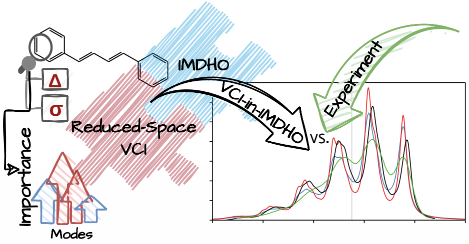
Zhuang Xiaoying

computational mechanics

I am developing computational models and multiscale methods for photonics and optics. With physics informed neural network, accelerated inverse design and optimization of nanostructures can be realized with wider possibilities in searching space.



Machine learning assisted materials and nanostructure design.



Development of a multi-level quantum-chemical approach for accurate calculation of vibrational line shapes of optical spectra

As computational chemists, we develop numerical methods and software for the atomistic simulation of light-matter interaction based on first principles. Within PhoenixD we apply these approaches in order to understand and design novel optical materials.

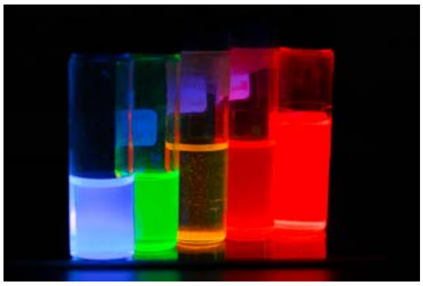
Carolin König

computational chemistry

Nadja Bigall

physical chemistry

As a physicochemist I develop new nanostructures with distinct optical properties owing to their designed nano-, micro-, and macrostructure. These new materials will support PhoenixD as light sources and other optically active materials.

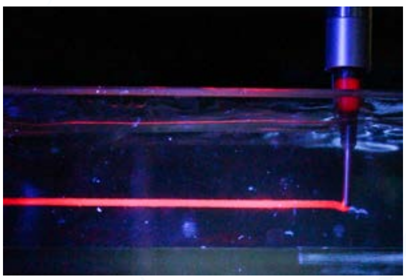


Change of emission colour for CdSe/CdS nanoparticles with increasing particle size.

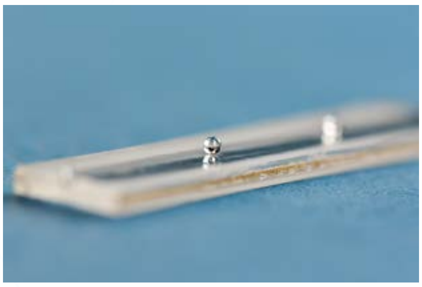
Tobias Biermann

additive manufacturing

Smart materials such as semiconductor nanoparticles are investigated within PhoenixD. We conduct research into manufacturing technologies in order to spatially incorporate these materials into printed waveguides for novel sensor applications.



Our embedded printing technology for manufacturing functionalized waveguides.



Spherical lens manufactured with Laser Glass Deposition.

As a physical engineer, I am working on the development of novel processes for laser-material interaction. In PhoenixD, for example, additive glass manufacturing will enable us to rethink manufacturing for light-guiding and -shaping components.

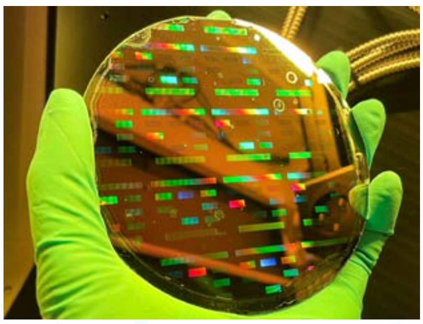
Katharina Rettschlag

3D printing

Zheng Lei

micro and nano production

I work on different techniques for optical manufacturing at the micro- and nanoscale. In PhoenixD, we are developing a nanoproduction chain with the aim of enabling the highly precise, flexible and resource-effective production of functional optical devices.

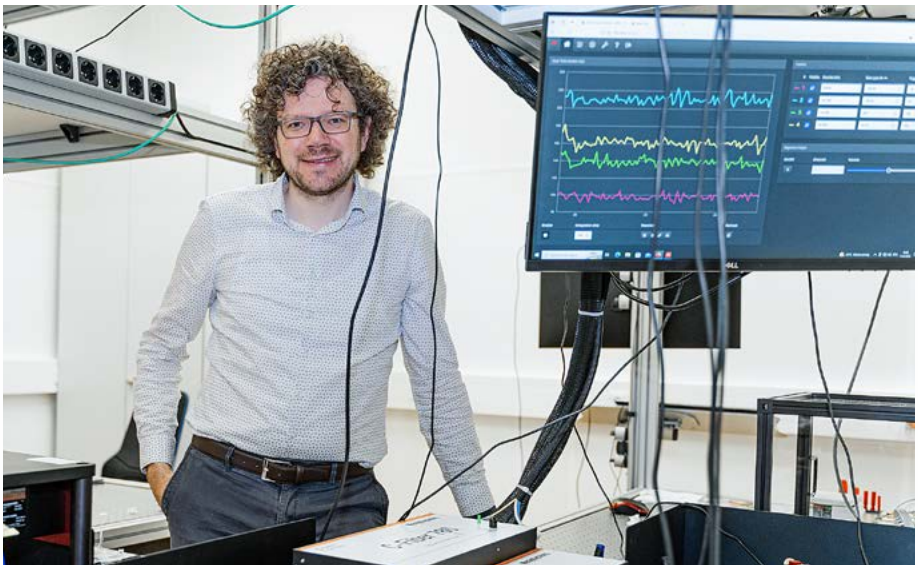


Wafer-level grating array produced by UV-nanoimprint lithography.

Interview with Michael Kues and Uwe Morgner: "If we can tame light even better, there will be many new opportunities for applications"

Sonja Smalian

Novel integrated optics promise numerous applications, from chemical sensing to quantum-secure communication. PhoenixD board members Michael Kues and Uwe Morgner discuss their research plans and why they welcome artificial intelligence such as ChatGPT.



Michael Kues, a member of the PhoenixD board, works on photonic quantum light sources in a laser lab.

Advances in quantum technology are receiving a lot of media attention. An international competition has broken out to develop powerful quantum computers for mass production. What role do optics and photonics play in the development of quantum technology?

Michael Kues: Photonics itself is a quantum technology, as it is the only system with which quantum information can be transmitted over longer distances. Keywords here are quantum communication and entanglement sharing, where quantum systems are linked over long distances. Technically this is possible only with photons. For this reason, we want to further intensify in PhoenixD our research in optical technologies, in order to bring integrated photonics, i.e., optical circuits, together with the characteristics of quantum systems.

Where will such integrated optics then find an application?

Uwe Morgner: In many quantum optical applications, such as quantum sensors, the transmission of quantum keys in communication encryption or quantum computers. The difficulty lies in transporting a single photon to the place of action without destroying its quantum properties. At present, the technically possible results are not yet satisfactory. There are still many technological hurdles to overcome.

Yet integrated optics is not a new technology. It originated in the 1970s.

Morgner: That's true. The effects are theoretically well understood. The challenge now is to put this knowledge "on the road". And for that, new types of integrated optics are needed. That's why long-term funding through the Excellence Strategy is so important. We can use it to fund open-ended projects. That is not possible with traditional funding programmes.

Currently, we find integrated optics in use in medical and processing technology and, of course, in data processing. What do you expect from new types of optics?

Kues: We expect a significantly higher data transmission speed and improved energy efficiency.

Morgner: A broad field of application is sensor technology, especially chemical sensor technology. If the paramedics could analyse different chemical substances in the patient's blood within minutes and already in the ambulance, this would improve further treatment considerably. Light offers many advantages that other systems cannot achieve. If we can tame light even better, i.e. control it, there are many, many more possible applications.

That means that job prospects for young people with knowledge of photonics are good?

Morgner: Yes. Young people should be interested in our study programmes, including the specialised Bachelor's and Master's programmes on optical technologies.

But the number of students in technical subjects is currently declining nationwide.

Morgner: Here in Hannover, the numbers are currently stable. It used to be clear that you could get a good job if you studied mechanical engineering. Today this is true for many degrees - especially for the courses in optics & photonics. Nevertheless, we must still work hard to fire the enthusiasm of young people for STEM subjects.

Some large STEM employers have announced their departure from Germany, partly because of too much bureaucracy.

Morgner: That is a complex topic. After all, large companies like Intel are building new plants in Germany, among other reasons because there are skilled people for the hi-tech sector. I believe that university excellence and industrial excellence go hand in hand. For that to happen, the framework conditions have to be right.

A persistent issue besides bureaucracy is the lack of digitization.

Kues: Yes. In other countries, the word 'digitalization' is not used anymore, because life has been digital for years there. When I returned to Germany from Canada, I was surprised that this was not the case and that the term is still used to describe something new.

The Wharton Business School in the USA had the artificial intelligence ChatGPT answer exam questions. The programme would have received a grade of "two minus". How does software like this change everyday university life?

Morgner: It's great that these new tools exist, and we'll use them in the best possible way.

Kues: We all have to learn how to work with artificial intelligence.

What does that mean in practice?

Kues: I have observed students using ChatGPT to prepare for exams. They asked, "Ask me ten questions about optics and photonics". But the software is not omniscient. In my question: "Name five important publications on a specific field", the programme listed references that didn't exist.

How would you use the programme in your work?

Kues: ChatGPT formulates concisely and precisely. It is, for example, suitable for creating summaries of longer texts.

Morgner: If the language of the texts is improved, it is definitely a gain. The tool reaches its limits when it comes to entirely new scientific achievements. So we have to observe the possible applications critically.

A photo agency is conducting a legal review to determine whether artificial intelligence may be trained using copyright images. How would you decide concerning your research articles?

Kues: I think that knowledge generated at universities should be freely accessible.

Morgner: Yes. If it uses published material, that's fine. We publish everything in "open access" as far as possible so that it is freely accessible and not hidden behind the paywalls of journals.

The cluster PhoenixD is now setting up its Manufacturing Grid on the Welfengarten Campus. Can you explain what that is?

Kues: This should make it possible for the individual working groups and their research to interact and thus explore the realisation of entirely new photonic systems.

Morgner: If all our expertise flows together in one place, new things will emerge. We want to build demonstrators and show applications like the skin cancer scanner.

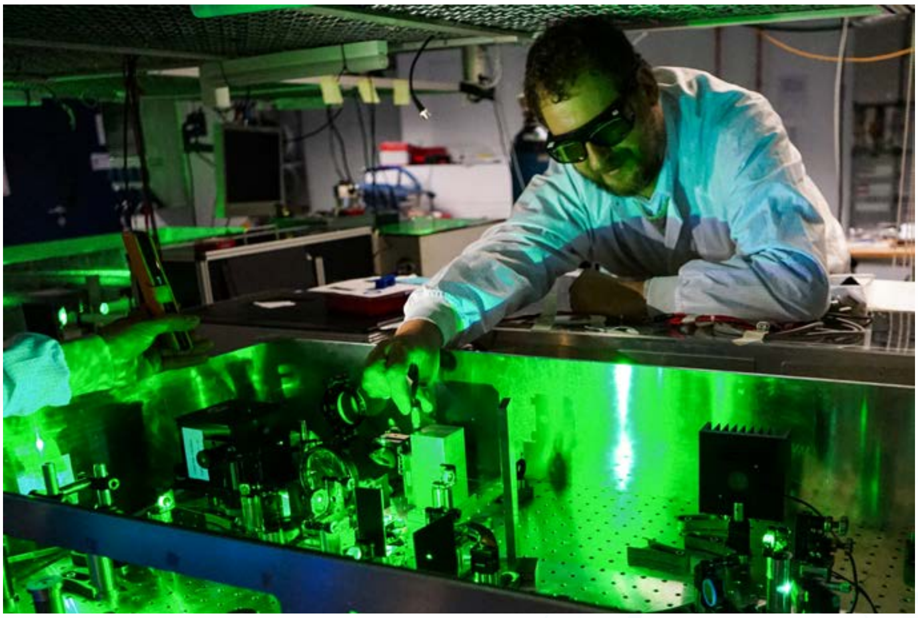
Why was such a place not set up long ago?

Kues: That has to do with the university structures. Large-scale equipment is usually assigned to research group leaders in their institutes, where only their staff can access it. We want to set up these devices in one place to form a manufacturing grid and perform research across disciplines.

Morgner: Shared use is always associated with much effort, and the cluster could be a door opener here. It's a question of safety requirements, employee training and responsibility for the operation. To permanently establish such new structures, there must be permanent funding - even beyond the term of the cluster funding.

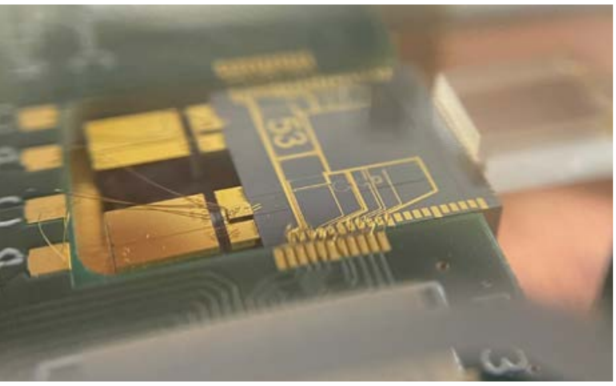
When the new research building, the OPTICUM, is completed, will the researchers move there with the Manufacturing Grid?

Morgner: Yes. The new Optics Campus in ScienceArea 30X in Marienwerder provides visual and spatial evidence that we want to combine fundamental research with the applied research conducted in the nearby Laser Zentrum Hannover and the many small companies in the Technology Park. The colleagues there know each other, exchange ideas, work with the same equipment and plan joint projects. And all this in a manageable location. The vision we are pursuing there has a good chance of delivering many more relevant and new findings.



Uwe Morgner, the spokesperson of the PhoenixD board, tests one of his students' experiments in a laser lab.

Quantum Light Source goes fully On-Chip, bringing Scalability to the Quantum Cloud



An international team of researchers led by Michael Kues, head of the Institute of Photonics and board member of PhoenixD, has demonstrated an entangled quantum light source that is, for the first time, fully integrated on a chip – smaller than a one-euro coin. The researchers reduced the size of the light source using novel hybrid technology combining a laser made of indium phosphide, a filter, and a cavity made of silicon nitride on a single chip. This new development is scalable and suitable for use in photonic quantum computers. "Our breakthrough allowed us to shrink the source size by a factor of more than 1000, allowing reproducibility, stability over a longer time, scaling, and, potentially, mass-production. All these characteristics are required for real-world applications such as quantum processors," says Michael Kues. The team comprises researchers from Leibniz University Hannover, the University of Twente (Netherlands), and the start-up company QuiX Quantum. So far, quantum light sources have required external, off-chip and bulky laser systems, which have limited their use in the field. However, the team overcame these challenges through novel chip design and exploiting several integrated platforms. Their new development, an electrically-excited, laser-integrated photonic quantum light source, fits entirely on a chip and can emit frequency-entangled qubit/qudit states.

A new Centre provides Nationwide Support to Artificial Intelligence Users in Medicine and the Energy Industry

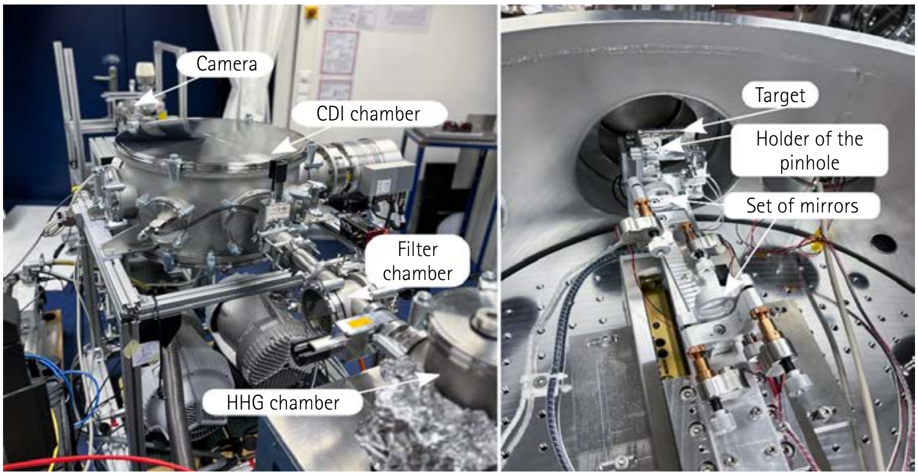
Lower Saxony is to be home to a new service centre for artificial intelligence. The centre will provide researchers and users of artificial intelligence in medicine and the energy industry with the necessary computing power and support nationwide. The low-threshold access to AI-based solution approaches will help to break down barriers to applying innovative ideas in medicine and the energy industry. The joint project KISSKI - KI-Servicezentrum für sensible und kritische Infrastrukturen (AI Service Centre for Sensitive and Critical Infrastructures) is headed by the University of Göttingen, with Leibniz University Hannover as one of the five project partners. PhoenixD member Bodo Rosenhahn (picture) from the Institute for Information Processing (tnt) is its coordinator. For him, two aspects of the project are crucial: firstly, the system works redundantly, i.e. if the centre in Gottingen fails, calculations can continue seamlessly in Hannover.. Secondly, a significant focus is the development of efficient machine learning methods to keep energy consumption and the resulting costs low. "With this project, we are addressing current challenges of recent times," says Rosenhahn. The Federal Ministry of Education and Research is funding the project with €17 million for three years.

PhoenixD supports Schools' Project to Develop Solutions for a Smart City

PhoenixD's school project workshop Protoys took part in the schools' project "Bessermacher:innen" (improvers). From November 2022 to June 2023, 16 to 18-year-old pupils from four local schools worked on sustainable solutions to real-world problems in housing, health, energy, and mobility.
"The students developed sustainable ideas for the smart city of the future in cooperation with enterprises like Continental AG and Gundlach Bau", says Oliver Burmeister, director of the Protoys workshop and a teacher at one of the four participating schools. "The focus also lay on training skills necessary for shaping tomorrow's world, such as critical thinking, problem-solving, creativity and intercultural competence." By working closely with partners from industry and business, the students also gained valuable insights into workplaces and professions. During the "Smart City Days" from 27 to 28 June on Opernplatz in downtown Hannover, they presented their prototypes and concepts for a livable and attractive city to the general public. There, PhoenixD offered several workshops where the students built optical experiments in cooperation with Leibniz University's Leibniz Lab. The project "Bessermacher:innen"and the „Smart City Days" were organized by the Hannover initiative "Nachwuchskraft" (young talent).

X-Ray Images reveal the Structure of Matter

Milutin Kovacev



Laboratory setup (left) for coherent diffractive imaging (CDI), consisting of a vacuum chamber (HHG chamber) with a gas cell, a filter chamber and a CDI chamber. An ultrashort pulse laser generates higher harmonics in the gas cell, and a pair of mirrors in the CDI chamber (right) selects a wavelength of 13 or 29 nm. Moving the target generates a coherent scanning diffraction pattern, and the signal is recorded with a CCD camera.

One of PhoenixD's key challenges is to provide optical precision metrology capable of achieving resolutions in the nanometer range. In addition, this metrology must be versatile enough to accommodate various geometries and materials while seamlessly integrating into the PhoenixD production cycle. The cluster is already developing multiple measurement techniques with varying ranges and resolutions. These techniques offer a broad spectrum of measurement resolutions, ranging from the nanoscale found in transmission Electron Microscopy, X-ray interferometry, and atomic force microscopy to macroscale resolutions, allowing for measurements from nanometers to meters.

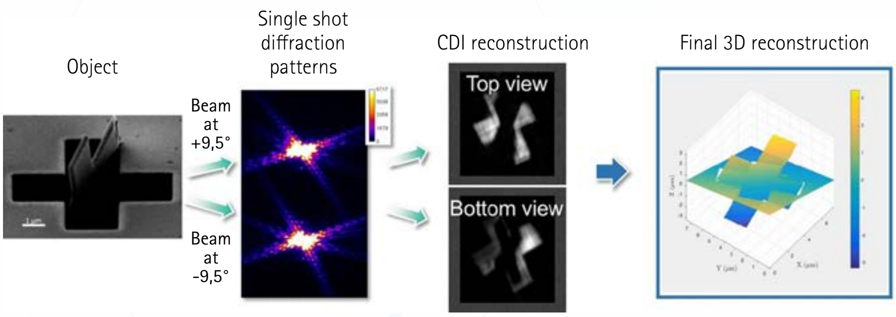
The new research building OPTICUM – Optics University Center and Campus in Hannover, whose completion is planned for 2026, will house a high-power femtosecond laser with intense emission in the near-infrared (NIR) range. This laser source will be used to generate short wavelength radiation from 20 eV up to 50 keV utilizing two physical effects: Coherent extreme ultraviolet radiation will be produced through high harmonic generation and partially coherent hard X-ray pulses will be emitted by laser-produced plasmas. We will apply both, extreme ultraviolet radiation and X-ray radiation, for imaging at the nanoscale using different technologies like X-ray microscopy, X-ray tomography, phase contrast methods and coherent diffraction imaging (CDI).

Detecting the Performance Drivers of Materials

CDI is a powerful imaging technique that allows researchers to study the structure of materials and biological samples at the nanoscale level. In contrast to traditional imaging techniques, no lenses or other focusing elements are available for radiation at such short wavelengths. Therefore, CDI uses the interference pattern of coherent X-rays produced by diffraction inside the measurement sample. Researchers can reconstruct a high-resolution image of the sample's internal structure by analyzing this pattern. This provides insight into its material composition and structural properties.

Structure, material composition, surface quality and interfaces define the performance of materials. The critical aspects of layer thicknesses, the roughness of surfaces and interfaces, and dopant profiles significantly affect device performance. As manufacturing technologies advance and devices become more intricate and compact, using CDI enables the exploration of new innovative materials.

The new X-ray laser metrology facility in the OPTICUM will be state-of-the-art and provide the latest research technology available for X-ray laser imaging and inspection, materials research, sub-surface structure determination, and interface analysis. Its four beamlines will support multi-user operation. The facility can conduct multiple experiments simultaneously, making it a valuable asset to the research community.



The pictures show an example of diffractive 3D imaging with soft X-rays with a single exposure (single-shot operation). This approach of "lensless" microscopy with X-rays uses computer-aided spatial vision, which is already established in robotics. Here, it is used for the first time in imaging with X-rays.

Hannover gets a New Optics Center – The OPTICUM

Reinhard Caspary
Sonja Smalian
Alexander Wolf

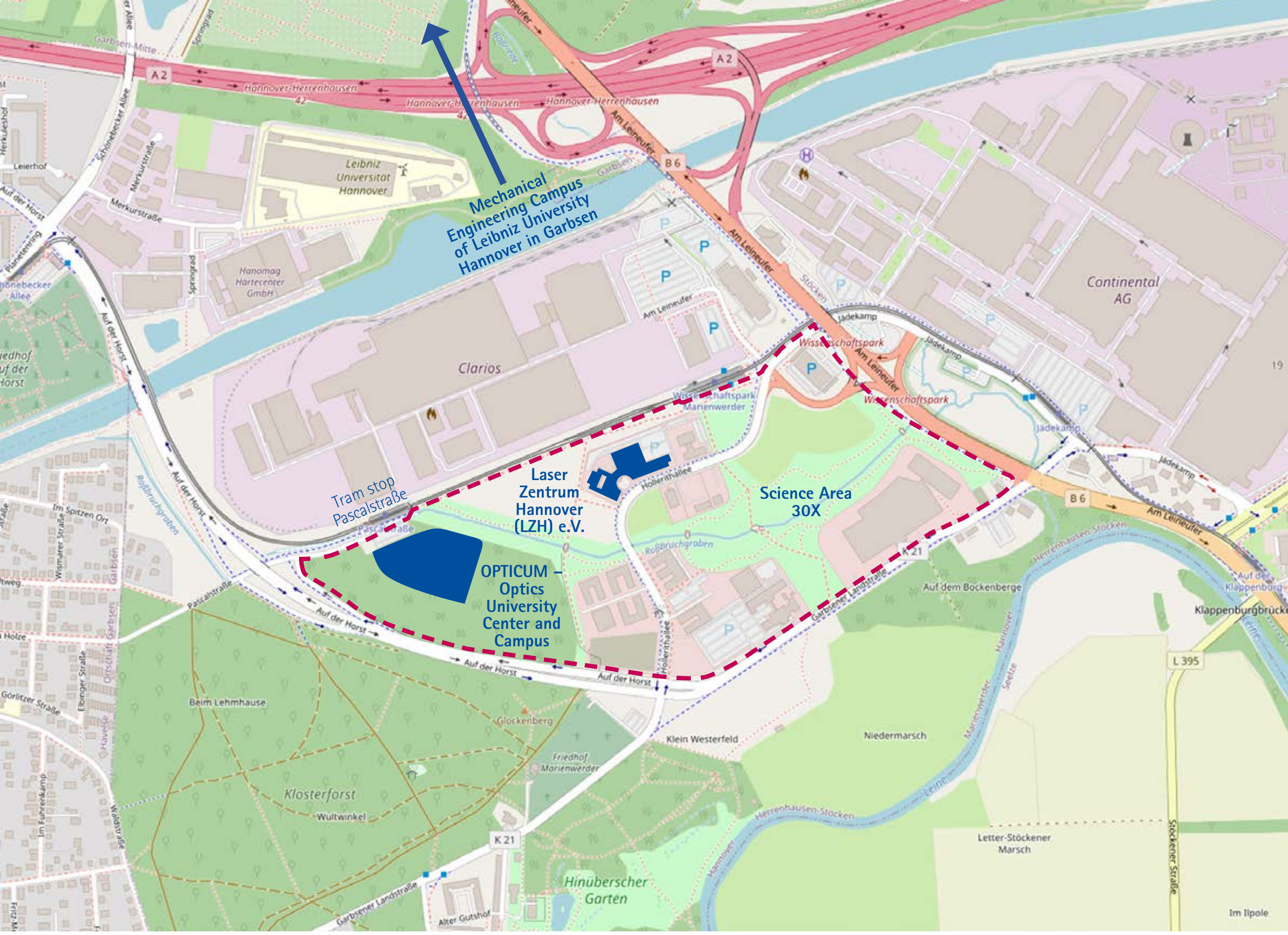
The four-storey building, designed by the architecture studio HENN, has a good 4,000 m² usable area (top) and a 380 m² inner courtyard (bottom).

Leibniz University Hannover is getting a new research building: the OPTICUM – Optics University Center and Campus. Starting in 2026, more than 120 optics researchers will work together under one roof at the Science Area 30X in Hannover-Marienwerder.

The planned four-storey building of the OPTICUM will have a usable floor space of a good 4,000 square metres. Besides offices, it will provide space for biology, chemistry and laser laboratories, production halls, workshops, and a conference room with a capacity of up to 200 people. According to the schedule, construction is to begin in 2023 and be completed in 2026. More than 120 researchers in optics will then move to the new building.

"Our OPTICUM will be the research building for all scientists from the disciplines of physics, mechanical engineering, chemistry, electrical engineering, mathematics, and computer science working together on the digitalisation of optics research and optics production," says Uwe Morgner, spokesperson of the PhoenixD board. The Leibniz School for Optics & Photonics (LSO), founded in 2020, will manage the OPTICUM. The Leibniz School is equivalent to a faculty in its structure and closely linked to PhoenixD, with Uwe Morgner heading its board.

The Federal Government and the State of Lower Saxony are collaboratively financing the OPTICUM: It will be built on a 1.6-hectare plot of land in the Science Area 30X, which has a total size of 28 hectares. The science park, founded in the early 1990s, is today home to more than 50 technology companies and research institutes, including more than ten from the field of optical technologies. PhoenixD's cooperation partner, the Laser Zentrum Hannover e.V. (LZH), is in the immediate vicinity. In addition, the Institute for Integrated Production Hannover (IPH) and global companies such as Forvia and Continental have settled nearby. With around 5,300 students and employees, the Science Park is just a five-minute drive from the Mechanical Engineering Campus of Leibniz University Hannover in Garbsen.



The OPTICUM is located near the Laser Zentrum Hannover in the 28-hectare Science Area 30X, home to around 50 technology companies and institutes. The site is 3 km from the Mechanical Engineering Campus of Leibniz University Hannover.

In addition, the OPTICUM is just three km far from the Hannover-Herrenhausen motorway junction and the building will also be accessible via the Pascalstraße tram stop.

At the OPTICUM, the researchers address the leading scientific question of PhoenixD, namely how future optical systems can be produced while balancing the necessary precision, degree of integration, individuality, and costs. Optical setups today are often very bulky and consist of discrete, precisely assembled individual components. The work at OPTICUM aims to transform these setups into integrated, intelligent and adaptive systems that can be manufactured with high-throughput processes.

Motivated by the constantly growing data processing capacities and the rapid progress in additive manufacturing, a digitally and physically networked production platform for individualised optical systems is being realised. The goal is to connect automated additive and subtractive production methods as well as cross-scale multi-physics simulations in real time and in a feed-forward loop using extensive inline measurement technology. Connecting additive and subtractive production methods with suitable measurement technology and real-time simulation enables correcting deviations to be undertaken during manufacturing, for example. The OPTICUM will provide space and infrastructure for a manufacturing grid to investigate and demonstrate these novel approaches.

By integrating suitable online measurement technology in the manufacturing grid, the manufactured optical system can be completed with its digital virtual model. This model accompanies the system through the various production steps, recording tolerances and deviations. In this way, it contains the calibration data of the actual product, ensuring control and adjustment of system functions over the whole life cycle.

Another essential prerequisite for modern optics production is the availability of novel materials with application-specific properties. The research in the OPTICUM focuses on polymers, hybrid materials, nanoparticles, and adaptive materials, whose properties can be switched via an external signal. Plasmonic nanoparticles, for example, can trap or guide light.

The goal of the simulation team is to create a global platform for open-source software for optical simulation called OPTISIM. The team will establish a virtual digital laboratory to simulate, design, accelerate, and optimise the experimentation and manufacturing phases. Thus, OPTICUM will be the hub for optical simulation software, knowledge transfer and the training of new simulation experts.

Interview with Ludger Overmeyer and Marc Wurz: "Light opens up new scales that previously seemed completely unattainable"

Ludger Overmeyer (left) and Marc Wurz (right) in front of a current research project: the forklift driver (centre) wears augmented reality glasses that mask out all mechanical obstacles, such as the lift mast as well as the supporting structures of the forklift so that the driver has a completely unobstructed view and can manoeuvre safely in space. "This new driver assistance topic will certainly come into use very quickly," Overmeyer says. "Currently, however, the systems are still too imprecise and slow."

Sonja Smalian

Developing the integrated optics of the future is a collaborative effort. Marc Wurz, professor of mechanical engineering, and Ludger Overmeyer, professor of mechanical engineering and PhoenixD board member, explain which manufacturing processes they rely on, why optics excites them and why it will work only with artificial intelligence.

The PhoenixD Cluster of Excellence involves researchers from six different disciplines. What tasks are you working on in mechanical engineering with your research groups?

Ludger Overmeyer: We want to develop a printing technique for manufacturing highly integrated optical systems as individual systems and as networks. Here, we will combine novel printing processes with ablative processes in order to extend process chains into a manufacturing system. We do not work on a semiconductor basis but use two materials, glass and polymers.

Marc Wurz: My working group has a somewhat different focus. Here in Garbsen, the process chain is available for microsystem technology, and we are using the experience gained in electronics manufacturing to now transfer it to optical systems. We can produce structures for optically relevant components using various coating and structuring processes from the nanoscale to the millimetre range. We then plan to integrate these onto the glass. In addition, we are experimenting with injection moulding processes to build an integration platform for optical systems that can realize both electrical and optical connections. The goal is to develop a manufacturing process for large-scale production.

Overmeyer: Mass production is an important keyword. As in electronics, manufacturing costs in the future should be determined primarily by the material and no longer by the manufacturing processes.

Unlike electronics, optics requires very high precision.

Overmeyer: That's right, and it's why we plan to make our systems as adjustment-free as possible. In other words, we have to develop manufacturing processes in optics similar to those we've had for a long time in electronics. We are researching this at our institutes, and the two groups complement each other well.

What open questions are you currently addressing?

Overmeyer: We are currently asking ourselves what technology we will use in the future to print large areas with a resolution in the sub-micrometre range. At the moment, we can use two-photon polymerisation (2PP) to create 100 nanometres or 0.1 micrometres structures. How will this succeed in integrated process chains?

And how do you plan to implement this?

Wurz: My group will create a master structure with elaborate technologies and then transfer it to the optical chip during injection compression moulding, just as we know it from CD and DVD production.

Overmeyer: Another approach involves combining two 3D printing processes with multi-beam applications. Here, we work with many laser beams in parallel to quickly produce large-area structures in different resolution ranges. These are visionary approaches that we would like to push further.

Assuming you are successful with your research, where do you see potential applications for integrated optical systems?

Overmeyer: I see a lot of potential in sensor technology, medical technology, and communications and automation technology.

And what might a specific application look like?

Wurz: We are thinking, for example, of navigation systems for autonomous driving and, more generally, measurement technology. However, in PhoenixD, we are concentrating on the fundamental technologies.

Overmeyer: Exactly. Navigation technology is not our primary topic. We are researching the technology required for it and developing the system and manufacturing technology.

Why do you think optics will be a "game changer" for all the promising future applications?

Overmeyer: At present, it is the photon that, in addition to the electron, enormously increases data transmission performance. Optical technologies are currently the only way forward. With light, we open up new scales that previously seemed absolutely unattainable. With optical technologies, we can even make viruses visible nowadays. As a student, I was taught that this was impossible. Optical technologies also allow us to look much deeper into space. In both cases, we use signals of different optical spectra and bandwidths to open up new worlds. I find this phenomenal.

So there is still a lot of uncharted territory for future generations to explore?

Overmeyer: Absolutely. Our understanding of how the world is structured is growing. But at the same time, the questions that arise are increasing exponentially. That's why we, as a Cluster of Excellence, are also working to steer education in a new direction.

In what way?

Overmeyer: Thanks to the longer funding period of seven years, we have already started many lengthy structural processes. For example, we have succeeded in initiating a new, interdisciplinary bachelor's programme: Optical Technologies: Lasers and Photonics. Additionally, we and our members have developed many new lectures and appointed professors. We can thus ensure that the latest knowledge is passed on to the next generation of optical engineers. I believe this is a fundamental advantage of the excellence strategy and a huge opportunity for students and doctoral candidates.

Wurz: The cluster structure also promotes interdisciplinary research, and the individual disciplines develop a mutual understanding of the specific fields of knowledge and their approaches. And now, we must learn how to turn an idea born in a physics laboratory into a system for application. And we can only do that through consistent collaboration.

What role will AI, or artificial intelligence, play in developing integrated optics?

Overmeyer: Artificial intelligence will form the bridge between the ideal model concept from physics and the real, implementable manufacturing world. In view of the large amounts of data that AI systems can process, they are a new, critical tool that we need. AI will be vital to calculating our planned structures and building system technology.

Wurz: Exactly, but that also means that we must train the AI to understand what is technically feasible and what is not. We need to take these aspects into account in our process technology.

Large amounts of data are produced during development and manufacturing and through integrated optics, not to forget your collected research data. How do you plan to deal with it?

Overmeyer: For me, the critical question is how we can reduce the accumulating flood of data so that it can be handled judiciously. In the second step, we will then have to decide which data should be stored and processed appropriately.

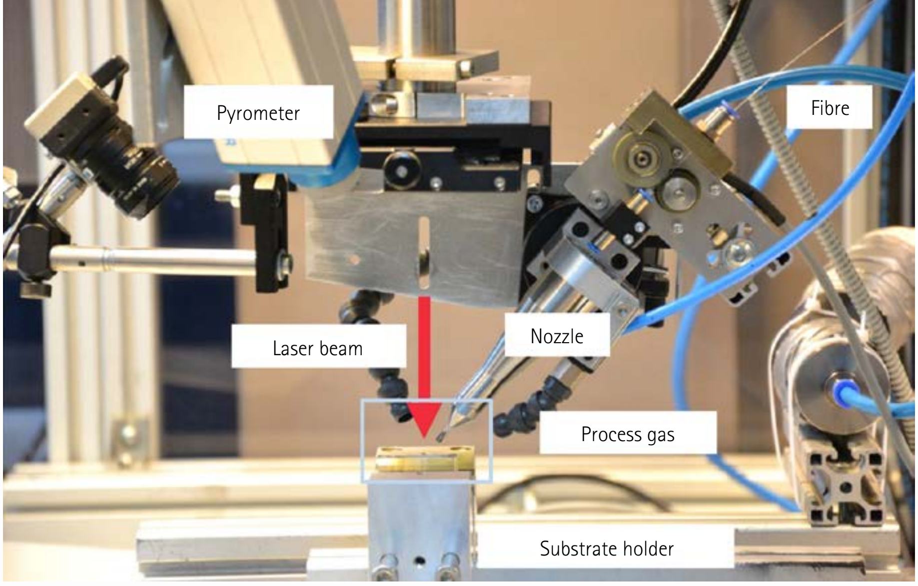
Wurz: Let's take the example of sensor technology. In such an application, the data should already be pre-processed locally. In other words, the sensor has to determine which data is relevant and should be forwarded. At the level of research data, we have to find answers to the same questions. What data do other groups need to be able to continue working with it?

Overmeyer: Whoever has sovereignty over data has sovereignty over being. That's why data management is a fundamental topic in our research.

Development of an Additive Manufacturing Process for Glass

Katharina Rettschlag
Khodor Sleiman
Peter Jäschke
Stefan Kaierle

Over the past few years, additive manufacturing (AM) has successfully implemented the motto "making the impossible possible" in a wide range of applications. The possibility of easily having a 3D printer at home is fascinating for many. Although AM seems to have fully arrived in industry, it is not yet established in many areas and there is still a high need for research and development. A special requirement in materials research is to perform AM processes with materials that were considered impossible to utilize in the past. One of these classes of materials is glass. Various approaches to additively manufacture glass are being pursued worldwide. These can be divided into processes with and without binders. In order to manufacture transparent optical components without defects, interfaces and inclusions, a binder-free process is required.



View into the process zone with the relevant process components.

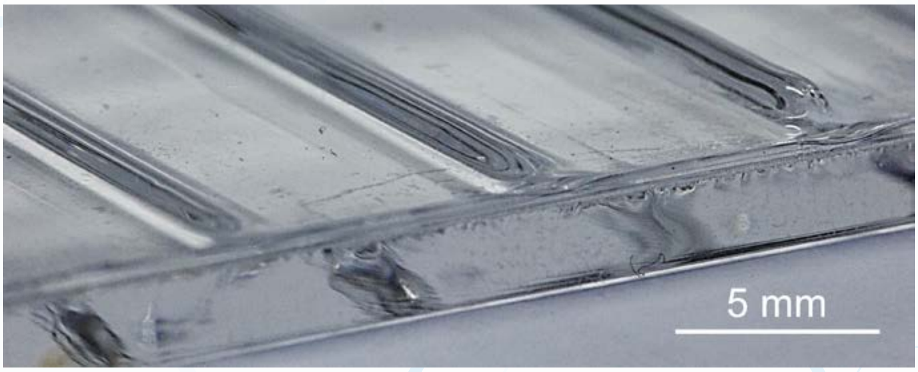
The Laser Glass Deposition Process

In the LGD process, a CO_2 laser is used to melt the fused silica glass. The laser radiation is guided into the process zone, and a fused silica fibre or rod is fed laterally through a nozzle. In this way, glass material can be deposited layer by layer.

In PhoenixD, this process will be enhanced to the extent that the material behavior can be controlled in the ongoing process. Extensive studies on deposition morphology of single and multiple lanes, formation of interfaces and variation of material application have already been performed. Investigations on selective generation of curved surfaces and combination of materials with different refractive indices will follow.

Manufacturing of Glass Volume Optics

Following these studies, the manufacturing of functional volume optics from multiple layers is envisioned. Here, the main goal is to generate a homogeneous material distribution with a targeted surface shape without defects, interfaces, or inclusions. The greatest challenge is posed by the interfaces because, like most AM processes, the fiber-based Laser Glass Deposition process is characterized by a layered structure. To avoid such interfaces, the process strategy has to be developed so that already deposited layers are influenced for a second time by depositing the next layer. The first fully transparent structures out of four layers have already been produced in this way.



Printed transparent fused silica structures consisting of one, two and four layers (from left to right) without boundary layers.

Complementing Traditional Processes

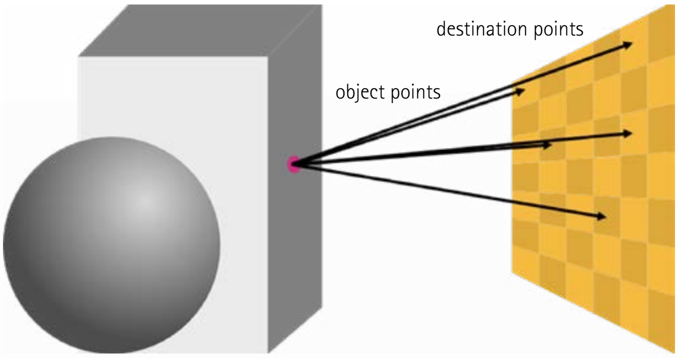
We want to exploit the main advantages of AM processes, such as high flexibility and design freedom, for glass manufacturing. The aim is to use the fiber-based Laser Glass Deposition process to manufacture optical components which cannot be produced using conventional methods without a very high time and financial investment. It is also conceivable that specific structures and functions can be applied to existing conventionally manufactured optics, e.g. to protective windows. In this way AM of glass will add new and promising options to optics production. A complete replacement of conventional manufacturing technologies is not intended.

In summary, the AM of glass is still at an early stage, especially with regard to the manufacturing of functional volume optics. In PhoenixD, the fundamentals of glass material behavior during the AM process are being investigated to expand the possibilities for optics design and fabrication.

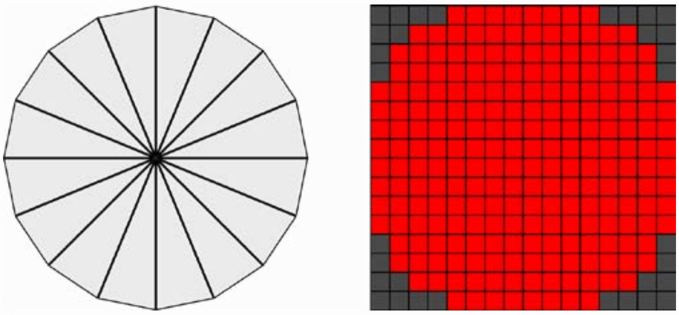
High Performance Algorithms for Holographic Systems

Sascha Fricke

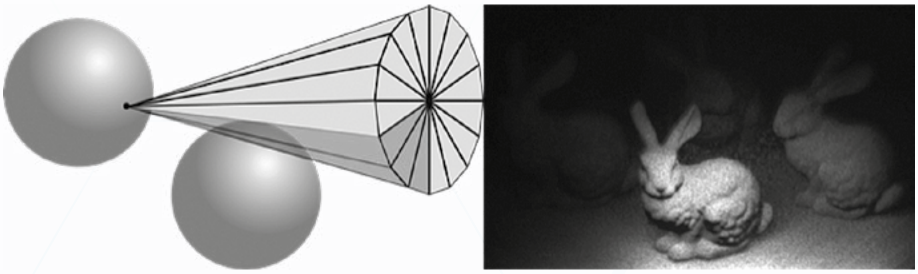
Holography, as introduced by Denis Gabor, describes a process of recording the properties of electromagnetic wave information on a photographic film in such a way that these waves can be reconstructed completely. In contrast to traditional photography, where light is focused into a single point, this recording technique makes it possible to reproduce the whole light field. This means that focal points and, to a limited degree, arbitrary viewing directions including full parallax occlusions, can be reconstructed.



The point-based method offers great flexibility for computing wave optical properties of reflected light planes or those emitted from surfaces at destination planes.



In our novel algorithm, we approximate the wavefronts emitted from a point by triangular fans. This can be executed very efficiently on modern graphics hardware.



Our triangulation approach makes fast occlusion computations possible. This can increase both the accuracy and runtime speed by discarding occluded parts of the wavefront from the hologram computation.

Need for Real-Time Synthetic Light Distributions

Holographic techniques have a wide range of applications. Next generation virtual or augmented reality glasses (VR/AR) provide the user with a true 3D scene, where the visual information needs to be focused at arbitrary depth – as in real life. Further applications are fast and accurate medical imaging without the need for complex objectives, and the design and manufacturing of diffractive optical elements (DOEs). Recording wavefronts in the way Denis Gabor did is not suitable for VR/AR and DOE design. For these applications, completely synthetic light distributions that cannot be easily generated from real world samples need to be computed. Furthermore, for VR/AR systems the results need to be generated in real time. Thus, there is a high demand for fast and accurate algorithms to compute holograms from synthetic data. A certain class of algorithms, the Point Based Methods, are particularly well suited for this purpose. They combine high accuracy with the necessary flexibility, something which is usually associated with a high computational cost.

Combining Precision and Speed

To avoid the current need to trade quality for speed or vice-versa, we initiated a collaborative PhoenixD project between the Institute of Computer Graphics at the Technical University of Braunschweig and Reinhard Caspary as a holography expert. Our combined knowledge of physics and real-time computer graphics enables us to merge the flexibility of Point Based Methods into modern graphics hardware to create next-generation, high quality, and high-performance algorithms that can compute accurate phase and amplitude distributions. We have already developed algorithms with a unique approach to compute occlusions. This allows us to generate extremely large holograms with complex parallax effects and arbitrary depth distributions. We plan to further improve these algorithms in order to achieve accurate results in real-time, driving the next generation of high-resolution holography displays like VR/AR systems. Thanks to our research efforts and the advancements in modern consumer grade graphics hardware, these goals are within arm's reach.

Overall, computer generated holography is a highly exciting research topic. This is especially true at the current moment, when the hardware development has finally caught up with the theory for many scenarios. Even more applications will emerge in the foreseeable future as graphics hardware and display technologies keep on improving.

Interview with Berend Denkena and Roland Lachmayer: "With the help of a digital twin, we can create a product that is more precise than its individual parts"

Sonja Smalian

In this interview, professors of mechanical engineering Berend Denkena and Roland Lachmayer talk about their work with digital twins, different scientific cultures, and why they believe optical technologies still have a lot of development potential.

Many people would probably not associate optical technologies with mechanical engineering. How has optics changed your work?

Berend Denkena: I see a lot of progress here, for example in production technology. It all started with using lasers for cutting and later for structuring surfaces. After that, complex shapes with tiny structures were created using light.

Roland Lachmayer: Optical technologies are crucial especially at the man-machine interface, no matter whether cameras, screens, or displays are concerned; humans perceive up to 90 % of information through vision, i.e., light.

And where do you see further growth potential for this technology?

Denkena: We see a substantial increase in the spread of optical and camera systems, which are becoming smaller and more powerful. PhoenixD's approach of compensating for the performance of less high-quality optics using digital correction in real time fits in with this. This approach will make the systems cheaper in the future and lead to even broader applications. Optical technologies will get another real push in the next 20 years. Time will tell where the most significant areas of application are going be.

Lachmayer: I think they will be in communication technology and autonomous driving or mobility systems. Cameras, lidar and other sensors that make this possible are a vast market. These days, cars are equipped with optical components that are more expensive than the engine. Optical technologies will also have a significant impact on medicine. Especially if we can make huge laboratory equipment more cost-effective, so that it can more often find its way into medical practices, or even be used by patients themselves via smartphones.

As a product developer, you deal with the processes and methods for developing and designing new products, Prof. Lachmayer. What challenges do you face when working with optical technologies in PhoenixD?

Lachmayer: We must manage to work extremely precisely in order to open up this technological world with our methods.

What methods would that be, for example?

Lachmayer: We use 3D printing as well as other additive processes. We often find that materials are less homogeneous in implementation than we previously assumed in our simulations. For this reason, we also investigate the microstructures of the materials. Professor Denkena, in production technology, on the other hand, you concentrate your research on manufacturing equipment and automation processes.

Denkena: Exactly. We also investigate methods for making production more economical, environmentally friendly, energy-efficient, or precise. Requirements, for instance in mould making, are also very high as far as manufacturing tolerances and precision are concerned. In some cases, we have to produce the necessary mould tools ourselves.

You use a digital twin in production. How does that work?

Denkena: With a digital twin, we match a model or a database with reality. We feed the digital twin with production data from reality and try to match our digital model as closely as possible.

And what do you use the model for, then?

Denkena: We then use the model to try to make predictions, for example. So, how the simulated system behaves if a manipulated variable is changed, if, for instance, I use a different tool.

Lachmayer: Digital twins are exciting for my field because it allows us to derive relevant results for the utilisation phase.

Denkena: But also during the training phase, i.e. when adjusting a machine tool, the digital twin works well. In the past, skilled workers did this. And they always needed several components for this training and setting of the machine, which were usually thrown away afterwards.

And the digital twin solves this problem?

Denkena: Yes. It allows us to start using the first manufactured component. This shows where development is heading in the future. The models use real-time data from the machine, thus delivering a quality much closer to reality than before.

Lachmayer: Of course, we know what we screw together is not precise. But we can recalibrate it digitally using the digital twin. And that is a fantastic challenge. With the help of the digital twin, we can create a product that is more precise than its individual parts.

Has the funding from the Excellence Strategy now opened up new opportunities for your research?

Lachmayer: Yes. Otherwise, you can hardly work on one topic for seven years. And when we get the follow-up funding, another seven years. We don't have formats like this in research funding any more.

Roland Lachmayer (seated) and Berend Denkena (standing) work at the Mechanical Engineering Campus of Leibniz University Hannover in Garbsen, where scientists use an integrating sphere (Ulbricht sphere) to determine luminous flux and specular distribution.

Denkena: That's true. In addition, the Excellence Strategy allows us to work with colleagues from six different disciplines, starting with physics, i.e. with the absolute basics, through the entire research chain to applications. It allows us to develop the technology focus in Hannover further. For me, raising the profile of the university is also a strong argument for the Excellence Strategy.

How did you find a common working level with the other five disciplines, i.e. the physicists, mathematicians, chemists, electrical engineers and software engineers?

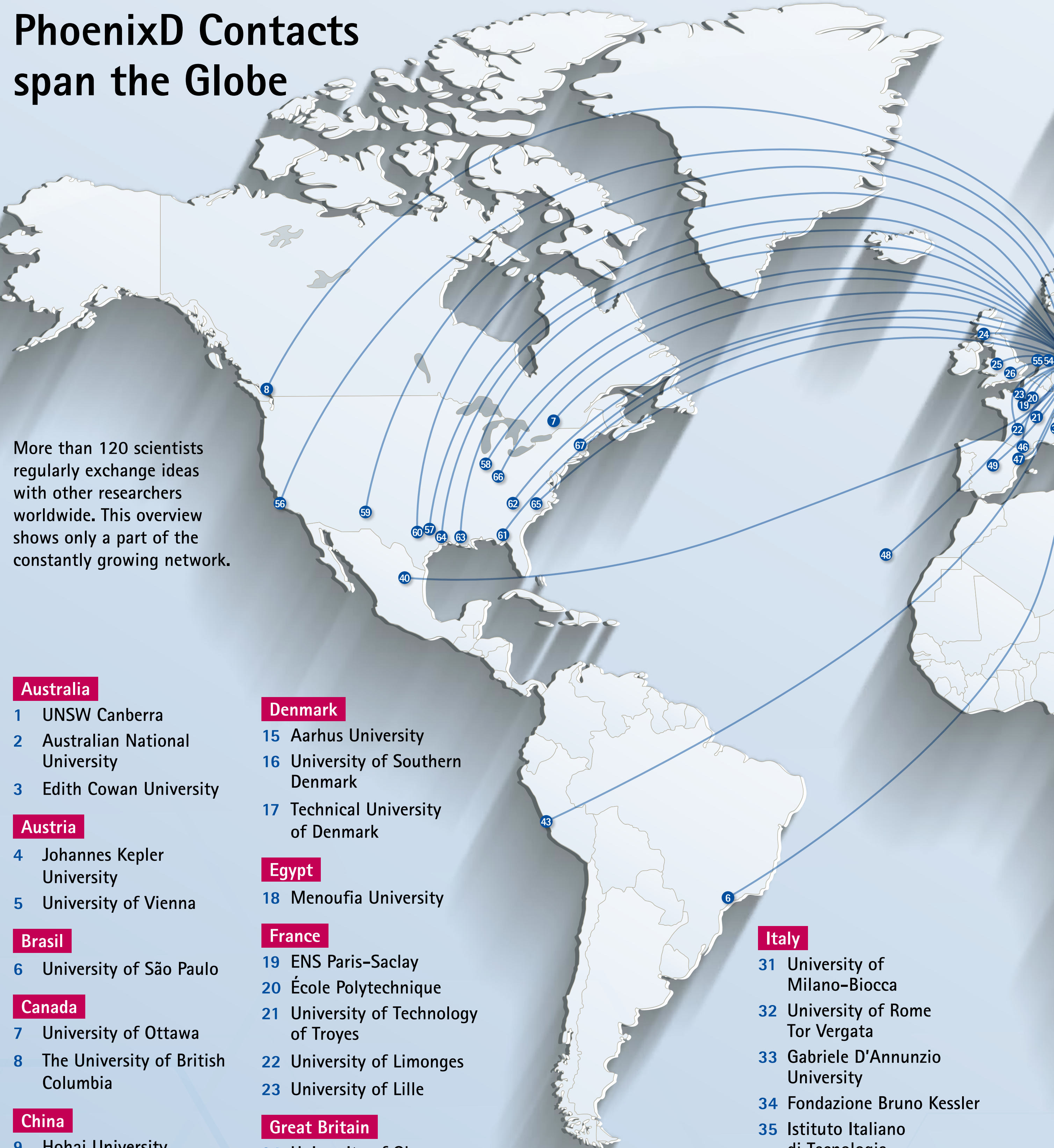
Lachmayer: That took work. The scientific culture of the individual disciplines is reflected in different technical languages. At the beginning, we did not always understand each other right away.

Denkena: A lot has happened in that respect. It's excellent when natural scientists work with engineers, and the chain from basic research to application is mapped. Natural scientists think about the concepts, and we think about the implementation, i.e. when do I have the device?

Lachmayer: By the way, this separation between basic research, applied research, and transfer is idiotic. There is research and there are different development goals; we should bring these things together in PhoenixD.

Denkena: That's right. As I see it, we have an obligation to ensure that some of our research is applied. Since we and our institutions are financed by tax money, this money should in turn be of benefit to society. Our research landscape, with the German Research Foundation and the Federal Ministry of Education and Research, is wonderfully positioned in this respect. We can start with the basics and try crazy ideas without involving companies. And the things that turn out to be promising can be developed to application in cooperation with industry. That's ingenious, and Germany has a unique selling point here. Especially since many doctoral students later switch to industry and pass on their knowledge. This transfer of knowledge is simply priceless.

PhoenixD Contacts span the Globe



More than 120 scientists regularly exchange ideas with other researchers worldwide. This overview shows only a part of the constantly growing network.

Australia
1 UNSW Canberra
2 Australian National University
3 Edith Cowan University

Austria
4 Johannes Kepler University
5 University of Vienna

Brasil
6 University of São Paulo

Canada
7 University of Ottawa
8 The University of British Columbia

China
9 Hohai University
10 International Center of Future Science, Jilin University
11 Tongji University
12 The Chinese University of Hong Kong
13 Chongqing University
14 Nankai University

Denmark
15 Aarhus University
16 University of Southern Denmark
17 Technical University of Denmark

Egypt
18 Menoufia University

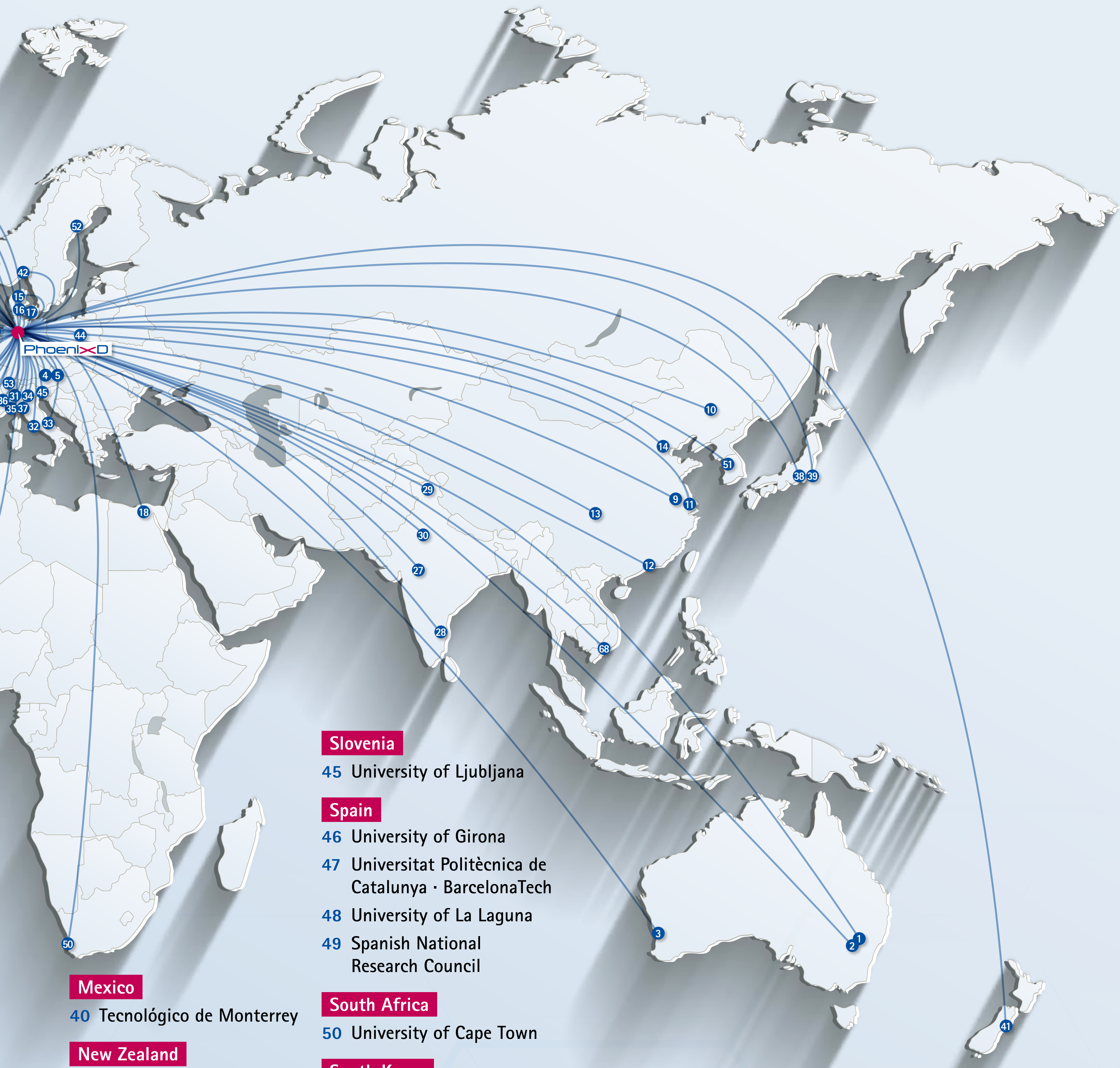
France
19 ENS Paris-Saclay
20 École Polytechnique
21 University of Technology of Troyes
22 University of Limonges
23 University of Lille

Great Britain
24 University of Glasgow
25 Aston University
26 King's College London

India
27 Indian Institute of Technology Indore
28 Indian Institute of Technology Madras
29 Indian Institute of Technology Mandi
30 Indian Institute of Technology Dehli

Italy
31 University of Milano-Biocca
32 University of Rome Tor Vergata
33 Gabriele D'Annunzio University
34 Fondazione Bruno Kessler
35 Istituto Italiano di Tecnologia
36 Politecnico di Torino
37 Istituto Italiano di Tecnologia

Japan
38 Keio University
39 National Institute of Informatics



Slovenia

45 University of Ljubljana

Spain

46 University of Girona

47 Universitat Politècnica de Catalunya · BarcelonaTech

48 University of La Laguna

49 Spanish National Research Council

Mexico

40 Tecnológico de Monterrey

New Zealand

41 University of Canterbury

Norway

42 University of Oslo

Peru

43 National Agrarian University

Poland

44 Łukasiewicz Research Network

South Africa

50 University of Cape Town

South Korea

51 Korea University

Sweden

52 Umeå University

Switzerland

53 ETH Zurich

The Netherlands

54 University of Amsterdam

55 AMOLF

United States of America

56 University of California, Berkeley

57 Texas A&M University

58 Purdue University

59 The University of New Mexico

60 The University of Texas at Austin

61 Florida State University

62 Clemson University

63 Louisiana State University

64 University of Houston

65 North Carolina State University

66 University of Louisville

67 Boston University

Vietnam

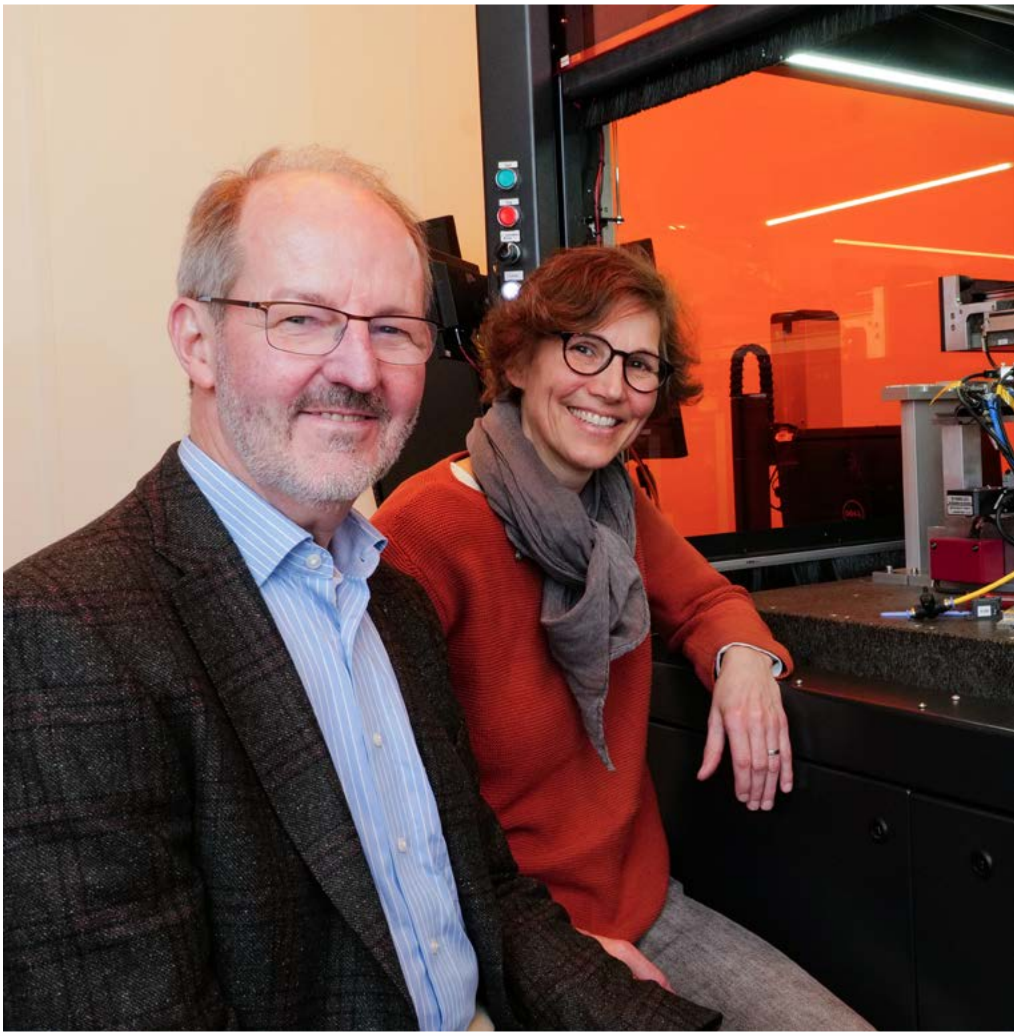
68 Ho Chi Minh City University of Technology

Interview with Annika Raatz and Wolfgang Kowalsky:

"I'm concerned about the naivety with which we release data"

Sonja Smalian

Annika Raatz, professor of mechanical engineering, and Wolfgang Kowalsky, professor of electrical engineering and PhoenixD board member, discuss in an interview how they aim to reduce production costs and why research data deserve more protection.



Wolfgang Kowalsky (left) and Annika Raatz (right) sit in front of the sub-micrometre precision robot, with which sensors or optical systems can be assembled with high precision based on sensor-guided assembly processes.

The Cluster of Excellence PhoenixD wants to build the optics of the future. What do you achieve with your research groups along the path to this goal?

Wolfgang Kowalsky: For the manufacturing of optical components, we supply the process measurement technology for production monitoring. By the way, this can be thought of as a computer chip. A digital twin, i.e. a virtual model, accompanies the production. For this, my team measures coatings, for example, and investigates the use of vertical cavity surface emitting lasers as distance sensors. We are also developing poled polymers for optical component design. Information can be sent via these "switchable" materials using light signals. And we are researching applications of optical technologies, namely optical sensors for bioanalytics. That's the topic that interests me the most right now.

Why?

Kowalsky: We can detect bacteria electronically with field-effect transistors, or FETs, and optically with plasmonics and ellipsometric evaluation. We have just launched the first patent on biosensor technology and microfluidics.

Why is the development of new detection methods so important?

Kowalsky: Optical sensor technology often delivers its results in real-time. Advancing urbanization and mobility means that pathogens will be transmitted ever faster. So, for example, we need to be able to react more quickly to outbreaks of diseases than we did with Covid. We can do that with optics.

Mrs. Raatz, your discipline, mechanical engineering, is responsible for assembling the optical components and designing the manufacturing process and production equipment. What challenges do you face?

Annika Raatz: We are investigating which processes are suitable for assembling the optical components. The challenge is to realize the required accuracies. Single-mode fibres and miniaturization require ever-lower tolerance ranges in manufacturing. We also want to develop processes and equipment that can produce cost-effective optical technologies for the consumer goods industry. We believe that the final assembly of optoelectronic products can also be carried out here in Germany at a competitive price.

Where do you see savings potential?

Raatz: We want to accelerate process development significantly. To this end, we are using a digital twin of the production plant to simulate all process sequences. We hope in this way to transfer the

individual assembly processes to the production line significantly faster than in the usual three or more months. In addition, we want to move away from a fixed sequence of operations and towards flexible matrix production that is easier to adapt, so that the production of small batches will be cost-effective.

How can I imagine this in practice?

Raatz: We plan production such that we don't have one station after the other, as on the old familiar assembly line. We use an autonomous transport module that moves the product flexibly to each station in any order, or skips steps entirely if the product does not require them. Ideally, the transport module serves as an additional axis of motion at the station, so there is no need for another robot anywhere.

What are your further plans?

Raatz: For cost-effective production, we want to reduce the number of complex high-precision assembly steps. To achieve this, components are pre-positioned in large quantities on a substrate to save time and then precisely aligned simultaneously. Using passive approaches such as self-alignment, we generate movement in the component without using expensive machines. The process will be very accurate with appropriate development.

Kowalsky: This is the future: the components placed on the circuit boards find their correct position independently. In biology, we already know something like this in the case of antibodies, which find their respective counterpart by thermally moving the antibody. Nature has already solved the problem chemically with a unique sorting algorithm.

Mr. Kowalsky, you work with your team at the TU Braunschweig, and you, Ms. Raatz, in Garbsen. How important is this collaboration for your research?

Kowalsky: Indispensable. In the past, one discipline placed its order with the other. For example, the electrician asked the chemist for an insulating plastic. It simply doesn't work this way anymore. The issues have become so complex that all disciplines must work on them together. Leibniz University Hannover has already taken this into account by establishing Leibniz Schools such as the Leibniz School of Optics.

Raatz: New structures are sometimes needed to institutionalize necessary and enriching collaboration on a large scale. Unfortunately, this is usually associated with an increased administrative effort during initiation, as the interests and established processes of the various stakeholders, such as faculties, have to be taken into account.

There are rarely saleable products at the end of university research projects, but plenty of new insights.

Data is considered the "new gold" in the economy. How do universities deal with this resource?

Kowalsky: Data is an incredible asset. It forms the basis for the development of artificial intelligence. But in my view, universities are too generous with this treasure.

In what way?

Kowalsky: The DFG, the German Research Foundation, i.e. the highest self-governing body of science in Germany, requires in its guidelines that researchers contribute their results to scientific discourse. I would put it the other way around: First and foremost, all data is secret. And then, I need to filter carefully which data I contribute to open discourse. I'm concerned about the naivety with which we release data; other countries stopped doing that a long time ago.

Because other countries hope to gain economic advantages from their research?

Kowalsky: Yes, exactly. That's why I think it mustn't be up to individual researchers to decide, following current practices in their respective disciplines, to what extent they make their research data publicly accessible in archives. As a funding body, the DFG also supports the economic interests of Germany and its entrepreneurs. Therefore, aspects of competitiveness and national security should also be taken into account. The efforts of some Asian companies to systematically evaluate German dissertations also show how much our results are appreciated abroad.

This raises the question of why we don't do this analysis ourselves.

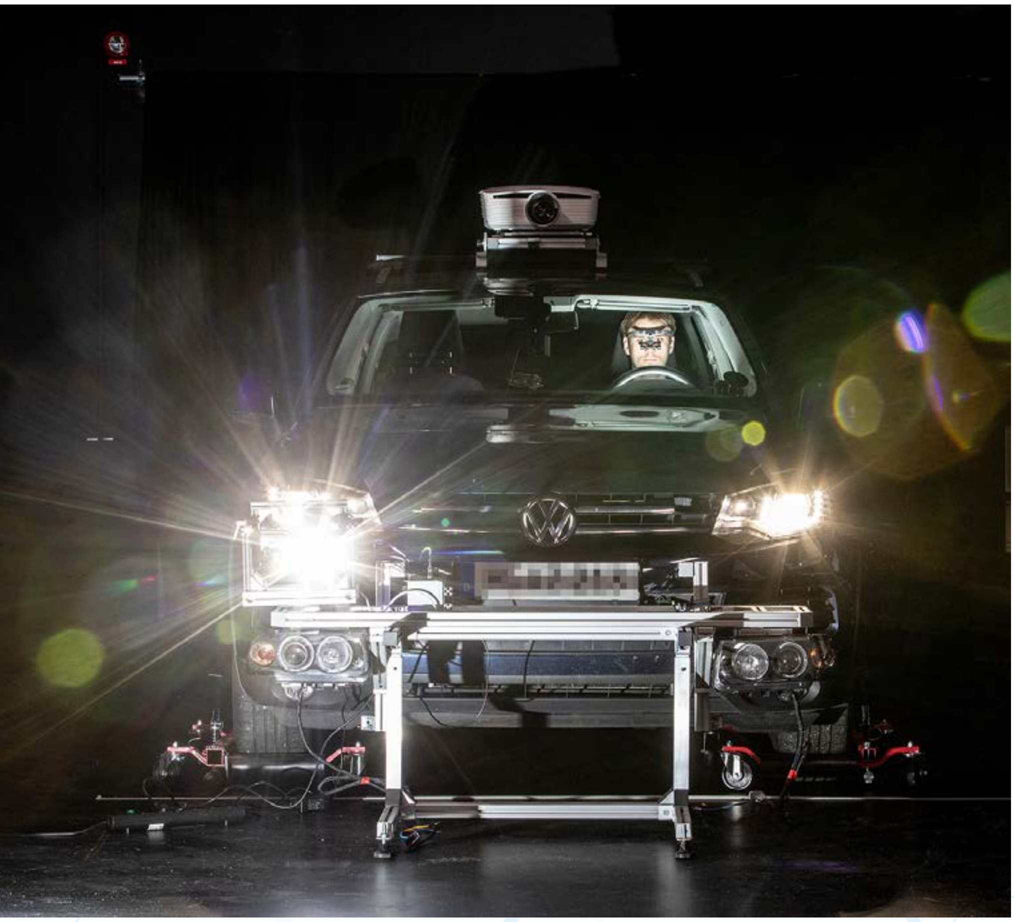
Kowalsky: Exactly. Technology transfer has always been treated inadequately at universities. I could imagine this as a new task for the future: networking researchers and their key findings with interested commercial enterprises.

Optical Systems for More Safety and Comfort in Road Traffic

Alexander Wolf

Light is one of the most important carriers of information for humans and it is impossible to imagine modern measurement technology without it. That is why we at PhoenixD develop systems that provide spatially, temporally and spectrally tailored light for a wide range of applications. One aspect of our work is designing optical systems for road traffic to increase safety and comfort. We often cooperate closely with partners from industry in this area.

For optimum vision for the driver, the road and its near environment must be brightly illuminated. When oncoming traffic is taken into account, it becomes clear that bright illumination cannot be the only goal. Rather, optimum visibility must be provided for all road users in every driving situation and, in particular, glare for others must be minimized. To achieve this, the classic low beam and high beam are increasingly being replaced by adaptive lighting functions. This glare-free high beam function was introduced in 2015 in compact-class passenger cars with eight individually switchable LEDs. Since then, the number of addressable pixels of a light distribution has increased. In recent years, we have investigated various technologies for generating high-resolution light distributions. We evaluated concepts and set them up as prototypes. Among others, micro mirror arrays, LED arrays and scanning lasers have been used.



Test setup including eye-tracking system to analyze the driver's reaction to different vehicle-based light projections.

LEDs for the realization of sustainable tailored illumination

With such systems, information or symbols can be projected directly onto the road and thus employed to communicate with the driver or other road users. For example, an autonomous vehicle can communicate planned driving maneuvers to pedestrians. A critical point here is the targeted addressing of the recipients. On the one hand, it must be ensured that the recipients, either the drivers themselves or other road users, can reliably recognize the projection; on the other hand, non-addressed persons in the traffic environment must not be irritated. Therefore, we conducted a physiological study to investigate the distraction potential of projections on the road surface in a highway scenario.

To provide the correct light distribution for every driving situation, traditional systems such as manual or automatic activation of the high beam are no longer sufficient. Instead, in the case of high-resolution headlights, a setpoint value for the light intensity to be generated must be assigned to each individual pixel at each point in time. For this purpose, data from various vehicle-borne sensors such as cameras, radar, LiDAR, and sensors for acceleration and steering angle are used and combined with global data such as road maps. At this point, infrared radiation is considered for information retrieval, both for LiDAR systems and as a glare-free light source for vehicle cameras.

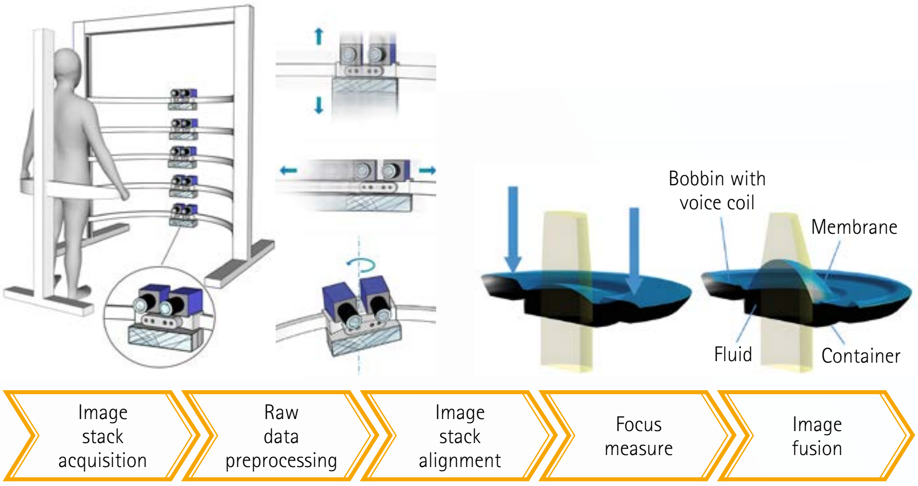
New paradigm in automotive illumination

Future research will focus on transferring existing approaches from cars to other road users. This is because it is currently difficult to detect and thus de-glare cyclists and pedestrians with vehicle-based systems, which in turn has a negative impact on autonomous driving in general.

AI-Powered Optical Body Scanner for Skin Disease Detection

Lennart Jütte, Gaurav Sharma and Bernhard Roth

Skin cancer is the most common human cancer, and its incidence has increased in the last decade. With more than 144,000 new cases per year, cutaneous melanoma is Europe's sixth most common type of cancer. Fortunately, skin cancer may be cured if treated at an early stage. However, if cancer cells spread, the survival probability after five years drops to below 30 %. Thus, rapid diagnosis is vital to increase the survival rate.



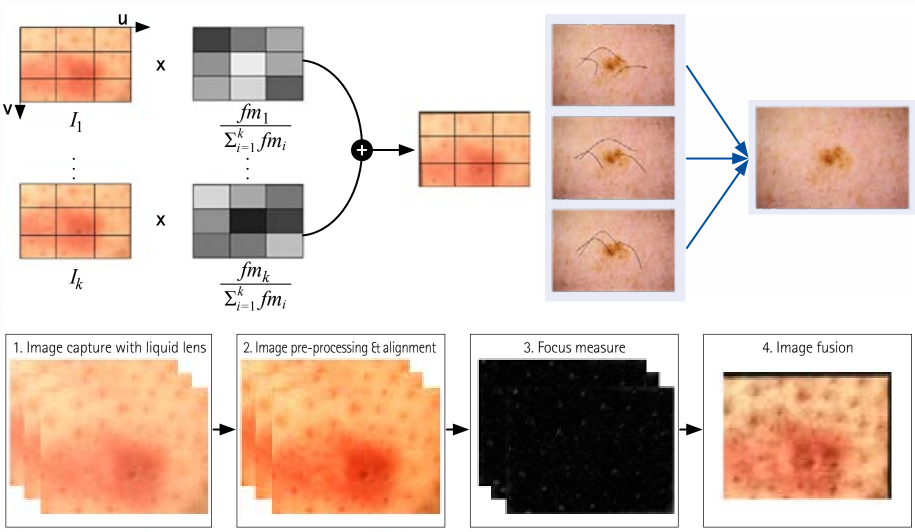
Top: Sketch of the iToBos system (left) and the lens with tunable focus for high resolution imaging (right). Bottom: Image processing pipeline.

EU-wide collaboration for early melanoma detection

The EU project iToBoS – Intelligent Total Body Scanner for Early Detection of Melanoma with PhoenixD (HOT - Hannover Centre for Optical Technologies) at Leibniz University Hannover as a partner, aims to reduce the mortality rate of skin cancer by improving early melanoma detection. "Our diagnostic system works contactless and captures the entire skin surface simultaneously", says Prof. Bernhard Roth (HOT). It combines optical imaging with artificial intelligence (AI) and incorporates information from all relevant sources, i.e. dermatoscopic images and patient records. It also includes specific characteristics such as age, gender and previous illnesses, as well as the location and size of the skin malformation.

In addition, the system takes care of the handling and protection of sensitive patient data. This is of paramount importance for approval and acceptance in the market. The AI in the scanner will – for the first time – not only diagnose skin cancer but also transparently explain what information was used to assess the diagnosis. This means that a comprehensive and meaningful conclusion can be drawn.

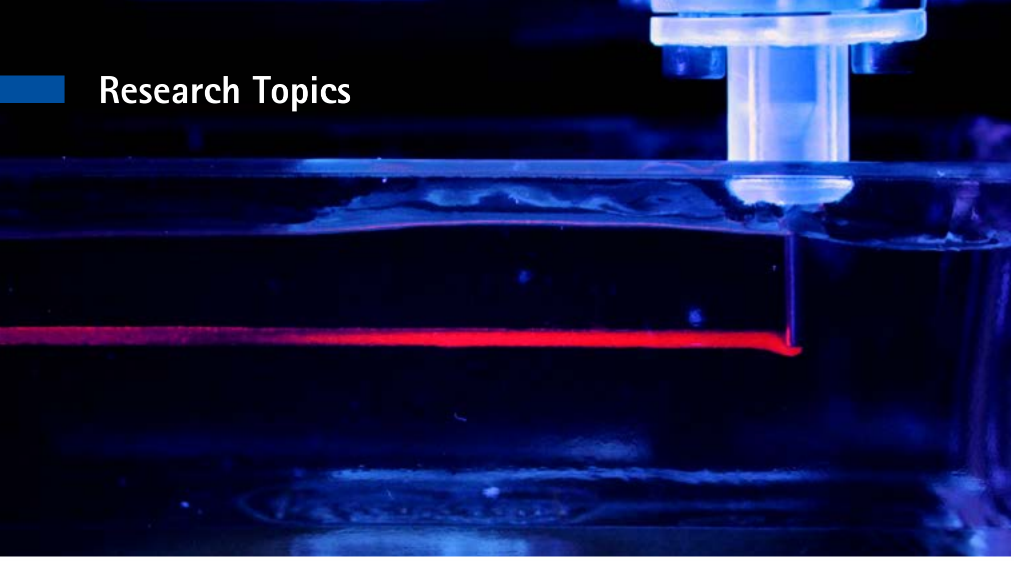
Coordinated by Prof. Rafael Garcia of the University of Girona, a total of 19 partners from Europe, Asia and Australia are cooperating to realize and validate this novel diagnostic system. "As part of PhoenixD, we are focusing on the development of the illumination and imaging system, which uses tunable optics," says Prof. Bernhard Roth. Two scientists from Roth's group, Lennart Jütte and Gaurav Sharma, contribute to the system as part of their PhD theses. "The greatest challenge is to reconcile optical imaging, mechanical design and artificial intelligence," says Lennart Jütte.

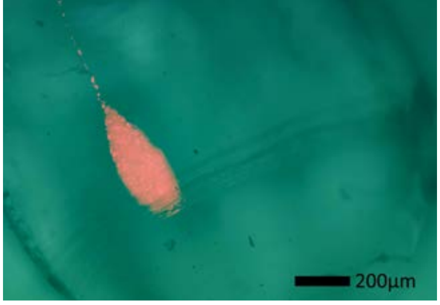


Top: Weight-based image fusion process (left). Digital hair removal is realized with several images of the same skin region ("true value inpainting") (right).
Bottom: Crop from focus stacked images (left) to increase the image resolution (right).

Our system can save several hundred million euros per year

The medical partner of Roth's group, Prof. Steffen Emmert from the University Dermatology Clinic Rostock, has high hopes for the new approach. He says: "If doctors could detect only 10 % of melanoma at an earlier stage, this could save costs of up to several hundred million euros per year. In future, such diagnostic systems could also be applied to other skin diseases and lead to completely new therapeutic approaches".





Top: Cross-section of a multimode wave-guide with a spatially resolved core of nanoparticle-infused silicone.

Left: Printing of a waveguide with a graded nanoparticle concentration (red fluorescence) from low (left) to high (right).

Developing Nanoparticle-Based Integrated Optical Sensors

Tobias Biermann
Gerrit Eckert
Roland Lachmayer
Nadja C. Bigall

Additive manufacturing processes allow the voxel-wise tailoring of material compositions. In this way, a high degree of functional integration can be achieved. Especially the in-process incorporation of fluorescent semiconductor nanoparticles opens up revolutionary possibilities which we investigate in PhoenixD. We develop highly flexible emitter and sensor structures such as waveguides with a wide range of application scenarios.

Semiconductor nanoparticles show promising and adjustable optical properties such as a tunable band gap, high conversion efficiency and sharp emission features. Using the spatially resolved incorporation of these particles in waveguides we investigate the potentials of using them for novel optical systems.

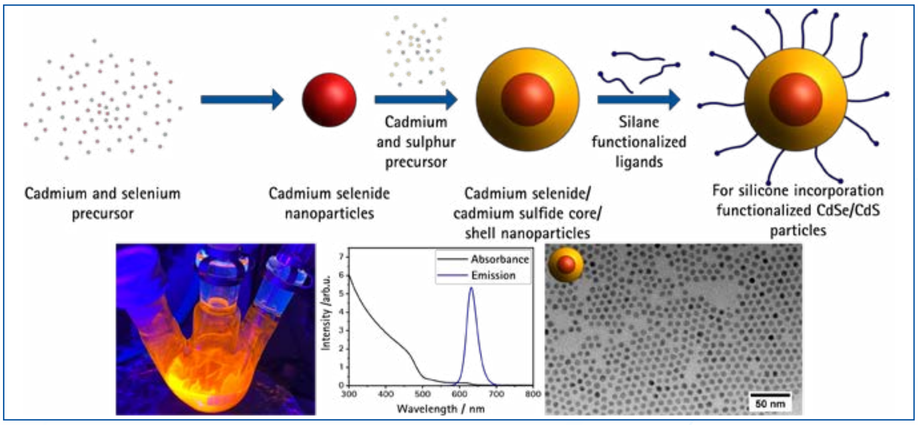
Our research is strongly based on the core principles of PhoenixD. Our interdisciplinary research approach combines aspects of optics, chemistry and engineering. This collaboration well beyond individual research groups provides us with access to resources, such as X-ray photoelectron spectroscopy (XPS), scanning laser optical tomography (SLOT) and transmission electron microscopy (TEM).

Within the Institute of Product Development (IPeG), the process control and targeted incorporation of nanoparticles during waveguide printing is being investigated. Embedded printing technology allows us to utilize temperature-, UV- and environmentally stable, highly transparent silicone materials. Our key goal in this project is the spatial injection of fluorescent nanoparticles. The underlying challenges to overcome are manifold and include the conception and simulation of novel 3D-printed optics, the processing of silicone as a viscous material, the controlling of the optical quality of the waveguides, and the precise control of the self-developed manufacturing system.

The chair of Functional Nanostructures (Bigall group) at the Institute of Physical Chemistry and Electrochemistry (PCI) investigates the synthesis and structure-property correlations of functional nanostructures obtained by the controlled assembly of various nanoparticles. Within this project the synthesis and incorporation of different particle systems, as well as their binding stability and homogeneity in the silicone matrix is optimized. Furthermore, the synthesis of particle systems for application-specific tailored emission spectra is investigated.

Fluorescent nanoparticles successfully implemented in waveguides

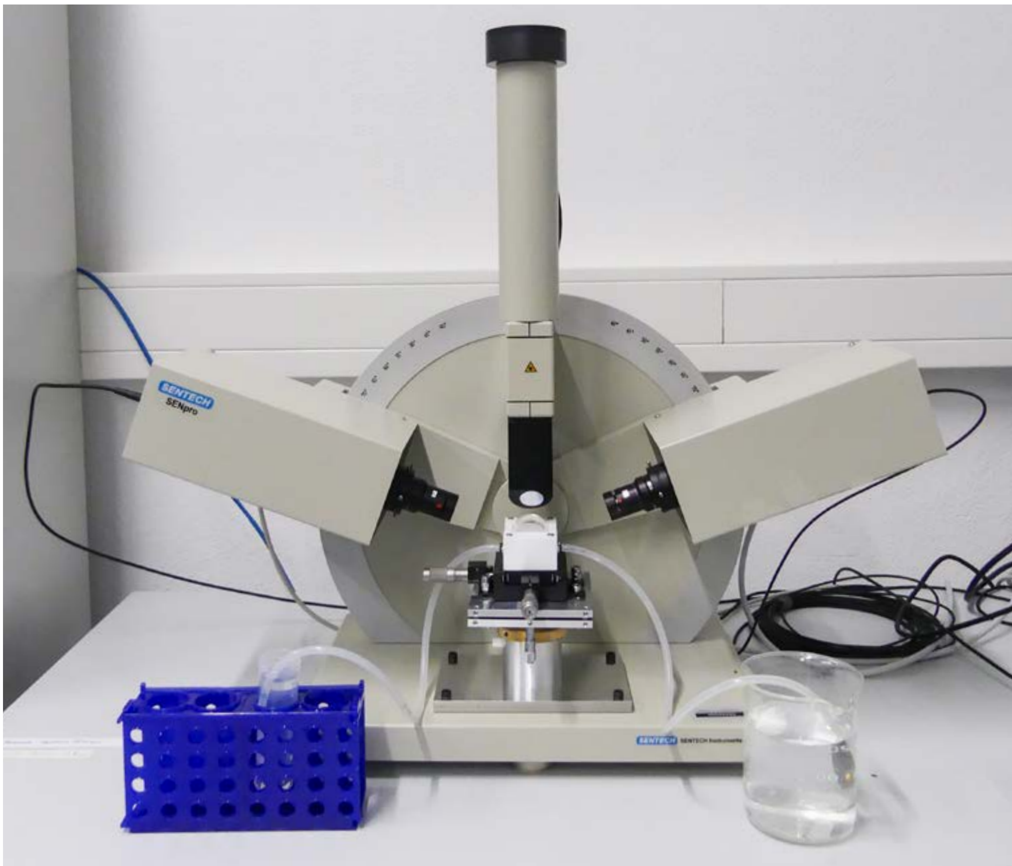
We have already reached our first research goal to spatially resolve the fluorescent nanoparticles along the length as well as in the cross-section of a waveguide. Our joint focus is now to ensure that the technology and the nanoparticle systems we have developed are suitable for practical use in emitter and sensor systems. Our goal for the future is to print these functionalized waveguides directly into flexible products such as soft-robotic contraptions.



Synthesis route of highly fluorescent "giant shell quantum dots" (top). The image shows the synthesis under UV light (left), along with the absorbance and emission spectra (centre), as well as a TEM micrograph (right).

Optical Biosensors to fight E. Coli Poisoning

Soraya Zangenehzadeh
Emil Agocs



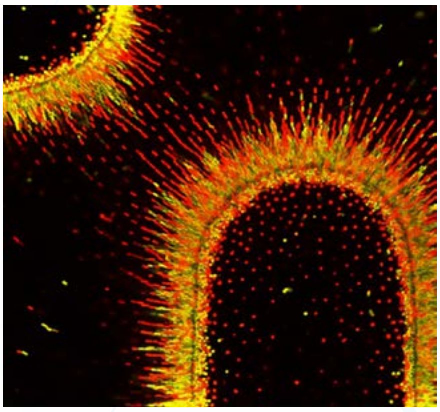
Kretschmann configuration flow cell designed by the TU Braunschweig students Fenja Schroeder and Max Schittenhelm attached to the ellipsometer.

Optical biosensors are used for a wide range of medical purposes. For example, they can detect harmful bacteria such as Escherichia coli (E. coli), and diagnose diseases such as Alzheimer's and various cancers. These sensors use light to convert biological and chemical changes in the target sample into analytical output signals. Using light makes optical biosensors highly sensitive and reliable for various applications. So far, measurement is typically based on characteristics like light absorption, total internal reflection, Raman scattering and refractive index changes.

Enhanced sensitivity by analyzing phase changes

Surface plasmon resonance biosensors are a more advanced type of optical biosensors. These sensors rely on the propagation of an evanescent field at the metal-dielectric interface, and are sensitive to changes in refractive indices within this field. Changes can take place, for example, when bacteria link to the metal surface with specific bio-receptor layers such as antibodies. Usually this is evaluated by analyzing changes in the intensity of reflected light, but studying the phase modulation can significantly increase the measurement sensitivity.

In PhoenixD, we aim to study the surface plasmon resonance effect under spectroscopic ellipsometry. This has the extra benefit that the phase shift of the reflected light can be analyzed, and thus increased sensitivity is achieved.



Dielectric particles feel inhomogeneous forces in an asymmetric electrodes design and move towards one of these electrodes according to their dielectric properties. This phenomenon is called dielectrophoresis.

Detection of E. coli

We use this method to detect living bacteria in a liquid environment produced in a laboratory. Our initial research work is focused on E. coli, common bacteria in the gastrointestinal tract, and part of the normal bacterial flora. However, some E. coli strains can produce a toxin that can cause serious infections. According to the Robert Koch Institute, the most common pathogen of hospital-acquired infections in Germany in 2011 was E. coli (18.0%). Using a precise method for early detection is therefore vital. For our measurements we use the spectroscopic ellipsometry system SE850 from SENTECH instruments. The optical properties of the reference medium, which here is phosphate-buffered saline (PBS), are characterized before and after attaching the bacteria to the sensor surface. In parallel, we are building and analyzing a simulation model to better understand how the presence of bacteria affects the optical properties of the substrate.

The Institute of High Frequency Technology (IHF) at the Technical University Braunschweig is cooperating with the Hannover Centre for Optical Technologies (HOT) at Leibniz University Hannover on this project. Our next steps are to characterize the improved sensitivity and the repeatability of our biosensor. We aim to increase the number of bacteria over the sensing surface by using the dielectrophoresis effect. Finally, after developing the optical biosensor based on spectroscopic ellipsometry to monitor E. coli we hope that our approach will become a regular medical tool in clinics all over the world.

Interview with Anna Lena Schall-Giesecke:

"Scalability and the interconnection of integrated photonic chips are the next milestones in research"

Sonja Smalian

Anna Lena Schall-Giesecke has been a PhoenixD's International Advisory Committee member since the spring of 2023. She knows Leibniz University Hannover well, having completed her physics degree there. For her doctorate, she moved to Heinrich Heine University in Düsseldorf. She is now a professor of electrical engineering focusing on integrated photonics at the University of Duisburg-Essen, and works at the Fraunhofer IMS. In an interview, she explains why fundamental research is often too rarely translated into products in Germany and why she has high hopes for sensor technology.

Ms Schall-Giesecke, why do you consider optical technologies to be one of this century's key technologies?

Anna Lena Schall-Giesecke: Light connects us all. Modern communication media already work with light. In this century, the main issue is to make data traffic even more energy-efficient.

In which areas do you see the most significant opportunities for this?

Schall-Giesecke: Optical fibres, i.e. fibre-optic cables, have been used for years for internet connections with long ranges, for example between Europe and the USA. But copper conductors are often still used for the very short ranges on a computer chip. These connections could also be much faster, more energy-efficient and more powerful. There are going to be a lot of changes.

How is this increase in performance achieved?

Schall-Giesecke: Through light. To put it simply, light cannot only be switched on or off like electricity but it can also be used in different colours. In this way much more information can be transmitted within one cable cross-section. Due to the progressive miniaturisation of laser sources, optical technologies find their way as sensors into mobile phones, for example. Something like this was previously unthinkable simply because of the space-filling size of the laser systems.

What are the next stages of development?

Schall-Giesecke: The next milestone would be scalability, i.e. producing integrated photonic components in high quantities. Hundreds, thousands of these components fit on a silicon wafer. Another significant milestone would be networking such photonic chips with each other and with electronics.

Where will we see these advances in use?

Schall-Giesecke: Human-to-human communication and human-to-machine communication will change as a result, as will the transmission of information within computers and networks. But I also expect many innovations in sensor technology and quantum technologies.

Which ones exactly?

Schall-Giesecke: I expect that in future there will be optical biosensors in mobile phones with which various parameters about one's state of health can be recorded and transmitted to a doctor. It would be an exciting application if, for example, patients could determine blood sugar levels through their skin. Cameras can also easily detect sleep apnoea. Optical technologies are currently being developed to enable patients to be monitored at home rather than having to go to a sleep laboratory. For this, however, the optical signal must first be evaluated with the help of intelligent software to offer added value. Incidentally, this applies not only to medical technology applications but is just as necessary for autonomous driving.

For autonomous driving, however, research is focussing on other optical technologies.

Schall-Giesecke: Yes, that's true. Among other things, a type of light radar called LiDAR is used. With the help of laser light, distance measurements are then carried out, and the sensor technology catches the reflected light again. This could turn into a megatrend. Many car manufacturers are already developing such systems for passive safety monitoring. With infrared light, it is possible to ensure reliable distance measurement even in poor visibility conditions such as fog or heavy rain.

Leibniz Universität Hannover is building its own Optics Campus, the OPTICUM. Where are other research centres for optical technologies located?

Schall-Giesecke: I see many positive developments in Bavaria and the border triangle of Germany, Belgium and the Netherlands, with the cities of Aachen and Eindhoven. The PhotonDelta in Eindhoven has successfully attracted national and European funding. The Berlin-Brandenburg region is also a centre for optical technologies. There is strong research there, for example, at the TU Berlin and in many university spin-offs. Numerous companies in this field are also located on the research campus in Adlershof.

Germany is strong in basic research. Why doesn't this more often lead to successful industrial products?

Schall-Giesecke: Basic research does not initially have a market focus but aims to push technological boundaries. Sometimes new solutions to problems emerge, for which there could be a market. But it is enormously time-consuming to move from the idea to the product, develop a prototype, and get it ready for series production. That's the only way to earn money.

Does that mean you need further financial support for prototype development?

Schall-Giesecke: Yes. And there is a lack of suitable funding programmes. In the case of collaborative funding, participation requirements are often not financially interesting for the potential user. The funding programme WiVoPro, short for preliminary scientific projects, of the Federal Ministry of Education and Research amounts to €600,000. Quite often, there needs to be more than this sum to prepare a research approach in such a way that one can attract industrial partners.

And founding a start-up company to raise money is not an alternative either?

Schall-Giesecke: It's not easy to find European investors for university spin-offs as the start-up culture in Germany is not yet widely developed. But it is also essential to find the right people who think in economic terms and drive things forward. An excellent scientist is not necessarily the right boss for a commercial enterprise. And that's not all: a new sensor, for example, also needs excellent software for its application, which would have to be programmed by a specialist. And then, sales experts who can also sell the sensor are required. In the end, there must be a functioning system and not just individual components.

Anna Lena Schall-Giesecke, a graduate of Leibniz University and now a professor at the University of Duisburg-Essen, joined PhoenixD's International Advisory Committee in the spring of 2023.

As a physicist, you have a professorship in electrical engineering and teach mainly young men. How could science and engineering subjects become more attractive to women?

Schall-Giesecke: That's an important point that we must work on. There are very few women among engineering students, which is noticeable. It is similar in my faculty. Women make up less than ten per cent of the 80 or so professors. More than that is needed for professors to be perceived as positive role models by female students.

What would need to change to make your job more attractive to women?

Schall-Giesecke: The lack of childcare, predominantly in the afternoons, is still a problem. Until there is a solution, meetings should not be held between 4 and 6 pm. At the same time, it is often socially unaccepted for fathers to ease the pressure on their working wives and look after the children during such late appointments. In general, universities and companies should rethink why they often don't make it possible for management activities to be carried out on a part-time basis.

The Secret behind Advanced Manufacturing of Micro-LED Arrays

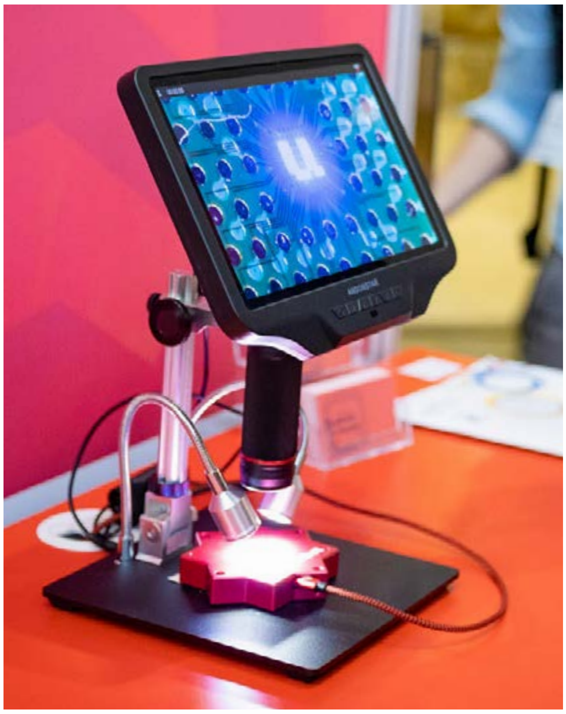
Florian Meierhofer
Jan Gülink
Andreas Waag

More than thirty years ago, the invention of the blue gallium nitride (GaN) LED heralded a new era in lighting technology and replaced the traditional "Edison" incandescent lightbulb in various ubiquitous applications such as room lighting, flashlights, and car headlights, among other lighting applications. Most of these devices rely on a rather large LED chip size of a few hundred micrometres to several millimetres, which conventional pick-and-place technologies can easily manufacture at a reasonably low cost.

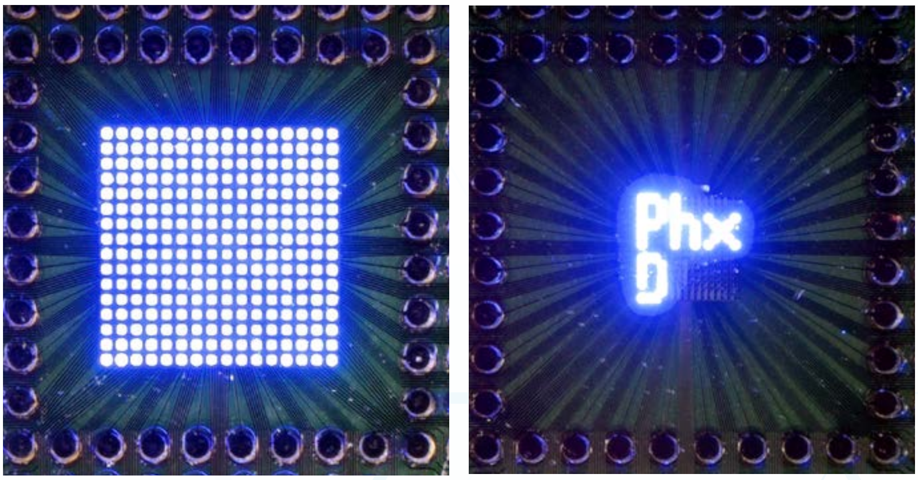
In addition, using dry-etching processes, the mature GaN-LED stack can also be structured into even smaller sizes. These so-called "micro-LEDs" feature pixel sizes of less than a hundred micrometres, sometimes even below one micrometre, and offer promising potential for consumer electronics (e.g. augmented reality, smart watches, head-up-displays). Beyond those additional unique applications in quantum optics, super-resolution microscopy or optical neural networks are conceivable. Since micro-LEDs from a single wafer emit light with only one wavelength, realizing systems with multi-wavelength emission is a major challenge.

One approach towards "multi-wavelength" is to use a downconverter material that transforms the blue light of the micro-LED into colours of longer wavelength - for example, red. To turn individual pixels on and off, each of them must be electrically interconnected to external leads, e.g. on a printed circuit board or a silicon-based CMOS chip. As pixel sizes decrease, however, cost-effective and reliable mass transfer technologies become more challenging, so that to this day micro-LED displays are not yet on the market.

As part of the PhoenixD network, we investigate tailored colour converters based on cadmium-free quantum dots and develop innovative connection and transfer technologies for the hybrid integration of next-generation micro-LED arrays.



A micro-LED platform playing a fast animation with several thousand frames per second is shown at a trade fair. The demo showcases the current status of the micro-LED arrays as a versatile platform for individual light projection with highest modulation bandwidths and brightness.



Micro-LED array integrated onto a printed circuit board during operation in full-light emission mode (left) and during display mode showing the letters "PhxD" (right). The pixel size is 30 micrometres, comparable to smartphone displays, but with much brighter light and a faster switch-on time. In combination with advanced colour converters, new mass transfer technologies are needed to accomplish even smaller and multicolour pixels. We develop the manufacturing processes required to realize micro-LED modules, focusing on reliability, high throughput and cost-effectiveness.

New Bachelor's Programme in Optical Technologies started in 2022

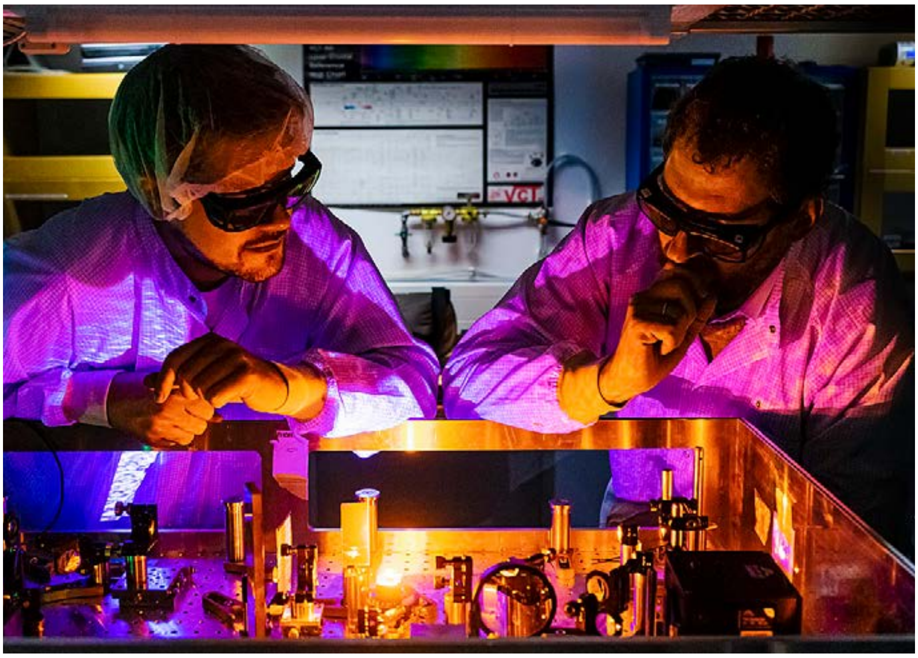
Sonja Smalian

Initiated by PhoenixD, Leibniz University Hannover (LUH) has developed a new bachelor's programme: "Optical Technologies: Lasers and Photonics". After six semesters, students will obtain a Bachelor of Science degree. The second intake is in the winter semester of 2023/24.

With a focus on optics, the degree is interdisciplinary and broadly diversified. Course topics include mechanical engineering, mathematics, construction theory, electrical engineering and information technology, optics and lasers, fundamentals of general chemistry, numerical analysis, quantum technologies and optical materials. This concept makes the new bachelor's programme unique at a German university. The Faculty of Mechanical Engineering manages the programme.

Students will also learn how to set up experiments, evaluate measurement data, and operate scientific software during their studies. Then, beginning in the fourth semester, they can choose two compulsory elective modules to further specialise in a specific field. Finally, during the sixth semester, they write their bachelor's thesis and can complete a twelve-week internship in research or industry.

The Hannover Centre for Optical Technologies, the Leibniz School of Optics & Photonics and the Laser Zentrum Hannover provide particularly favourable conditions for students in optics. Graduates of the new bachelor's programme are generalists in optics and photonics. They are thus well equipped to work in one of the most important key technologies of the 21st century – the laser and optics industry. Furthermore, students wishing to pursue further studies can choose between a range of specialised master's programmes at LUH, including Optical Technologies, Quantum Engineering, Physics, and Nanotechnology etc.



The bachelor's programme graduates are generalists in optics and photonics and have gained knowledge in laser technology (above) and mechanical engineering.

The bachelor's programme Optical Technologies: Lasers and Photonics is suitable for students with a strong interest in natural sciences and technology and the ability to think in logical and abstract ways. The degree course requires a basic understanding of mathematics and physics.

Who should apply?

Applicants should be able to recognise structures and have a precise way of working.
The language level requirement for international students is C1 German.

Programme Profile

Course type:	Undergraduate studies (1 subject bachelor's)
Standard Course Duration:	6 semesters
Course Start:	Winter semester
Primary Language of Instruction:	German
Language Requirements:	Applicants with German University entrance qualification: none; International applicants: Proof of language proficiency for the level German C1, good command of the English language recommended
Special Requirements:	Pre-internship (recommended)
Admission:	Unrestricted
International exchange:	Stay abroad is possible, but not mandatory

You have further questions?
Please contact the programme's team via email
opticaltechnologies@maschinenbau.uni-hannover.de

http://go.lu-h.de/BSc_Optical_Technologies

PhoenixD Research School

PhoenixD PhD students during the monthly seminar.

Nadja-C. Bigall

Attracting young people to science and technology has to start early in order to maintain their interest for years. Helping them to gain qualifications for science and especially for industry is the key aim of the PhoenixD early career support concept. The Cluster of Excellence supports all age cohorts, starting with elementary schoolchildren and ending with well-trained scientists entering into high-level positions in industry, starting their own young spin-off companies or following an academic career.

The PhoenixD Research School (PRS) institutionalises all teaching and career development activities as an integral part of the cluster and promotes young scientists in many ways. "In the increasingly fast-changing professional world, interdisciplinary understanding is particularly in demand", says Nadja-C. Bigall, head of PhoenixD Research School and member of the cluster's board. "PRS creates a basis for interdisciplinarity in an international environment through regular exchange and further training."

School Projects

With the Leibniz Lab, PhoenixD brings optical experiments into classrooms. In addition, pupils can learn to identify challenges and problems at school and develop digital and technical solutions, among other matters, as part of our specially founded project workshop PROTOYS. Furthermore, young people can get to know the research labs at events such as "Science Night" or "Future Day" (also known as "Girls' Day").

Voluntary Scientific Year between School and Study

In a voluntary scientific year, young adults can experience everyday life at university. They are part of the PhoenixD community and can conduct small projects of their own.

Studying Optical Technologies

Especially in the research and development of new technologies, creativity and thinking beyond fixed disciplinary boundaries are required. The study of optical technologies enables students to think and work in a solution-oriented, creative and innovative way. Here, engineering sciences meet physics, chemistry and mathematics. Since the winter semester 2022/23, Leibniz University Hannover offers the new bachelor's degree programme "Optical Technologies: Lasers and Photonics". The established master's programme "Optical Technologies" caters for the next stage, leading to a career in industry or a doctorate.

PRS for PhD Students

The PhD students are the heart of the PRS, since here, interdisciplinary science is strongly supported. Doctoral students gain a profound insight into the broad range of different optic-related fields. In addition to monthly colloquia, where guests from Germany and abroad report on the current state of research in their field, there is a monthly seminar, in which doctoral students from different disciplines meet. In a further step, the PRS4PhD (PhoenixD Research School for PhD students) offers lectures that bring the doctoral researchers to a common level of knowledge, excursions to participating institutes and to industry, and, finally, courses in key competencies to round off the PRS4PhD programme.

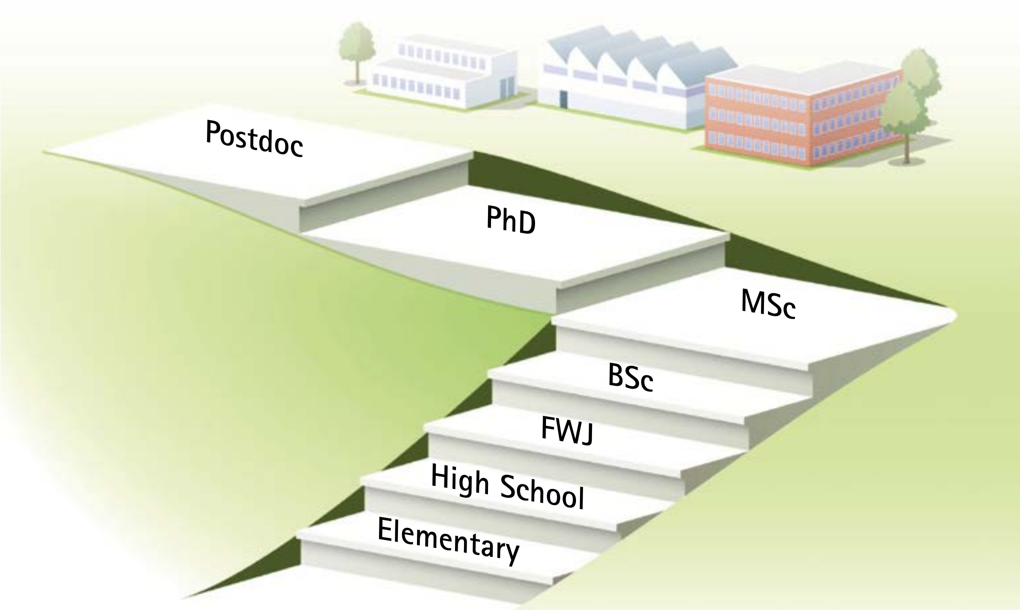
The doctoral students receive financial support for courses, participation in conferences, publications, and research stays abroad. They also have the opportunity to participate in an annual summer school. A further benefit is the integration into the research community from the very beginning through the mentoring programme, in which every PhD student can receive interdisciplinary support on their career path from the ranks of PhoenixD.

PhD students collect "PRS points" for participating in these different activities. After successful completion of their doctoral studies, they receive the PRS certificate to verify their additional competencies. After successful completion of their doctoral studies, a PhD degree awaits the researchers.

PostDocs

The PhoenixD-PostDoc Forum is a regular networking meeting for PhoenixD PostDocs. The forum is a platform for collegial exchange beyond one's own department. It provides personal support for individual career paths and opens up possibilities for further scientific collaboration.

The "PRS Award" is granted to an advanced PhD student or to a young PostDoc in recognition of outstanding achievements in research during their PhD period at PhoenixD.



The PhoenixD Research School (PRS) supports all age cohorts, from elementary school to well-educated scientists.

Nadja-C. Bigall

Head of
PhoenixD Research School
PhoenixD Executive
Board Member

Franziska-Marie Jarchow

Coordination of
PhoenixD Research School

Janna-Lee Steenblock

Coordination Diversity
PhoenixD Research School

Sarah Langhorst

Assistance
PhoenixD Research School

Going East: Two PhD Students work in Japan

Sonja Smalian

PhoenixD's PhD students, Hai Nam Nguyen and Talash Malek, spent three months at Japan's Keio University in Tokyo. We asked them why they chose to go East and what they learnt abroad. The two also share some advice for those who would like to broaden their knowledge by experiencing a foreign culture.

Talash Malek (left) and Hai Nam Nguyen spent three months in Japan's capital and visited Tokyo Skytree, the 634-metre-tall TV tower and city landmark.

What is your field of research, and in which departments/institutes are you working?

Hai Nam Nguyen: I work in function-oriented process planning at the Institute of Production Engineering and Machine Tools (IFW).

Talash Malek: I work in the NC Simulation and Optimization Department at the Institute of Production Engineering and Machine Tools (IFW).

Why did you choose the country and the university you visited?

Nguyen: The Kakinuma Lab at Keio University in Japan has a long-standing partnership with our institute. Japan is a country of contrast with an exciting culture to discover.

Malek: Japan was always very interesting for me to learn about, both culturally and technologically. Furthermore, our institute is collaborating with Keio University. The Kakinuma Lab has the same topics we are working on in PhoenixD, so it was a good opportunity for us to do research there.

What kind of research did you both pursue in Japan?

Nguyen: Talash and I investigated the interaction between the process steps in the additive and subtractive process chain. This is then considered in a holistic planning process to achieve predefined quality values using the available information in a digital twin.

What insights did you take home?

Nguyen: Flexibility in thought and action. Communication can be done not only through words but also with your hands and many drawings.

Malek: Scientifically and professionally, I saw a lot of new things. From a project management perspective, it was a great experience for me to move the project forward quickly with new people who work in a completely different way. Personally, I also took home the Japanese politeness and patience in different situations.

(1) Talash Malek (right) holds a degree in Mechanical Engineering, and Hai Nam Nguyen (left) in Engineering and Business Administration. The two PhD students worked in the Department of System Design Engineering at the lab of Yasuhiro Kakinuma (centre). Malek and Nguyen show their respect by calling him "sensei" (teacher). Founded in 1858, Keio University claims to be Japan's oldest private university. (2) They outlined their thoughts on a whiteboard during brainstorming sessions in the idea room.

1

2

Although Malek and Nguyen speak a total of six different languages – German, English, French, Spanish, Vietnamese and Persian - they have yet to learn Japanese. But getting around the city and finding scenic spots was successful.

What was the hardest lesson to learn when starting your exchange period?

Nguyen: Communication and establishing new networks were hard. They need time, patience and a lot of repetition.

Malek: Optimal communication and finding a common language in view of the different cultures was a big challenge; overcoming it was an important lesson for me.

What is the most significant difference between doing a PhD at PhoenixD and the country you visited?

Nguyen: You get paid here in Germany, but you also have to do more than just your own research. Besides, if you want high quality in the end, it's common in Japan to take more time for it.

Malek: I think, basically, there are not so many differences in research between the two countries. One advantage we have here is that we are fully funded. So you might have fewer financial worries. However, unlike there, as an institute staff member you have additional tasks and other projects. These are mostly full of learning but are also time-consuming and may prevent you from fully concentrating on your own research. Another advantage, especially with PhoenixD, is the collaboration and exchange opportunities between PhD students. You have less of this in Japan due to the smaller number of doctoral students at a lab.

What advice would you give other PhD students in PhoenixD who are interested in going abroad?

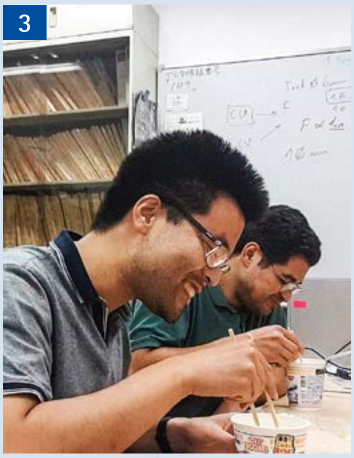
Nguyen: Izakayas (the Japanese version of a bar with food and alcoholic drinks) and karaoke are cheat codes for breaking the ice with new people. In addition, the best thing is if you can experience this time abroad with someone else. We provided motivation and mental support for each other during some hard times.

Malek: I recommend them to take advantage of this special opportunity at PxD and start international cooperations. In this way, you will develop both professionally and personally.
When you start something like this, you should stay open and flexible and try to observe and understand things from their point of view.

What is your most heart-warming memory?

Nguyen: There are several. My favourite is the unexpected karaoke event with our sensei and the group for our farewell party.

Malek: Besides very tasty food :), the people there and the moments I spent with them will always stay with me.



(3) When they had to work late in the lab, instant ramen soups from the vending machines served as a quick dinner for 31-year-old Nguyen and 34-year-old Malek. (4) Malek assists a fellow student in changing equipment for the machine in the lab. (5) In autumn 2022, Nguyen and Malek wore face masks to protect against Covid when riding the subway in the Tokyo Metropolitan Region. It is the most populous metropolitan area in the world.

Our First Four Years

Milestones and Selected Events

Sonja Smalian

03/04/2017

Deadline for submitting pre-proposals to the national funding initiative "Clusters of Excellence."

29/09/2017

Success in the first round of the Excellence Initiative: The Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) invites PhoenixD to submit a full proposal. The DFG will announce its final funding decision on the 45 to 50 Clusters of Excellence in Germany in September 2018. Successful applicants will receive funding for seven years with the option of applying for a second and third funding period.

21/02/2018

PhoenixD submits its funding proposal to the DFG German Research Foundation's initiative "Clusters of Excellence."

12/06/2018

The DFG German Research Foundation reviews the PhoenixD application in Bonn-Siegburg. The team presents its ideas and visions for developing novel optics.

05/07/2018

Production Engineering and Physics at Leibniz University Hannover acquires the highest third-party funding from 2014 to 2016, according to the DFG Funding Atlas 2018. Across Germany, Leibniz University Hannover comes second regarding the highest DFG grants awarded in the scientific disciplines of Mechanical Engineering and Production Engineering, with grants totalling €37.3 million. In Physics, LUH comes ninth at €19.1 million, regarding DFG grants across Germany. The research field of Optics, Quantum Optics and Physics of Atoms, Molecules and Plasmas acquired the largest share of this sum with a total of €15.3 million, resulting in an excellent first place in the ranking for the physics domain.

27/09/2018

The DFG German Research Foundation grants Leibniz University Hannover funding for PhoenixD and QuantumFrontiers (Light and Matter at the Quantum Frontier: Foundations of and Applications in Metrology) as Clusters of Excellence. In addition, the existing Cluster of Excellence Hearing4all, led by Oldenburg University in close cooperation with LUH and Hannover Medical School (MHH), is also supported. At the MHH, the Cluster of Excellence RESIST (Resolving Infection Susceptibility) is approved for funding. The DFG has accepted four out of five clusters in Hannover in its programme Clusters of Excellence.

01/01/2019

The seven-year funding period for the new Cluster of Excellence begins officially.

16/01/2019

PhoenixD members meet for a kick-off workshop at Leibnizhaus in Hannover

04/04/2019
The PhoenixD office moves from the HOT Hannover Center of Optical Technologies at Nienburger Straße 17 into the main building at Welfengarten 1.

13/05/2019
The PhoenixD Research School holds a kick-off meeting with talks by Uwe Morgner and Peter Behrens, and an open discussion.

04/07/2019
PhoenixD offers hot waffles, cold drinks and sweet candyfloss at the LUH "Sommerfest" (Summer Party) for LUH's students, employees and their family members.

08/08/2019
Stefan Muhle (left), State Secretary of Lower Saxony's Ministry of Economic Affairs, Employment, Transport and Digitalisation, presents the "Digital Venue Niedersachsen" award to the Laser Zentrum Hannover e.V. (LZH). Dr. Dietmar Kracht, Executive Director of LZH, accepted the badge of honour on behalf of the organisation.

26/08/2019
Uwe Morgner talks about "Digitalisation in Optics Research – The PhoenixD Cluster of Excellence" at the SommerUNI at LUH to the general public.

27/09/2019
PhoenixD appoints its International Advisory Committee (IAC), comprising seven scientists and representatives of industry.

Kilwon Cho (South Korea) is also a member of PhoenixD's advisory team.

The PhoenixD International Advisory Committee is complete (from left): Guido Voit (Germany), Liberato Manna (Italy), Luc Bergé (France), Michelle Sander (USA), Volker Pape (Germany) and Lutz Rissing (Germany).

25–26/09/2019
More than 180 scientists discuss how optical technologies could shape the future at the International Symposium "Future Optics", which marks the official launch of PhoenixD. In his welcoming speech, Björn Thümler, Lower Saxony's Minister for Science and Culture, stresses the importance of optical technologies for Leibniz University Hannover. Volker Epping, President of Leibniz University Hannover, outlines LUH's long-term vision of creating a new Faculty of Optics.

Uwe Morgner (right), spokesperson of PhoenixD, welcomes the Minister for Science and Culture of Lower Saxony, Björn Thümler (second from right) and LUH-President Volker Epping (left), to the conference. Karl Joachim Ebeling (second from left) from the University of Ulm held the keynote lecture.

The PhoenixD Chronicle

29/10/2019

The German "Manager Magazin" honours two PhoenixD scientists: Xiaoying Zhuang receives the "Curious Minds Award" for scientists under 40. In addition, the magazine appoints Karsten Danzmann to its "Hall of Fame of German Research".

6–8/11/2019

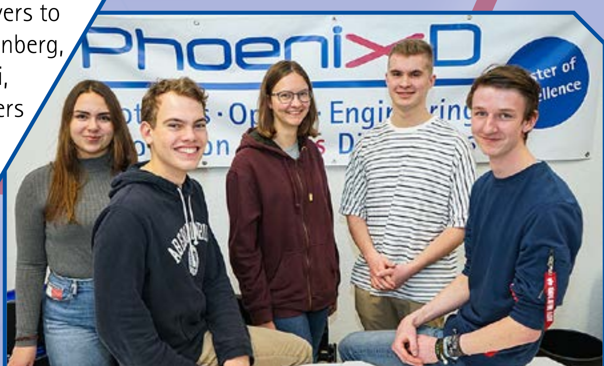
The Cluster holds its first retreat, an annual scientific plenary meeting and its first Summer School for the PhD students of the PhoenixD Research School at Hotel Schnuck, Schneverdingen.

13/11/2019

Uwe Morgner holds the lecture "It's laser time" at Herrenhausen Late, an event organized by The Volkswagen Foundation to promote scientific communication towards the general public.

28/11/2019

PhoenixD is committed to attracting more young people to the STEM subjects, i.e. science, technology, engineering and mathematics. For this reason, the Cluster plays an active role in the programme "Freiwilliges Jahr in der Wissenschaft" (FWJ – Voluntary Year in Science) and supports five young school leavers to experience university life. Helena Isenberg, Jasper Hüchting, Friederike Mai, Darian Rozok, and Jasper Lammers (from left to right) are the "FWJ'ler" of PhoenixD.



14/04/2020

In order to consolidate its expertise in optics, LUH establishes the Leibniz School of Optics & Photonics (LSO). The LSO is closely linked to the PhoenixD Cluster of Excellence and has the same structure as a faculty.

LSO
Leibniz School of Optics & Photonics

01/05/2020

The Working Group of German University Professors of Chemistry in the German Chemical Society (GDCh) grants the ADUC award for excellent young scientists to Jannika Lauth for establishing her own field of research on 2D semiconductors.

15/05/2020

Physik Journal 19 (2020) No. 6 reports on PhoenixD in its title story. The Physik Journal is the members' journal of the German Physical Society (DPG). With a circulation of around 55,000 copies, 11 monthly issues and two special issues, the Physik Journal is the most important physics journal in the German-speaking world.

03/09/2020

Michael Kues receives a European Research Council Starting Grant for his research project on developing photonic quantum coprocessors. Kues will receive almost €1.5 million in funding over the next five years.

09-10/09/2020

The Cluster holds its second retreat online due to the Corona pandemic.

15/09/2020
PhoenixD submits its outline proposal to obtain a new research building, the OPTICUM: Optics University Center and Campus at Hannover-Marienwerder.

30/10/2020
Uwe Morgner defends the draft proposal for the OPTICUM - Optics University Center and Campus in an online call with a working group of the German Council of Science and Humanities (Wissenschaftsrat).

01/01/2021
Ludger Overmeyer is appointed president of the WLT – Scientific Society Laser Technology (Wissenschaftliche Gesellschaft Laser-technik e.V.).

15/01/2021
PhoenixD submits its full proposal for the new research building OPTICUM.

20/01/2021
The Lower Saxony Ministry for Science and Culture (MWK – Niedersächsische Ministerium für Wissenschaft und Kultur) forwards the full proposal for the OPTICUM to the German Science Council (Wissenschaftsrat) and the Federal Ministry of Education and Research (BMBF – Bundesministerium für Bildung und Forschung).

05/02/2021
The WGP, the Scientific Society for Production Engineering, grants Marc-André Dittrich the Golden Otto Kienzle Commemoration Medal. Dittrich receives the award of the association of leading professors in production engineering for his work on self-optimizing manufacturing systems.

03/03/2021
Uwe Morgner successfully defends the proposal for the OPTICUM a second time in an online call with the German Council of Science and Humanities (Wissenschaftsrat).

23/04/2021
The German Council of Science and Humanities (Wissenschaftsrat) recommends an investment of €54.2 million to build the research building OPTICUM – Optics University Center and Campus. LUH shares first place on the funding list with the universities in Marburg and Münster.

02/07/2021
The Joint Science Conference (GWK) officially confirms the funding recommendation of the Science Council of 23rd April 2021. As a result, the construction of the research building OPTICUM – Optics University Center and Campus will be funded half by the federal government and half by the state of Lower Saxony.

07-10/09/2021
The third PhoenixD retreat, the cluster's annual scientific meeting, takes place in Schneverdingen with plenty of scientific exchange and talks. The members of the PhoenixD Research School meet for the third Summer School and train how to apply for jobs in industry.

01/11/2021

Members of the Hannover Lions Club visit the Cluster of Excellence. The club's president Volker Pape (second from right), is a member of PhoenixD's International Advisory Committee. After a lecture by Uwe Morgner, researchers give the guests a tour of the laser laboratories.

24/11/2021

The Goslar-based Stöbich Group awards PhoenixD member Bernhard Roth and his team the Kaiser Friedrich Research Prize 2020 for Photonic Technologies for Environmental and Climate Protection. This €15,000 prize is awarded every two years to German scientists from research or industry on a particular focus topic in optical technologies.

21/03/2022

The Cluster of Excellence voting members elect the new Board. On 1 April, Nadja Bigall takes over the leadership of the PhoenixD Research School from Peter Behrens, and Michael Kues succeeds Annika Raatz. Uwe Morgner (speaker), Ludger Overmeyer and Wolfgang Kowalsky continue to be board members.

19/04/2022

The Leibniz School of Optics & Photonics (LSO) is granted permission to award the doctoral degree title doctor rerum naturalium (Dr. rer. nat.), in translation doctor of natural sciences, and equivalent to the PhD granted in English-speaking countries.

27-30/04/2022

The Quantum Alliance, a collaboration of seven quantum research clusters, among them PhoenixD, has a joint stand at the new fair „World of Quantum" in Munich. Parallel to this, the established fair „Laser World of Photonics" takes place at Messe München. The PhD students of the Quantum Alliance's clusters and the International Max Planck Research School for Quantum Science and Technology (IMPRS-QST) join forces and organise their own conference after the Corona lockdown during the fair. PhoenixD members Mariia Matiushechkina, Anna Karoline Rüsseler, and Stephanie Willms present their research at this two-day event.

28/04/2022

The state of Lower Saxony supports the universities in Lower Saxony with €24 million in their preparations for the next round of the Excellence Strategy, which will begin in 2026. Besides PhoenixD, five other Clusters of Excellence at universities in Lower Saxony receive funding in the current round of the Excellence Strategy. Consequently, more than €320 million will flow into top-level research in Lower Saxony during the current funding period until 2026, three-quarters of which will come from federal funds and one quarter from state funds.

12-14/06/2022

The new conference event "Humboldt meets Leibniz – Emerging Topics in Optics and Photonics" brings 150 international PhD and Post-doc students together with 13 Alexander von Humboldt award winners in Hannover. The aim is for participants to expand their scientific networks, present their research, and discuss relevant personal career development questions. Selected members of PhoenixD participate in the conference. The Cluster also presents its research activities on stage. LUH organizes the event in cooperation with the Volkswagen Foundation, and is supported by the Humboldt Foundation. PhoenixD is the partner of the event.

15/06/2022

The two scientific workshops, "PhoenixD Laser Day 2022" and "Hannover Materials Chemistry Symposium", take place at LUH and attract more than 210 participants. Among the lecturers are three of the Humboldt award winners, who attended the event "Humboldt meets Leibniz", researchers from internationally acclaimed institutions like Fraunhofer Institute for Laser Technology (ILT), DESY, and the company trinamiX, a subsidiary wholly owned by BASF. The talks cover topics from "Perovskite nanocrystals in light-emitting devices" to "Laser point grid projectors in smartphones: enabling a new approach for secure biometric face authentication".

02-10/07/2022

PhoenixD presents the new Bachelor's degree in Optical Technologies: Laser and Photonics at Leibniz University's stand at the fair IdeenExpo in Hannover. Uwe Morgner, Bernhard Roth and Anatoly Kukk (right, scanning the arm of the moderator) show on stage how optical skin scanners work. The IdeenExpo is Europe's largest youth event for technology and science, attracting more than 425,000 visitors from Germany and Europe in 2022.

12-16/09/2022

Members of the PhoenixD Research School meet for their fourth Summer School in Schneverdingen (picture). Afterwards, the fourth PhoenixD retreat, the cluster's annual scientific meeting, takes place there, with more than 130 participants.

28/08-02/09/2022

The 10th EPS-QEOD Europhoton Conference on Solid-state, Fibre and Waveguide Coherent Light Sources is held at Herrenhausen Palace in Hannover and attracts more than 150 international researchers. PhoenixD is the official partner of the European Physical Society (EPS) and Quantum Electronics and Optics Division (QEOD) of the EPS for the organization of this international conference in collaboration with the Volkswagen Foundation. The General Chair of the event is PhoenixD spokesperson Uwe Morgner. In addition, Michael Kues (picture) lectures at the two-day Summer School for PhD students at the conference. Hannover's mayor Belit Onay welcomes all participants at the City Hall.

02/08/2022

The Leibniz School of Optics & Photonics (LSO) is also granted permission to award the doctoral degree Dr. Ing., besides the doctoral degree Dr. rer. nat. Both degrees are equivalent to the PhD awarded in English-speaking countries.

28/09/2022

Thirty-two members of the two departments - Micro Technologies and Productronics - of the EMINT (Electronics, Micro and New Energy Production Technologies) trade association in the VDMA meet at PhoenixD. With 3,600 members, the VDMA is the largest network organization and a voice for Germany and Europe's machinery and equipment manufacturing industry. The association represents this unique and diverse industry's common economic, technical and scientific interests. The conference participants discuss the issues of "Mechanical engineering and global crises - what's next?" and what applications power semiconductors and quantum technologies make possible. Uwe Morgner, Ludger Overmeyer, Bernhard Roth, and Volker Pape (pictured) join the conference. The latter is a member of the International Advisory Committee of the Cluster of Excellence.

07/12/2022

The European Research Council (ERC) awards PhoenixD member Boris Chichkov an ERC Advanced Grant of €2.5 million for five years. He works on reproducing the complexity and structure of functional circulatory systems (arteries and veins, as well as micrometre-sized arterioles, venules and capillaries). New procedures for high-resolution, multi-level biological constructs are required to achieve this goal. Chichkov researches new approaches involving laser-based bioprinters and two-photon polymerisation. This unique combination of methods is expected to enable the production of complex vascular networks for the first time.

26/01/2023

The Faculty of Mathematics and Physics and the Leibniz School of Optics & Photonics invites applications for a University Professorship in Optics & Photonics. The successful candidate is to start as soon as possible.

13/02/2023

Gudrun Wanner receives the Beate Naroska Junior Guest Professorship 2022 for her outstanding research in Gravitational Physics and her active involvement in creating equal opportunities for women in physics. With the Beate Naroska Guest Professorships, the Cluster of Excellence Quantum Universe at the University of Hamburg honours international female scientists' scientific excellence and commitment to gender equality. Wanner is a member of the two LUH Clusters of Excellence QuantumFrontiers and PhoenixD.

02–03/03/2023

The International Advisory Committee meets for two days in Hannover. At the event, with around 130 participants, numerous researchers present the current state of their research. New members of the committee are Roberto Osellame (CNR - National Research Council, Milan; second from left), Anna Lena Schall-Giesecke (University of Duisburg-Essen; third from left), and Dr. Kai Exner (BASF; second from right), who succeeds Guido Voit (BASF).

03/03/2023

Leibniz University Hannover awards a prize to Dag Heinemann for his outstanding teaching. The PhoenixD member receives the €2,000 prize in the category "motivation and inspiration". A total of six university members nominated by university members and chosen by a selection committee receive an award for teaching.

5–10/03/2023

More than 12,000 physicists present their research at the American Physical Society's (APS) March Meeting in Las Vegas and online. PhoenixD also presents itself on-site at the German joint „Research in Germany" stand as part of the Quantum Alliance. Seven research associations belong to the Quantum Alliance, with around 1700 members.

30/03/2023

Liberato Manna, member of PhoenixD's International Advisory Committee and Associate Director for Materials and Nanotechnologies Area at IIT – Istituto Italiano di Tecnologia (Geneva), receives an ERC Advanced Grant 2022 of €2.5 million for his project „Nanoscale Epitaxial Heterostructures Involving Metal Halides". Possible applications for these epitaxial interfaces in nanocrystals are, for example, photocatalysis, photodetectors, solar cells, and solar concentrators.

17-20/06/2023

The 7th European Physics Olympiad takes place at Leibniz University in Hannover. At the scientific competition, over 170 outstanding pupils from 37 countries solve theoretical and experimental problems and compete for gold, silver and bronze medals. PhoenixD is one of the supporters of the Physics Olympiad and guides young STEM scientists through its laboratories. Spokesperson Uwe Morgner introduced the research field of optical technologies to the group of international participants in the atrium of the main building.

22/06/2023

The PhoenixD cooperation partner Laser Zentrum Hannover e.V. (LZH) hosts the „Light for Innovation Conference: LZH Panel and Lectures" and the „Women in Innovation" lecture during the three-day „Innovercity Festival" at the pop-up event centre Aufhof in the former Galeria Kaufhof department store in Hannover's city centre. Uwe Morgner, Michael Kues, Michèle Heurs, Dietmar Kracht and Katharina Rettschlag speak on stage. Afterwards, they inform Lower Saxony's Minister of Science, Falko Mohrs (third from right), about the LZH research on applications of optical technologies in agriculture.

29/06/2023

Mariia Matiushechkina wins an award for her poster on the „Realization of silicon metasurface mirror on sapphire for telecom wavelength" at the 11th International Conference on Materials for Advanced Technologies (ICMAT2023) in Singapore.

25/07/2023

PhoenixD members have already published their research on the focal areas of the cluster in more than 560 publications. Learn more: http://go.lu-h.de/PhoenixD-Publications

04-08/09/2023

Members of the PhoenixD Research School plan to meet for the fifth Summer School in Schneverdingen. The fifth PhoenixD retreat, the cluster's annual scientific meeting, is to take place in Schneverdingen.

04/11/2023

From 6 pm to midnight, PhoenixD will open the doors to its experimental halls in the House of Optics. In addition to lectures on light and optics, the team will provide information about its research, applications for optical technologies and the planned new building, the OPTICUM, during the university-wide event „A Night out with Science: Hands-On Research!" ("Die Nacht, die Wissen schafft"). Will we see you at Welfengarten 1A?

22/04/2024

All Clusters of Excellence must submit their proposals for another funding period by this date. The review of proposals is scheduled from approximately early October 2024 to mid-February 2025.

22/05/2025

The Excellence Commission will reveal its decision on funding Clusters of Excellence based on the recommendations made by the Committee of Experts. This consists of 39 members with proven research track records representing the entire range of academic disciplines. The Excellence Commission comprises the government ministers responsible for research at the federal and state levels and the Committee of Experts. The Chair of the German Council of Science and Humanities and the President of the DFG German Research Foundation are non-voting committee members and preside over it.

You have yet to reach the end of the PhoenixD chronicle. There will be many more events until the end of the funding period at the end of 2025. The PhoenixD team is already preparing their application for follow-up funding.

Acknowledgements

The Cluster of Excellence PhoenixD (EXC 2122, Project ID 390833453) is funded by the

Deutsche Forschungsgemeinschaft
German Research Foundation

Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy.

Digital Object Identifier

Find the The PhoenixD Magazine – News from the German Cluster of Excellence on Optics and Photonics online easily with its Digital Object Identifier (DOI):

http://dx.doi.org/10.15488/14123

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Published by
Cluster of Excellence PhoenixD
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Welfengarten 1A
30167 Hannover

Published: 11/2023

Typography:
Simone Scheurer
www.scheurer-medien.de

English Proofreading:
Nancy Hulek

Printing Company:
printworld.com GmbH
Messering 5
01067 Dresden
Germany

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