PhoenixD
Photonics · Optics · Engineering
Innovation Across Disciplines

Leibniz
Universität
Hannover

PhoenixD Magazine

News from the German Cluster of Excellence on Optics and Photonics

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).

Our objectives for advancing optical technologies are to:

- Develop a toolbox for novel types of optics and implement examples of these, using innovative materials and new concepts.
- Establish a multi-scale, multi-modal simulation platform.
- Develop a manufacturing grid with an optimized manufacturing loop.
- Demonstrate a high-precision in-line measurement technology and connect it to the simulation platform and the manufacturing grid.
- Enable more than 150 PhoenixD scientists to work together under one roof. In 2022, several research groups will move into two dedicated buildings at the Welfengarten Campus in order to synergetically work closely together. Our new optics building, the OPTICUM (Optics University Center and Campus) is planned to be finished in 2026.
- Establish spin-off companies from the PhoenixD network.
- Establish the Leibniz School of Optics & Photonics as a new cross faculty for Optics & Photonics.
- Set up a new undergraduate optics degree programme – The new bachelor's programme "Optical technologies: Laser & Photonics" is to start in October 2022.
- Appoint ten tenured professorships in optics – five new colleagues have already joined the team.

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

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

Dear Reader

At the latest when the transistor was invented 75 years ago, we learned to control electrons. This led to the birth of microelectronics, and the world had changed forever.

Controlling electrons is comparatively easy, because the particles are charged and slow. Today, we photonics scientists face the incomparably greater challenge of trying to control uncharged particles travelling at the speed of light. This is increasingly successful, and it is worthwhile. The major advantage of these particles is that they are only slightly influenced by matter. This enables worldwide data transmission with light pulses over several-thousand-kilometre-long glass fibres, and the screening of people or large batteries using modern X-ray diagnostics.

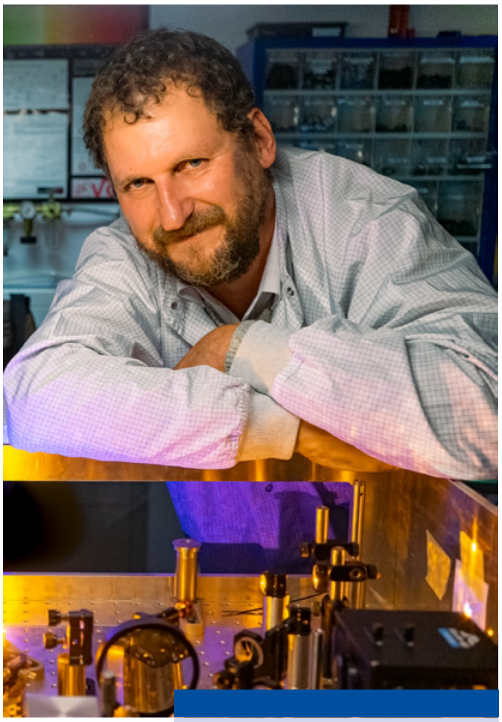
PhoenixD has dedicated itself to this control of light, ranging from the generation and detection of single photons to the development of ultra-powerful laser technology, from the infrared spectral range to hard X-rays. But, as a result, we are leaving behind the centuries-old technology of polished glass lenses and focus on new digital, flexible, customised optics.

This requires a concerted and interdisciplinary approach, which is precisely what PhoenixD and the future optics campus with the new OPTICUM and the Laser Zentrum Hannover stand for. Based on the work of us all, a unique centre of excellence with global impact is created here.

Our essential driving force and our unique selling point lie in the synergies - between the simulation activities and the machinery, between Hannover and Braunschweig and most importantly, between the scientists from the different disciplines and faculties.

After the three and a half years that our cluster has been running, this booklet presents an overview and takes stock of our research landscape, and not only for experts. We aim to motivate school students to find out about the new Bachelor's degree programme "Optical Technologies: Lasers & Photonics" as an option for their undergraduate studies. Students will be able to discover in which areas interesting and ground-breaking final theses are possible. Scientists and representatives of the industry are cordially invited to identify points of contact for cooperation projects.

With this in mind, I hope you enjoy reading and gain new insights at the same time.



Uwe Morgner

Spokesperson PhoenixD

Uwe Morgner

Uwe Morgner

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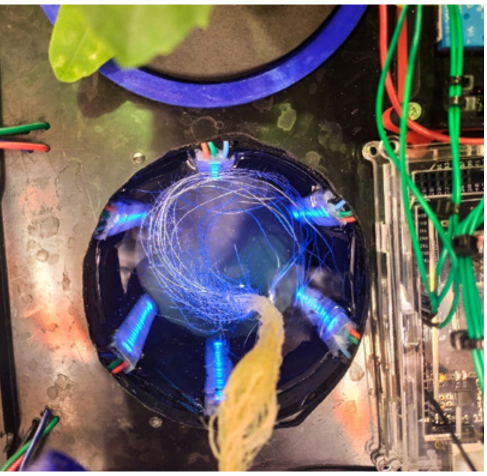

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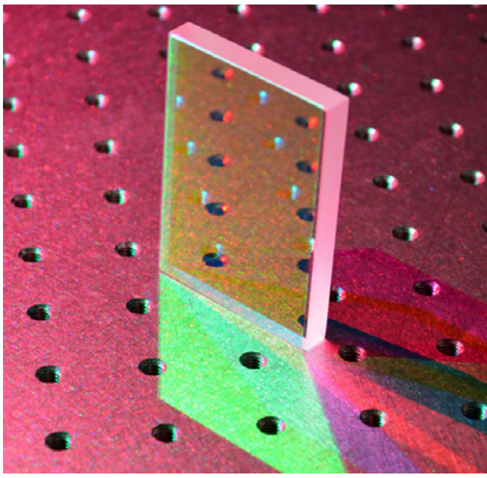

The PhoenixD Chronicle

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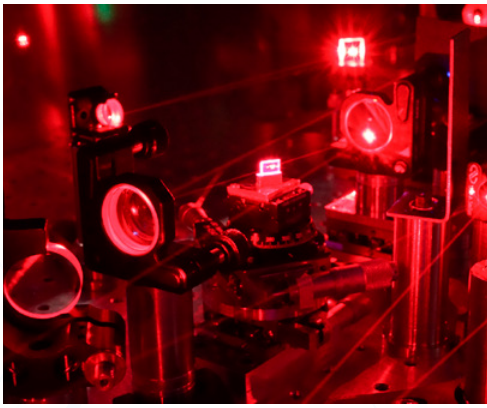


PhoenixD supports Leibniz Lab

In 2019, PhoenixD financed a second Volkswagen van to support the work of Leibniz University's so-called Leibniz Lab. The vans carry a wide range of experiments from natural sciences, mathematics, engineering and technology, among them also optical experiments with light, lenses and mirrors. Teachers can book the Leibniz Lab to visit their school in the Hannover region and have university students to work with their classes. The service is free of charge for the schools – and very popular. From 2011 to 2018, the team visited more than 660 schools. In addition, more than 16,000 schoolchildren from grades 4 to 13 carried out the experiments. To meet the increasing demand by the schools, the organising body UniKIK needed a second van. So PhoenixD supported UniKIK with a Volkswagen Crafter and a new exterior design depicting laser beams and lab quipment.

Promoting STEM Subjects to Schoolchildren

PhoenixD aims to increase the proportion of female scientists within its cluster. Now, their share makes up 14 %: 21 % of PhD students, 10 % of post-docs, and 13 % of professors are women. To encourage women to study a STEM subject – i.e. from the fields of science, technology, engineering and mathematics – PhoenixD is committed to a variety of activities. On 28th April 2022, the cluster welcomed 15 girls between the age of 10 to 16 to the national action day "Girls' Day" (Zukunftstag, or Future Day). The cluster also organized a Q&A session focusing on women in science on 17th May 2022. Female students in particular were encouraged to ask questions concerning their further study plans. The cluster will also be present on Leibniz University's booth at the fair IdeenExpo in Hannover from 2nd to10th July 2022. Here, school students can find out about the university's new bachelor programme, "Optical Technologies: Laser and Photonics", the Voluntary Year in Science (FWJ), and PhoenixD's project workshop for schoolchildren, Protoys. Together with Bernhard Roth and Anatoly Fedorov Kukk, PhoenixD spokesperson Uwe Morgner will give a talk on applications in medicine using optical technologies. They will also present a skin scanner on stage, capable of detecting malignant melanomas (black skin cancer). Supported by companies, research institutions, universities and schools, IdeenExpo is Europe's largest youth fair for technology and science. In 2019, the event offered 670 exhibits to touch and try out, which attracted more than 395,000 visitors from Germany and other European countries in 2019.

Kaiser Friedrich Research Prize 2020 for Bernhard Roth and Ann-Kathrin Kniggendorf

PhoenixD member Bernhard Roth and his colleague Ann-Kathrin Kniggendorf have received the award for their research on detecting microplastics in water using optical technologies. The prize, endowed with €15,000, is awarded every two years by the Goslar-based Stöbich Group. The company rewards German scientists from research or industry for pioneering new environmental and climate protection developments using optical technologies. The submitted work should also demonstrate the possibility of practical, industrial implementation. "Our team's newly developed method makes it possible to monitor microplastics in the drinking water stream in real-time and without filters or sampling," says Roth. According to the physicist, this is a real innovation in the field, as such examinations need so far expensive analytical methods and a laboratory. Moreover, if the probes are not analysed under controlled laboratory conditions, subsequent contamination with microplastics from the air is unavoidable and can cause errors, especially in examining drinking water. On the contrary, Roth's award-winning system "Optimus" is mobile and uses laser light to analyse samples. Optimus allows water contamination to be accurately determined with a response time of milliseconds, enabling users to react quickly to contamination and, for example, stop the supply of drinking water for general supply or beverage production.

Lower Saxony's Secretary of State Stefan Muhle Visits PROTOYS

Oliver Burmeister (left) explained to politician Stefan Muhle (right) how PhoenixD's project workshop PROTOYS teaches schoolchildren digital competencies such as programming in the project "Make Your School". Muhle, Secretary of State in the Ministry of Economic Affairs, Labour, Transport and Digitalisation of Lower Saxony, visited Burmeister during the so-called "Hack Days" at Gymnasium Goetheschule in Hannover. Burmeister, a teacher, worked for three days with grade nine students to find ideas and design solutions to improve their everyday school life with technical and digital tools. One group, for example, developed digital key-boxes to unlock footballs from a closet for a quick match during school breaks. Burmeister holds the cardboard model of this idea in his hands. The initiative „Make Your School" supports two- or three-day-long "Hack Days" in schools all over Germany. It is a project by "Wissenschaft im Dialog" (Science in Dialogue).

Ludger Overmeyer is President of the WLT

The WLT – Wissenschaftliche Gesellschaft Lasertechnik e.V. (Scientific Society for Laser Technology) has appointed PhoenixD board member Ludger Overmeyer as their new president from the beginning of 2021.

Overmeyer is also a board member of Laser Zentrum Hannover e.V. (LZH) and chairs its Scientific Directorate. PhoenixD member Moritz Hinkelmann, who leads the group Optical Systems at LZH, supports Overmeyer in his new position and has taken over the management tasks of the WLT.

The WLT commits itself to identifying and actively promoting strategic goals to continue the scientific development of laser radiation as a universally valuable tool and make it usable for new interdisciplinary fields of application in optical technologies. The organisation is thus at the interface between laser-oriented research and development, industrial production and medical application. Founded in 1997, its members are heads of some 35 institutes at universities, the Fraunhofer-Gesellschaft, the Max Planck Society, the Leibniz Association, the Helmholtz Association and other non-university institutions.

State of Research in Optics and Photonics

LUH researcher Tobias Grabe holds the prototype of a partially additively manufactured Raman spectrometer in his hands.

Reinhard Caspary

In the last decades, digitalization has led to profound changes in the field of optical technologies. Computer simulations and computer-aided design facilitate and accelerate the development of precision optical systems. A typical example are lenses for imaging with minimal geometric distortions or chromatic aberrations. Such classical optical systems are based on the skillful and precise combination of spherical surfaces, which are relatively easy to manufacture to high precision and require relatively little computational effort in optics simulation.

Increasing computing power has led to the establishment of aspherical optics in recent years. The production of lenses and mirrors with a cross-sectional profiles that deviates from the classic circular shape is many times more complex. Instead of two-dimensional polishing processes, high-precision computer-aided turning processes are used. Design and simulation of aspherical optics also requires much higher computing power. However, the advantages of aspherical optics far outweigh the increased effort in design and manufacturing, especially in mass production. Aberration-free optics can be realized with only a few lenses and can be extremely miniaturized. Today's smartphones contain several high-quality camera modules whose extremely flat design would be impossible without aspherical lenses.

The final stage of the development outlined above is currently freeform optics, in which the rotational symmetry of the aspherical surfaces is also released. This step is based on further increasing computing power as well. From spherical over aspherical to free-form surfaces, the geometric degrees of freedom grow from zero over one to two dimensions, which increases the complexity in each case. Today, optical free-form surfaces are produced directly with ultra-precision diamond milling machines and no longer need to be polished. This development is of particular interest for mirror optics with a folded beam axis, such as spectrometers or illumination systems. A folded optical axis leads to significant distortions in the case of rotationally symmetrical surfaces, which can be completely avoided with free-form surfaces.

Optical waveguides represent another important branch of optics. In the form of the worldwide fiber optic network that constitutes the physical internet, optical waveguides are of fundamental importance for modern everyday life. Today, data transmission is carried out almost exclusively by optical fibers, except for the last few meters to the end device. Network technology such as switching matrices or optical transmitting and receiving systems are also increasingly based on optical waveguides in the form of planar integrated optics. In addition to classic lithography, optical waveguides are increasingly being printed, but injection molding and other forming techniques are also being used.

Currently, silicon photonics is revolutionizing integrated optics. By using the classic CMOS technologies from the production of electronic microchips, the development and the production of complex optical components can be separated. In retrospect, this separation was a decisive factor for the breakthrough of microelectronics, and a similar development is now emerging for integrated optics.

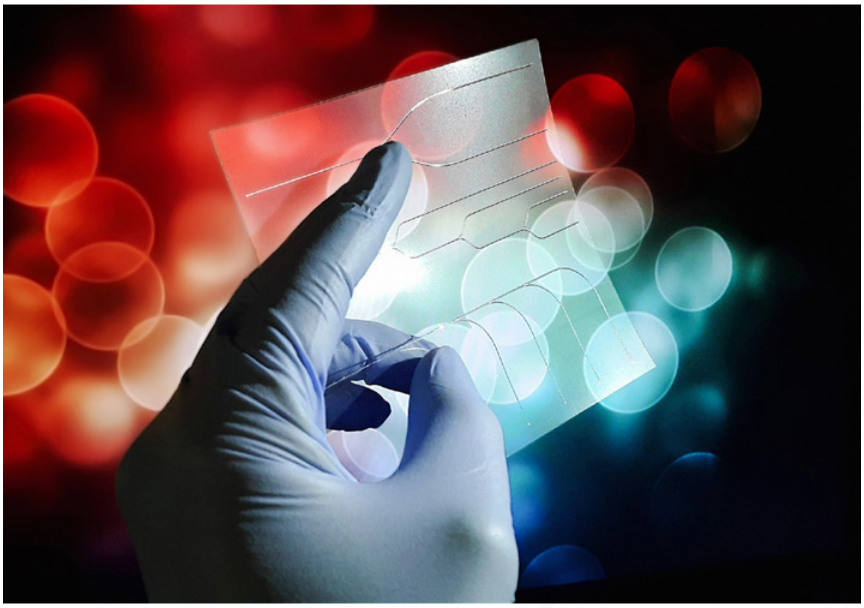
In addition to the abovementioned beam and waveguide optics, the field of diffractive optics is becoming increasingly important. While optical line gratings were the most important diffractive optical elements for a long time, nowadays surfaces can be structured almost arbitrarily with resolutions in the order of light wavelengths. In the simplest case, such surfaces allow almost lossless conversion of a laser beam into arbitrary patterns and shapes. Photorealistic three-dimensional holograms are based on the same principles and can be digitally calculated and fabricated today. The simulation of diffractive optics is based on the calculation of electromagnetic fields and their interactions instead of classical beams. Beyond simple line gratings, the computational effort is immense due to the high spatial resolution required. Especially when temporal developments are taken into account, even today's computer technology reaches its limits.

The production technologies for classical free-beam optics and diffractive optics differ considerably in principle. While smooth surfaces with a roughness below the wavelength must be achieved in the one case, defined geometric structures with resolutions below the wavelength are required in the other. Traditionally, lithographic instead of grinding and polishing processes are used in the latter case. However, the differences between the two worlds are becoming increasingly diffuse. Diffractive surfaces can also be produced with ultra-precision diamond milling, and additive manufacturing processes today achieve resolutions of 150 nm and below with two-photon polymerization technology. This makes the process suitable for both the manufacture of diffractive optics and the production of high-quality free-form surfaces. The general trend in production technology away from subtractive and towards additive processes is still in its infancy in the field of optics production, but major efforts are being made worldwide to make optics printable to a high degree in the future. Today, researchers have already printed a complete micro spectrometer onto the end of the optical fibre of a medical endoscope using two-photon polymerisation.

The future: Printed volume optics

As already explained, the boundaries between classical ray optics and diffractive wave optics are becoming increasingly diffuse in modern optics. However, both are still based almost exclusively on surfaces or at least structures close to the surface. The next big step, which is already beginning to be imminent with the successes of additive manufacturing, is the merging of waveguide and free-beam optics into integrated volume optics, where optical functionality will be defined by modifications of the refractive index at sub-wavelength resolution in volume material. Simulation and fabrication still significantly exceed the capabilities available today, but the Cluster of Excellence PhoenixD aims to identify ways in which the printing of complex optical systems in volume can be realized in the long term.

Printed polymer optic waveguides on foil substrate.

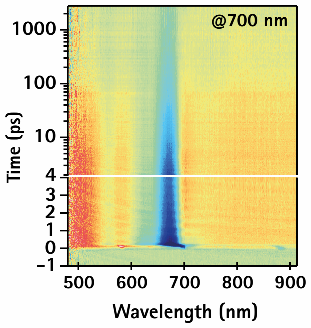


Spotlights on PhoenixD

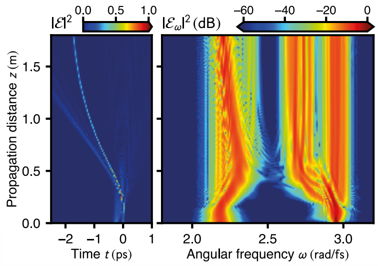
Modern optical technologies have little in common with the traditional grinding and polishing of lenses and glasses. Nowadays, optics and photonics are core technologies with interfaces to almost all areas of engineering and science. Light is a tool as well as a material in many ways, and this light is generated, manipulated, transmitted and detected by optical systems. 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 micro-electronics or 3D printing technology to optical production. Today, optical technologies are inconceivable without digital technology. Mathematicians and computer scientists are therefore in demand for the development of new algorithms for the optimization of optical systems. On this page, we present a small part of the bright spectrum of research topics in PhoenixD.

Jannika Lauth
physical chemistry

I am working on smart materials for photonics, and as a physical chemist I span both disciplines. This is important for tailoring material properties that help us control and direct light, for example in lasing applications. In the future, a straightforward processing of our wet-chemical materials will enable their larger-scale integration in photonics.

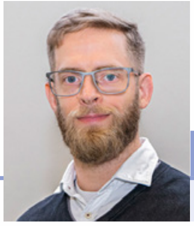


Hyperspectrum with short-time spectroscopic measurement (transient absorption) of photoresponsive 2D semiconductors.

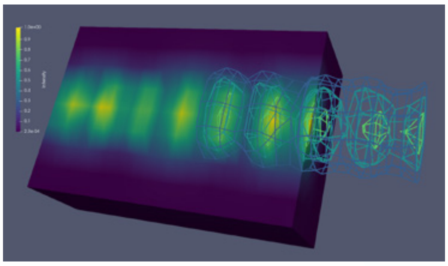


Numerical simulation demonstrating the interaction between a fundamental soliton and a dispersive wave in a NL-PM-750 photonic crystal fiber. Shown are the pulse intensity (left panel) and the spectrum (right panel).

As a theoretical physicist I develop software to simulate and analyze the dynamics of ultrashort light pulses in nonlinear media. This research will enable PhoenixD to devise novel methods for controlling light-light interaction on chip-size scales.



Oliver Melchert
optics simulation



Three dimensional wave guide simulation using the time-harmonic Maxwell equations.

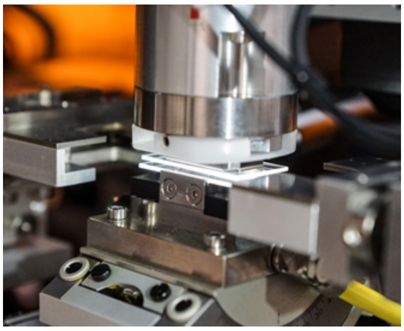
I work on modelling, numerics, and optimisation for modern optics simulations. Rigorous mathematics improves simulations by making them more efficient. In PhoenixD, I love the challenging applications, for which my group and collaborations at our institute design and and analyse new numerical methods.

Thomas Wick
optimisation

Dag Heinemann
phytophotonics

I work at the interface of optical technologies and plant sciences. My research focuses on how the instruments developed in PhoenixD can be used to accurately measure plant conditions and thereby contribute to greater sustainability in the long term.

A tobacco plant leaf is investigated by combined Brillouin and Raman scattering. These modalities allow for contact-free investigation of the mechanical and chemical characteristics of the plant. This information can for example be used to unravel plant-pathogen interactions in detail in order to support the breeding of resistant plant traits.



Optical components are joined together in an automated assembly machine.

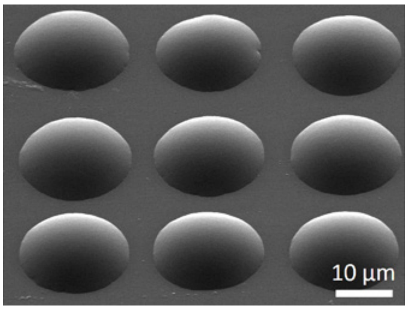
The individual components developed within PhoenixD are assembled into optical systems. To cater for systems requiring tolerances in future production we develop novel processes that predict the resulting quality by combining manu-facturing data and/or through the collection of data.

Annika Raatz
assembly

Alexander Wolf
product development

As a mechanical engineer, I develop novel optical systems that are to be used as precise measuring devices or support human vision in automotive lighting technology. For this purpose, I collaborate with scientists from various disciplines in PhoenixD.

Lighting test vehicle with prototype high-resolution headlamps that use technologies from video projectors.



A polymer optical microlens array produced by µDispenser 3D printing.

Additive manufacturing is an enabling technology for integrated photonics. In PhoenixD, I am working on novel 3D printing methods to fabricate high-quality micro-optics with tailored functionalities. Our vision is to develop on-chip photonic systems similar to their microelectronic counterparts.

Moritz Hinkelmann
3D printing

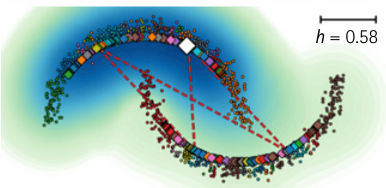
Bernhard Roth
optical metrology

As a physicist, I develop new concepts for integrated optics and photonics, e.g for detecting harmful microplastics or skin cancer. These developments require collaboration with researchers from different disciplines, which is the guiding principle of PhoenixD.

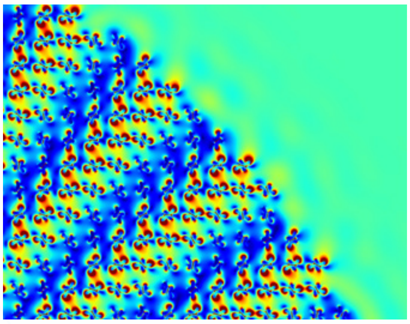
A measuring probe of the optical system to detect skin cancer. It is being further developed for clinical use.

Bodo Rosenhahn
artificial intelligence

I work as a machine learning expert on data analysis for industry 4.0. Methods from explainable AI allow me to understand correlations and relevant factors from data to optimise process parameters.



Constrained mean-shift clustering for unsupervised learning.



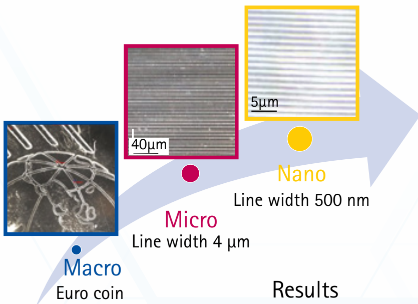
Simulation of a metasurface made out of gold nanostructures for non-linear beam structuring.

We work on miniaturized lenses and filters called metasurfaces. These are nanostructured surfaces that provide functionalities beyond natural materials. Our software automatically designs such devices and provides input for validation and fabrication in PhoenixD.

Antonio Calà Lesina
optical surfaces

Jens Twiefel
acousto-optics

Our objective at PhoenixD is to combine optics with acoustics or vibrations. We investigate the possibilities of integrating acousto-optical transducers into miniaturized optical components, and we also use ultrasound to improve the manufacturing processes for integrated optics.



Specimen formed by ultrasonic embossing.

Interview with the PhoenixD Executive Board:

"Our PhD Students are being Snatched out of our Hands"

The PhoenixD Executive Board (from left):
Uwe Morgner, Michael Kues, Ludger Overmeyer, Nadja-C. Bigall and Wolfgang Kowalsky.

The optics and photonics industry recorded a worldwide turnover of €654 billion in 2019, and the trend is rising. However, the possibilities of this key technology are far from exhausted. It is impossible to imagine our everyday digital life without optical technologies. We use them daily: as optical fibres that bring the internet to our offices, as laser scalpels that restore our vision. Now optics is about to take the next evolutionary step: its miniaturisation. This should make the technology so cost-effective that it will enable many more digital applications in the future – from autonomous driving to mobile medical diagnostics. More than 120 researchers of the Cluster of Excellence PhoenixD are also involved in this race for the next stage of development.

In this interview, the five board members talk about their structural and scientific goals, knowledge as a value and why quantum technology cannot do without photonics.

Sonja Smalian

Board members Michael Kues (left) and Uwe Morgner (right) discuss the goals of the cluster.

PhoenixD is one of 57 clusters of excellence at German universities. From 2019 to the end of 2025, you are receiving €52 million in funding through the Excellence Strategy of the federal and state governments. What are you doing with all the money?

Uwe Morgner: We are in the process of establishing optics as an independent discipline in Hannover. That is our overriding structural goal. To achieve this, we have established a broad scientific base.

Ludger Overmeyer: This includes bringing together the various disciplines - physics, mechanical engineering, mathematics, electrical engineering, chemistry and computer science - to shape the optics of the future.

What does that mean exactly?

Overmeyer: We want to take the step from so-called discrete optics, which mechanically arranges beam splitters and optical lenses, to integrated optics. And we don't just want to think about and develop this. We also want to be able to implement it in exemplary production technology.

> Integrated optics will become much cheaper

And this miniaturised optics is then as big as a …?

Overmeyer: …chip! The challenge is to think about the systems and change the design to apply the components to a glass chip, a polymer chip or a semiconductor chip. This makes it possible to map functionalities that we have so far only been able to implement on an optical table.

Morgner: Let's take a spectrometer, for example. These are usually large boxes. However, with an integrated optical solution partly produced by 3D printing, the light can be divided into spectral components. And something like that can now be realised in an integrated, tiny way.

And who benefits from this?

Overmeyer: The users, because such components will become much cheaper and thus much more widespread in future, enabling completely new applications. They are currently still unaffordable, because they can only be realised in a laboratory at considerable expense, and require a scientist to operate them. Making such systems cheap and producing them in large quantities in a highly integrated way is similar to the development in electronics, which has also been perfected more and more over the past 50 years.

Wolfgang Kowalsky: I think comparing optics with electronics is like comparing apples with oranges. Electronics is unimaginative. It primarily knows the CMOS process. This is getting smaller and smaller, and the number of transistors is getting larger and larger, but the functionalities remain as simple as ever. In optics, on the other hand, we have much more diversity. This means that, in optics, we will probably not establish the globally valid rules for CMOS design, the so-called PDKs, Process Design Kits, which we use as a standard in silicon electronics. We won't get this standardisation due to the diversity of components - and that's a good thing.

Morgner: The components will never be as small as the electronic modules. The wavelength gives us

Uwe Morgner

Physicist
Spokesperson
Executive Board Member

a lower limit, but you can build additional functionalities into such a chip. Chemistry provides a whole construction kit of different optical materials, functionalised with nanoparticles.

Nadja-C. Bigall: That's right. Materials chemistry can do a lot for optics, including illuminants, filters and functional coatings, etc., and other completely new optical components.

> Our graduates will develop the optics industry

What areas of application can you imagine for such integrated optics?

Morgner: This is a vast field. In Hannover, plant photonics is a current topic...

Overmeyer: ... in agriculture.

Morgner: Generally speaking, chemical sensor technology will benefit significantly.

Overmeyer: In medical technology, optics could pave the way from expensive large-scale apparatus to mobile, patient-oriented laboratory diagnostics, perhaps even with a smartphone adapter.

But PhoenixD itself will not produce such devices, will it?

Kowalsky: No, our "main products", if you want to call them that, are well-trained young people who will later develop the industry, rather than any devices. We produce knowledge. And knowledge in itself has a value that must not be underestimated.

Overmeyer: Exactly; a cluster is a community of scientists that offers a preview of the future. What is relevant for us is whether the ideas are exciting and can be implemented at some point. And whether they might then move us a real step forward, be it in two or in 20 years. We are not Intel, developing a specific product. We create the ideas for new products.

Isn't that a breach if the market readiness of the ideas is never tested?

Overmeyer: In no way. It's an entirely normal chain of events. First, we generate the ideas, then think about how to implement them in production technology and whether it is economically feasible. Then, finally, we do all the preliminary work in our cluster. Only then do the companies come into play.

Morgner: Unlike in a typical three-year research project, the extensive funding period of the Cluster of Excellence allows us to transfer our results to applied research after the fundamental research is completed. We are currently working with a laser company that is highly interested in our activities in X-ray beam generation. Here, our results flow directly into industry without any exploitation gap.

Bigall: This is our strength: through the interdisciplinary approach, and the cooperation of researchers who are further away with those closer to the application, results can be applied more quickly.

An interdisciplinary approach is a core element of PhoenixD. This is already clear from the name: xD stands for "across disciplines". Physicists, mechanical engineers, computer scientists, mathematicians, chemists and electrical engineers cooperate in the cluster. Nevertheless, one of your goals is to establish optics as an independent discipline. What should that look like?

Kowalsky: Optics should become a separate discipline, and not remain a special field of physics or mechanical engineering. The subject should be interdisciplinary, with powerful interaction with the existing faculties.

Overmeyer: It is also important for us to transfer this new optics discipline from the natural sciences to applied sciences.

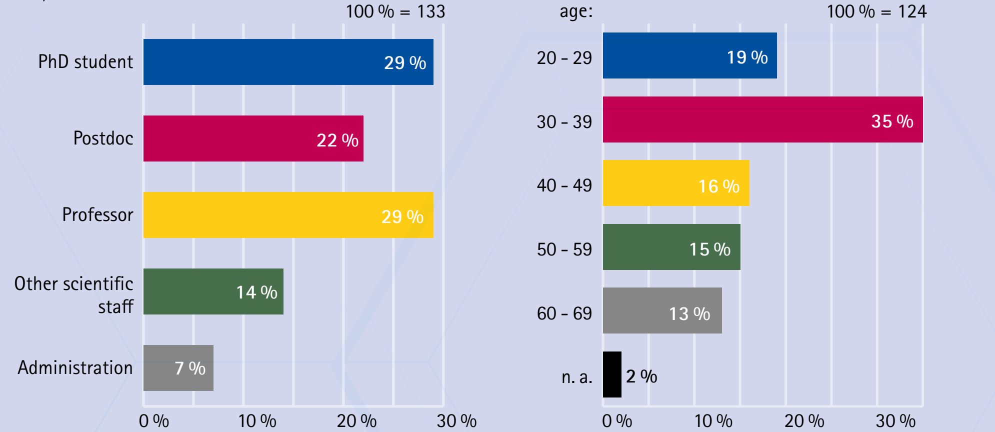
Ludger Overmeyer

Mechanical Engineer
Spokesperson
Executive Board Member

PhoenixD in numbers

More than half of PhoenixD's researchers are PhD students and postdocs – and younger than 40 years.

Survey date: November 2021



When the DFG German Research Foundation gave its funding approval for PhoenixD on 27th September 2018, the cluster members celebrated this success with an impromptu barbecue behind the main building on the Welfengarten campus. Front in picture (from left to right): The two PhoenixD board members Uwe Morgner and Ludger Overmeyer with the President of Leibniz University Hannover, Volker Epping.

The news magazine Der Spiegel recently reported that the Technical University of Munich wants to partially replace its traditional faculty structure with inter-disciplinary "schools". PhoenixD is following a similar path and has founded the Leibniz School of Optics & Photonics (LSO) with Leibniz Universität Hannover. What are the advantages of this structure?

Morgner: Optics has found its new organisational home in the LSO. With it, we can strengthen the cross-connections between the disciplines. The School is interdisciplinary, has powers similar to those of a faculty and can award doctorates.

Kowalsky: It is crucial to have the faculty structure in the background for teaching. However, the individual faculties can no longer deal with many subject areas for research. So you need facilities like an LSO that better reflect this interdisciplinary approach.

The discipline optics is also reflected in a new bachelor's degree programme, "Optical Technologies: Lasers and Photonics", which LUH will be offering for the first time in the winter semester of 2022/23. Which target groups will this serve?

Overmeyer: Up to now, companies have always had the difficulty of either looking for a physicist who can't do the engineering stuff or an engineer who doesn't know the basics of physics. With our approach to training "optical engineers", I believe that we can fill this very gap. I am convinced that there are enough companies that need these people.

Morgner: Company representatives have told me that they are looking for specialists who understand optics and can also master electronics, data processing, and mechanics. These are aggregated profiles that are not yet represented in the university. With the new degree programme, we are taking a step in the right direction. Incidentally, this is the first bachelor's degree of this sort at a German university.

If you then want to continue, you can add a two-year master's programme in "Optical Technologies", which can also be studied in English.

Bigall: Exactly. And with the PhoenixD Research School, we also offer a structured doctoral programme, and are currently supervising around 40 doctoral students from very different disciplines. From the very beginning, the doctoral seminar has been held monthly. Here, the doctoral students exchange information about their research topics and find out about current opportunities for further education. The seminar is also used to visit facilities, institutes and companies. These regular meetings are crucial to promoting interdisciplinary understanding and cooperation. As a representative of the field of chemistry, I can only confirm that it is desirable for doctoral students in chemistry to have a particular application in mind with optics.

Morgner: I am against further reductions in study time. A longer period of study ensures that the students are really prepared and deeply educated when they leave. So far, the market has proved us right. Our graduates are being snatched out of our hands by companies.

Kowalsky: Our doctoral students don't need to apply for jobs. They are all "sold" before they graduate. The demand is gigantic.

Nevertheless, only a few women are interested in studying optical technologies.

Morgner: Yes, that is a problem. That's why we use the "Leibniz Lab" experiment bus to try to get young schoolchildren interested in technology topics at school. PhoenixD also offers places for a "Voluntary Year in Science" (FWJ). Yes, an above-average number of female high school graduates have applied for this. They are always a little unsure about technical subjects and then use such a "gap year" to come to a decision. We need to encourage young people at school to choose technical subjects. And we need modern courses of study, like the new bachelor's programme, to attract high school graduates who are not convinced by the traditional subjects. The crucial question is: how many young people do we attract into the first semester?

Half of the funding period has almost passed. How many of your objectives have you already achieved?

Overmeyer: We have met all the structural goals we set ourselves with PhoenixD: the Opticum research building, the bachelor's programme in Optical Technologies: Laser & Photonics, the professors who have been appointed, and the junior professorships that have been filled.

Morgner: Yes, and that's before the funding period is even halfway through.

At the scientific level, PhoenixD cooperates with the Laser Zentrum Hannover e.V., the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) and the Technical University Braunschweig. What makes Hannover such a good location?

Morgner: In the cluster, we have brought together the expertise necessary for scientifically mapping the new optical systems in every respect, starting with the sources, through the conduction of light, sensor technology and detectors, all the way to integration. All of these questions require very different skills, and for each of these topics we have experts here on-site to realise this overall system. Decades of preparatory work were necessary to obtain this unique combination of expertise.

> We have a particular head start

Overmeyer: To give you an example: With the help of additive manufacturing, we can already print optical gratings, waveguide structures and lenses from polymers and glass materials.

Morgner: I believe only a few other places worldwide can establish this connection between basic research, engineering research, chemistry, and computer science. Many are currently embarking on a similar path, but we have a particular head start here. In Hannover, a common language, a basis of trust, has already developed through many years of cooperation. You can't just create something like this by gathering a few chemists, a few physicists and a few engineers together to make optics.

In Hannover, a research centre for optical technologies costing nearly €60 million is being built next to the Laser Zentrum: the Opticum – Optics University Center & Campus. The 120 or so optics researchers from PhoenixD are expected to move into the 4,000 square metre building in the Hannover-Marienwerder Science Park in 2026.

Morgner: Yes, our optics campus will be built, and there is plenty of space around it for further complexes.

Do you expect numerous spin-offs?

Morgner: Spin-offs also live off the fact that they can use the university's equipment at the beginning. This is already apparent but will pick up speed once we move into the Opticum.

Kowalsky: We can also be a contact point for industry. The Opticum is next to the Laser Zentrum Hannover. Suddenly, a concentrated mass of experts can handle complex inquiries because the equipment and the experts are at one location.

Wolfgang Kowalsky

Eletrical Engineer
Spokesperson
Executive Board Member

Nadja-C. Bigall

Physicochemist
Executive Board Member
Head of PhoenixD Research School

Michael Kues

Physicist
Executive Board Member
Diversity Coordinator

Why do the established and successful optical technologies have such a shadowy existence in public perception while the whole world is talking about quantum research?

Kowalsky: Hardly anyone knows anything about quanta, but they expect spectacular things.

Michael Kues: Quantum technologies are generating a lot of enthusiasm right now. But what outsiders find difficult to grasp: Integrated optics will be a major innovator for quantum technologies.

What role do optical technologies play, for example, in mechanical engineering? After all, China overtook Germany as the world export champion in this segment in 2020.

Overmeyer: Without optical technologies, mechanical engineering is no longer possible. The Chinese recognised this and overtook us because they invested precisely in the processes required to develop electronics and integrated optics.

> Germany is a leader in laser technology

And the price is now being paid?

Overmeyer: Unfortunately, yes. While we were manufacturing cars to perfection, the Chinese were building factories for semiconductor chips. For example, many wafers are now produced in China and no longer here in Europe. We can only support the structural change in German mechanical engineering with our well-trained engineers.

The US chip producer Intel has just announced that it will start building a chip factory with 10,000 jobs in Magdeburg in 2023.

Morgner: That's great for Northern Germany as a research location.

What would you like to see from politicians to secure Germany as a research location?

Morgner: Our cluster focuses on fundamental research. Our German Research Foundation is in an excellent position here, and this cluster funding is the envy of almost everyone internationally.

Overmeyer: We would like to see more endurance power in the funding of key technologies.

Why is that?

Overmeyer: Germany is one of the world's leading nations for laser technologies, in part due to many years of public funding. In photovoltaics, which is by the way also an optical technology, factories were built up with subsidies for many years, and before they started to earn money, the support was stopped. As a result, the factories were closed and are now located in China, even though researchers in Germany developed the technology.

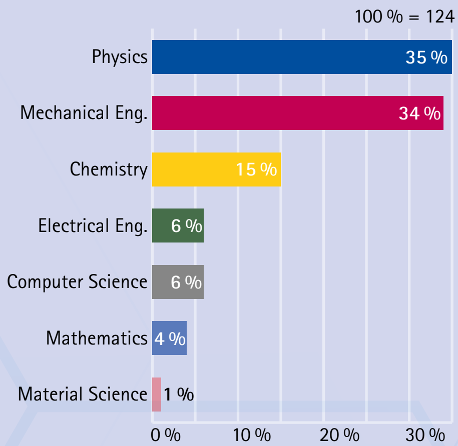
Are we also facing such developments with "our" key technology?

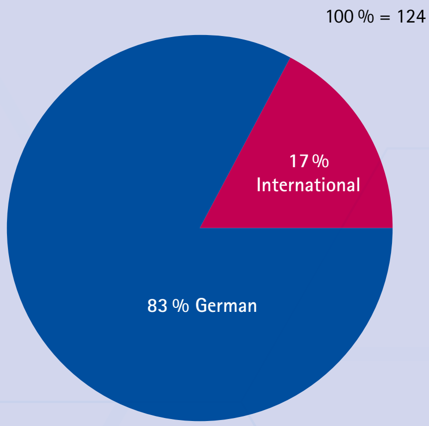
Kues: No, I don't think so. At the end of 2021, the Federal Government decided on an economic stimulus and future package to promote quantum technologies in their entire breadth to the tune of

PhoenixD in numbers

More than two-thirds of the cluster's members comprise Physicists and Mechanical Engineers. 17% of international researchers come e.g. from China, Russia, Iran, Japan, and Mexico.

Survey date: November 2021





Members of the PhoenixD Research School, e.g. PhD students, Postdocs and participants of the voluntary year in science, also attended PhoenixD's launch event, the international symposium "Future Optics", on 25th and 26th September 2019. The event took place at Herrenhausen Palace in Hannover, in cooperation with Volkswagen Foundation.

two billion euros. These funds will be used to launch funding measures in the areas of quantum computing, quantum communication, quantum sensors and basic technologies. Photonic technologies are explicitly mentioned as the second key technology. Future quantum communication will work only with photonic systems. We at PhoenixD can strongly support these goals with our vision.

Photonic quantum encryption is said to enable tap-proof communication. Why is this important?

Morgner: Communication must be confidential, in private and in business. If a company can no longer communicate securely, it can pack up at some point. For this reason, we need such encryption standards, especially as a knowledge society.

Kues: That is why our research must be financed with public funds, i.e. by the taxpayer. We need to do research in such forward-looking technologies in Germany and Europe so as not to depend on other countries. For example, when we introduce the next mobile-phone standard 6G in Germany, we don't want to have to acquire this technology from certain countries because we simply don't know what's in it.

Kowalsky: You can see from this latest example that our government has learned from the past. Germany first lost optical communications technology and then mobile communications, and has become dependent on other countries. With Intel, there will soon be a new chip factory in Magdeburg. I believe that we have now realised that we have to bring certain key technologies back to Germany ...

Morgner: ... or at least back to Europe.

Hannover gets a New Optics Centre – The OPTICUM

Reinhard Caspary
Sonja Smalian

Leibniz University Hannover (LUH) gets a new research building: the OPTICUM – Optics University Center and Campus. The construction of the four-story building will be funded half by the Federal Government and half by the State of Lower Saxony with €54.2 million in total. According to plan, more than 120 researchers in optics will work together under one roof starting in 2026.

On July 2nd, 2021, the Joint Science Conference (GWK; Gemeinsame Wissenschaftskonferenz) officially confirmed the funding recommendation of the German Science and Humanities Council (Wissenschaftsrat) of April 23rd, 2021 for the OPTICUM. That was the starting signal: At LUH, the detailed planning for the new building began. Its completion is planned for 2026.

"Congratulations to our scientists on this outstanding success," says Leibniz University President Prof. Dr. Volker Epping. "LUH already demonstrates the importance of optical technologies through its own research focus and its own research school, which is comparable to a faculty. I am glad that this future topic is also underpinned by a new research building and receives appreciation and support from science policy. The funding recommendation for the Opticum also means a further strengthening of our Cluster of Excellence PhoenixD, Leibniz University and Hannover as a centre of scientific research."

The OPTICUM is managed by the Leibniz School of Optics & Photonics (LSO), which was founded in spring 2020. The LSO is closely linked to the Cluster of Excellence PhoenixD and is equivalent to a faculty in its structure. "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 Executive Board of PhoenixD and the LSO. "We are very pleased about the Science Council's decision. Now, with the support of the federal government, the state and the state capital, we can build the optics campus in the Hannover-Marienwerder Science Park."

The four-story building with a usable area of a good 4,000 square metres will be built in the Hannover-Marienwerder Science Park. The location on Pascalstraße will be easily accessible via its own tram stop. Nearby are the Laser Zentrum Hannover e.V. (LZH) and the participating institutes on the Mechanical Engineering Campus of Leibniz University Hannover in Garbsen. In addition, the Technology Centre, the Institut für Integrierte Produktion Hannover (IPH; Institute for Integrated Production Hannover) and the Technopark Hannover, where numerous innovative companies from the research and science sectors have already settled, are located in the neighbourhood.

> Many innovative companies nearby

"Having the LSO and the OPTICUM in one place is very innovative in optics", says Luc Bergé, president of the European Physical Society and member of PhoenixD's international advisory committee. "We do see the tendency to draw on the different academic communities (in cooperation with industrial partners) in the education of engineers elsewhere too, for instance in Jena and Milan", says Bergé.

"This approach also has a long tradition in France, through the Technological University Institutes. However, with a strong department of high-performance computation and the future option of selling products, the LSO's concept is original and timely, and I believe it will be successful. Other countries should have a close look at it."

At OPTICUM, the leading scientific question of PhoenixD is being addressed on a long-term basis, namely how future optical systems can be produced while balancing the necessary precision, the degree of integration, the individuality of resource consumption and the costs. Optical setups today are often still very bulky and consist of discrete, precisely assembled individual optical components that have to be realized laboriously, mostly by hand. The work at OPTICUM aims at transforming traditional optical systems into integrated, intelligent and adaptive systems. The ultimate goal is to manufacture these systems using high-throughput processes.

The envisioned paradigm shift in optics production of the future will be accomplished along four research lines. Motivated by two global trends, the constantly growing capacities of data processing (research line OS, see below) and the rapid progress in additive manufacturing (research line OP), a digitally and physically networked production platform for individualized optical components and systems is being realized. The goal is to connect automated additive and subtractive production methods as well as cross-scale multi-physics simulations in real time in a feed-forward loop using extensive inline measurement technology. Precisely pre-calculated production steps based on predefined tolerances will ultimately be replaced by a flexible manufacturing strategy optimized in real time

The four-story building has a usable area of a good 4,000 square metres. The location on Pascalstraße in the Hannover-Marienwerder Science Park will be easily accessible via its own tram stop.

View of the first floor with conference rooms and space for networking.

during production. Neither the necessary computing power, nor the algorithms, the production or the measurement technology are available today for a complete realization of this vision. The OPTICUM will provide space and infrastructure for a manufacturing grid to investigate and demonstrate these novel approaches.

Another essential prerequisite for modern optics production is the availability of novel materials, the functionality of which is optimized for the respective targeted application (research line OM). The basis of modern optics, as outlined in chapter "Focus on optics – State of research in optics and photonics", is optical polymers and hybrid materials as well as semiconductors in the field of integrated planar optics. Depending on the application and manufacturing process, different polymers are used, which can be modified in the OPTICUM if required. However, the focus of material development is on adaptive materials, whose properties can be adapted to environmental conditions and requirements during operation.

In addition to the actual structure, the manufactured optical system also contains its own digital virtual model as an integral system component (research line OI). This virtual model is used to exploit the achievable manufacturing precision of individual components for the assembly of the overall system, while at the same time keeping

The European Perspective

Two questions to Luc Bergé, President of the European Physical Society and member of PhoenixD's International Advisory Committee

PhoenixD puts an emphasis on an interdisciplinary approach. How essential is this in research into optical technologies?

Luc Bergé: It is vital. Indeed, we can see a new trend, where the academic sector takes some leads from the industrial sector to build something together. PhoenixD represents this development perfectly in my opinion. Here you can see the power of numerical simulations with predictive high-performance computations, and a strong commitment to fundamental science in order to test new devices that will then be integrated into broader structures to be sold on the market. For me, this is a key interdisciplinary process that fits, by the way, the main orientations in research and innovation initiated by the European funding programmes. This transpires from the updated roadmap for European photonics (2021 - 2027) where "photonics for a healthy, green and digital future" makes a contribution as one of the six Key Enabling Technologies.

How important is an interdisciplinary campus like the OPTICUM for research in optical technologies?

Bergé: Years ago, French optical graduate schools revised their strategy and started to be part of consortia with regional academic laboratories having strong links to industry and building up "poles of excellence". This changed their way of teaching optics and training a new generation of engineers, and they also erected entirely new buildings for this. According to the Shanghai ranking 2021, the University of Paris-Saclay, hosting such an important graduate "Grande Ecole" (or engineering school) in optics, is among the top 50 of the world's best universities in 11 disciplines. It is ranked 9th in physics and 1st in Europe. These results are excellent, and I do not doubt that the OPTICUM will experience similar success quite soon. So, it is good to pool resources, and it is nice to have a new building to represent this change of mind.

the precision requirement within an economically reasonable range. In particular, it represents a critical element for the function of the real optical system and ensures the control and adjustment of system functions over the life cycle of the system. This novel, comprehensive approach in the sense of Industry 4.0 and the Internet of Things has not yet been realized for the production of precision optics and can only be achieved through the collaboration of different disciplines. The processes are to be used with the knowledge gained from measurements and simulations and artificial intelligence approaches to build a learning database, so that the optics production of the future will be continually improved and automated on this basis.

OS – Optics Simulation

The goal of the simulation team at OPTICUM is to become an international centre for optical simulation. It is creating OPTISIM as a global platform for open-source software for optical simulation. OPTISIM will become a widely visible flagship, where standards for software and data are defined and established. OPTISIM is long-term and wide-ranging. Quantum computing, artificial intelligence, and data-driven methods will be explored on the platform to advance the state of the art. Based on OPTISIM, a virtual digital laboratory will be established not only for simulation and design, but also for accelerating and optimizing the experimentation and manufacturing phases. Thus, OPTICUM will be the hub for optical simulation software, knowledge transfer and the training of new simulation experts.

OM – Optics Materials

Material systems with diverse requirements for integrated optics are developed at OPTICUM. New optical materials are developed and existing material classes are optimized. Nanomaterials offer a broad repertoire of different usable optical effects. Many trillions of nanoparticles can be produced simultaneously with the precision of a few atomic monolayers. Plasmonic nanoparticles, for example, can be used to trap or guide light. Other optically active nanomaterials include semiconductor nanoparticles (quantum dots) that exhibit size-dependent absorption and emission with high temperature and aging resistance. Thus, they are suitable as light-emitting devices as well as special optical filters. Aerogels and hydrogels are ultralight macroscopic materials composed of crosslinked nanoparticles. They are monolithic, nanoporous and have large specific surfaces. Special crosslinking of the particles creates tailored optically effective properties for applications in optics. Examples include active components such as LEDs, lasers or optical detectors, or refractive index adaptive materials.

In metal-organic framework (MOF) compounds, organic molecules connect small metal oxide units to form nanoporous three-dimensional crystalline frameworks. Molecules with different properties can be incorporated into the pores. In this way, the refractive index can be changed in a controlled manner. Adaptive MOFs contain molecules with large dipole moments that can be oriented by external electric fields.

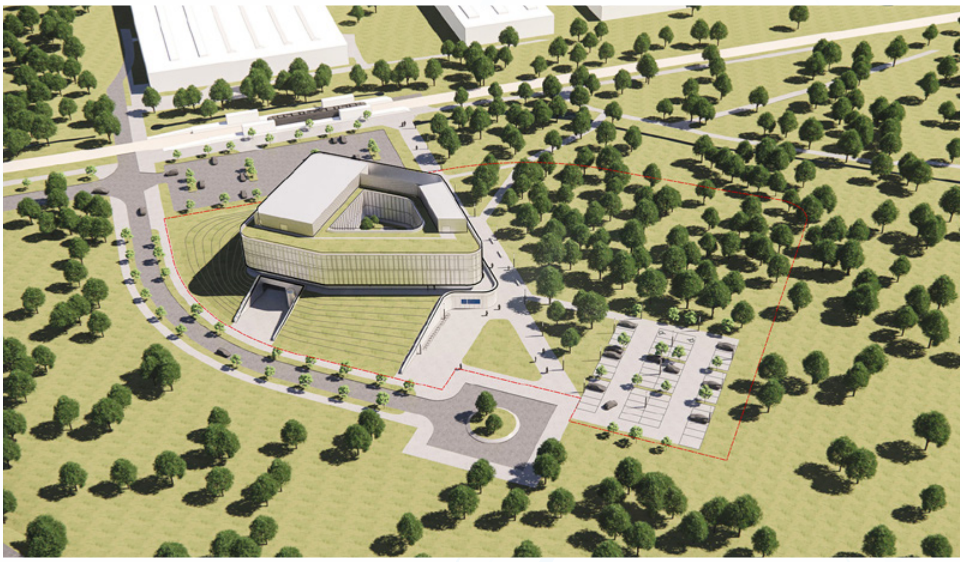
OP – Optics Production

Known and new manufacturing processes are combined to a manufacturing grid at the OPTICUM. This network will contain automated production processes with a high degree of digitization. An important aspect is the extensive use of online measurement technology, for example sensors for individual production parameters, and the integration of this data into a virtual model for simulating the entire system behaviour. Based on this data, individual production steps are planned functionally, and the individual history of each component is taken into account. The combination of the individual production machines within the manufacturing grid in different sequences allows great freedom for experiments and the demonstration of new manufacturing concepts.

OI – Optics Integration

The research line OI addresses all activities for the integration, testing and application of the new optical components and systems. It combines and validates new hardware components together with the virtual model as an integral part in a system. In particular, aspects of design, manufacturing, characterization and application must be considered. Classical optics are increasingly being replaced by free-form optics and integrated volume optics with diffractive and nanophotonic elements, for whose integration new concepts must be developed.

Around the planned research building, there is still room for expanding the optics university center and campus.



Printing a Raman Spectrometer

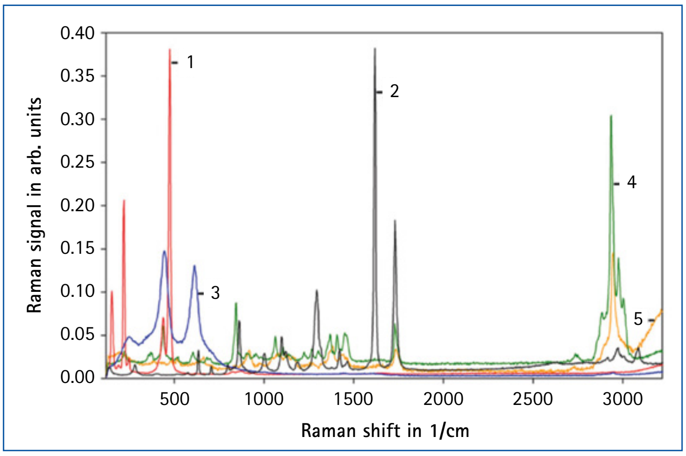
Alexander Wolf
Tobias Grabe
Bernhard Roth

Raman spectroscopy is a powerful technique for the highly specific detection of molecular information. It is used in chemical and biological analysis, e.g. for the detection of microplastics and viruses.

The Raman effect is based on the inelastic scattering of photons at different chemical bond types and provides an inherently weak signal. Only in one out of about a million photons is the relevant information encoded. Within PhoenixD we are working on a novel type of Raman spectrometer that increases the signal strength when established techniques for signal amplification cannot be used. This applies, for example, to in vivo medical analyses or the detection of transient events in analytics.

We use additive manufacturing processes such as stereolithography, multi-jet modeling or two-photon polymerization to fabricate transparent components with three-dimensional freeform shapes. Optical systems can thus be miniaturized and customized to address application-specific requirements. Different components can be manufactured in a single step, eliminating the need for optical alignment or stitching processes. Consequently, for many Raman detection tasks, additive manufacturing processes offer outstanding yet unexplored possibilities to produce highly specialized and thus sensitive systems.

Additive manufacturing of optics



Raman spectra are molecular fingerprints of molecules: Spectrum 1: polyacetylated cellulose; Spectrum 2: polyethylene terephthalate (fibre); Spectrum 3: TiO_2 in rutile conformation; Spectrum 4: polypropylene; Spectrum 5: polyamide; spectrum.

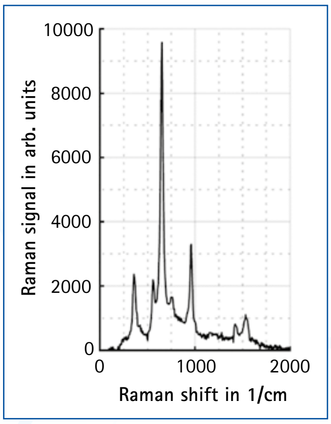
In our system, a freeform lens is used in the spectrometer to maximize the efficiency-limiting acceptance angle, and a diffractive optical element will optimize the use of the detector. The lens is based on the optical concept of total internal reflection, focuses the excitation radiation, and collimates the information-carrying backscattered Raman photons. This concept is almost independent of the wavelength of the backscattered photons and much easier to be realized additively than with classical technologies.

Furthermore, conventional spectrometers analyze a continuous spectral range of the Raman signal. However, if the molecule to be detected is known a priori, a detection of several narrow-band ranges is often much more advantageous. This principle enables us to focus only on the relevant wavelength ranges on the detector, and thus significantly increases sensitivity and measurement speed of the system. Tailored diffractive optical elements are used for this molecule-specific separation of wavelengths. The elements are manufactured using two-photon polymerization, which, in addition to miniaturization, enables realization with virtually no geometric restrictions.

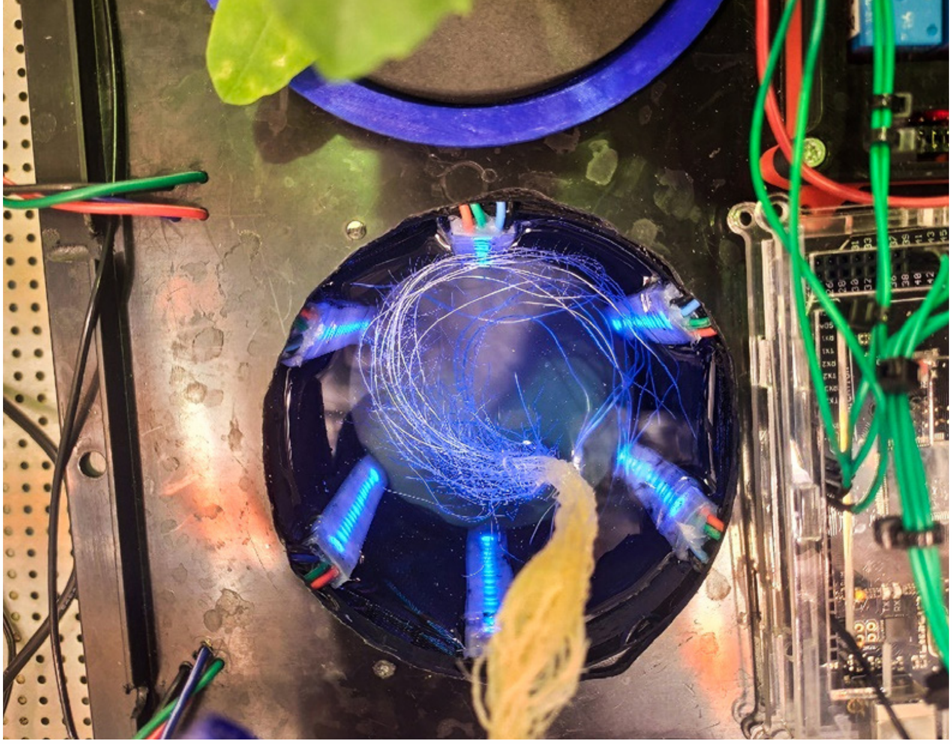
Tailored optical systems

Still, additive manufacturing of optical elements and systems is subject to challenges which need to be addressed. For example, a better understanding of restrictions like surface inhomogeneities and volume imperfections on the one hand and the design of freeform geometries on the other has to be worked out and made accessible to optical designers, and ideally openly accessible around the world.

Furthermore, design rules and guidelines like adapted V-models from engineering and product development, and optimized simulation strategies are strongly required to explore the full potential of the manufacturing technologies for a large variety of applications.



Raman spectrum of melamine with the characteristic peak at 675 cm⁻¹, measured with an additively manufactured freeform lens as collimation optics.



An LED module to illuminate the roots of Chenopodium Quinoa plants in hydroponic culture. Different light qualities affect the growth and composition of the plant, as they interact with different photoreceptors present in the roots. This can lead to photo-induced stress, but could also increase the content of valuable compounds in the plant.

Light Sources

Dag Heinemann
Alexander Wolf
Roland Lachmayer
Andreas Waag

Artificial light sources improve a wide range of tasks. Our research in this field enhances metrological applications, such as Raman spectrometers (see also article by A. Wolf, T. Grabe and B. Roth, page 22), influences plant growth selectively, or interacts with our visual sense. Our miniaturized light sources pave the way for novel optical neural networks.

Efficient indoor farming

Indoor farming enables plant production under controlled conditions. In closed systems, the used resources stay in a closed-circle economy. Since the lighting is completely artificial, we can adapt the lighting conditions individually for each plant. The temporal and spectral composition of light and its intensity have a massive impact on plant growth. For example, it affects the length of a growing season. With unsuitable light quality, plant growth is even negatively affected. Therefore, the continuous development of light sources in terms of efficiency, cost, and light quality is our key research concern.

Are you aware that not only the leaves but also the roots of plants are light-sensitive? At PhoenixD, we investigate how different light characteristics in the root zone affect plant growth and its constituents. This enables modern breeding systems in which leaves and roots are exposed to artificial light. With adapted lighting, we can specifically influence the plant constituents, for example to produce medicines more efficiently.

Enhancing perception

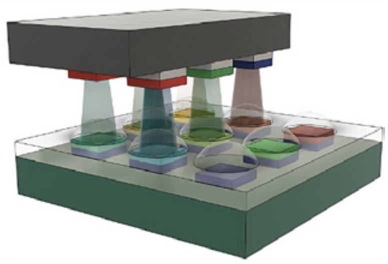
The spectral composition of light affects not only plants, but also our human sense of sight. This applies to our ability to perceive and distinguish colors, among others. Our eye has photosensitive retinal ganglion cells that react to blue light. Without giving us a visual impression, they directly influence our day-night rhythm. This type of detector was discovered only 20 years ago, impressively demonstrating that human vision is not yet fully understood and therefore part of our research at PhoenixD.

Another challenge in our development of lighting systems is the balance between providing sufficient illumination with adequate light quality, and avoiding glare. In vehicle headlamps, we meet these conflicting requirements with adaptive systems using micromirrors or LED arrays, see article by Wolf et al., page 35. Like in a video projector, they can provide pixel-based illumination of the traffic area.

Powerful microLEDs

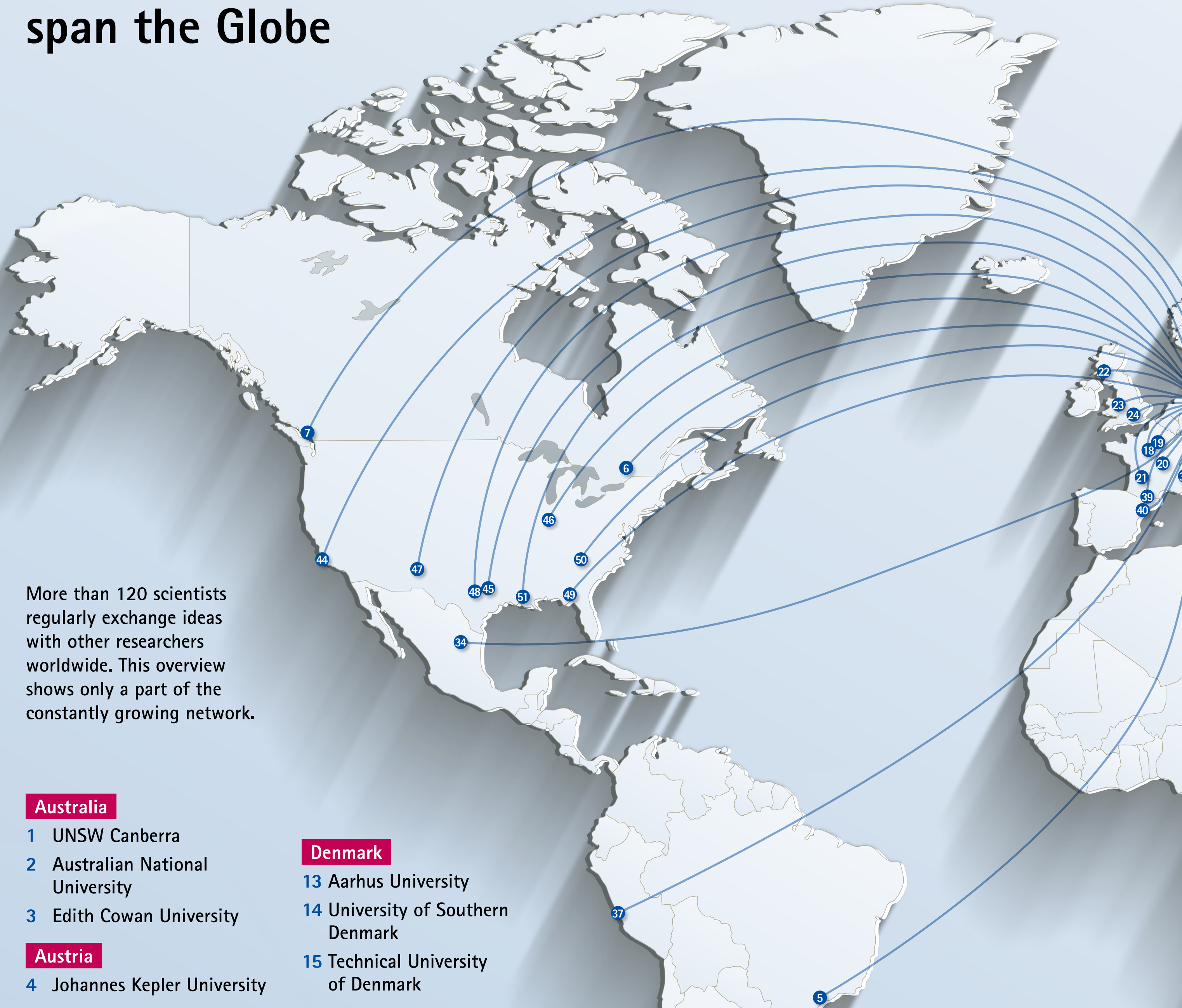
LEDs for room lighting or smartphone flashlights usually have a size of about one square millimeter. While the individual LEDs in the arrays for car headlamps have sizes of several square micrometers, the microLEDs we develop at PhoenixD are so small that they are invisible to the human eye – unless they light up. One million microLEDs can be contained in one square millimeter, see figure bottom

These microLEDs enable unique applications, e.g. as microdisplays for augmented reality, in quantum optics and in super-resolution microscopy. In combination with appropriate detector arrays, a microLED array can even process information in a way similar to neurons in our brain. Since light propagates in many directions simultaneously, we can create an "optically wired" network. Our goal is to connect one million LEDs with one million detectors and even more, which is a basic requirement for the realization of artificial – in this case optical – neural networks.



MicroLED array (bottom) imaged onto a detector array (top) via an array of micro-lenses. The detector array is coated with a sensor material. Such a configuration allows the operation of micro-sensors, similar to the principle of an "artificial nose". The microLED modules, the sensor materials for optical sensor technology, and the required micro-integration techniques are developed in PhoenixD.

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

Brasil
5 University of São Paulo

Canada
6 University of Ottawa
7 The University of British Columbia

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

Denmark
13 Aarhus University
14 University of Southern Denmark
15 Technical University of Denmark

Egypt
16 Menoufia University

Finland
17 University of Oulu

France
18 ENS Paris-Saclay
19 École Polytechnique
20 University of Technology of Troyes
21 University of Limonges

Great Britain
22 University of Glasgow
23 Aston University
24 King's College London

India
25 Indian Institute of Technology Indore
26 Indian Institute of Technology Madras

Italy
27 University of Milano-Biocca
28 University of Rome Tor Vergata
29 Gabriele D'Annunzio University
30 Fondazione Bruno Kessler
31 Istituto Italiano di Tecnologia
32 Politecnico di Torino

Japan
33 Keio University

Mexico
34 Tecnológico de Monterrey

New Zealand

35 University of Canterbury

Norway

36 University of Oslo

Peru

37 National Agrarian University

Slovenia

38 University of Ljubljana

Spain

39 University of Girona

40 Universitat Politècnica de Catalunya · BarcelonaTech

South Africa

41 University of Cape Town

Sweden

42 Umeå University

Switzerland

43 ETH Zurich

United States of America

44 University of California, Berkeley

45 Texas A&M University

46 Purdue University

47 The University of New Mexico

48 The University of Texas at Austin

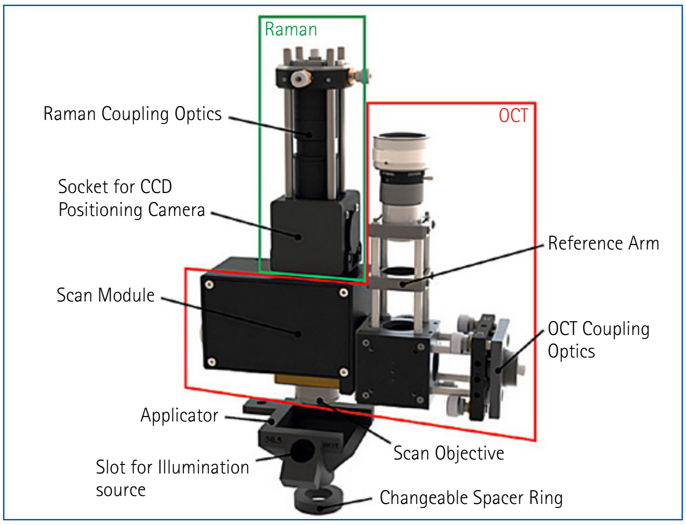
49 Florida State University

50 Clemson University

51 Louisiana State University

Development of Intelligent Optical Systems

Bernhard Roth
Bodo Rosenhahn



Part of a multimodal optical measurement system for skin cancer screening: The key development aspects are additive manufacturing of crucial components, miniaturisation and integration, and artificial intelligence analysis.

Smartphone-based optical sensor for the highly sensitive and efficient detection of biomolecules: Among them are e.g. cardiac markers for clinical diagnostics or biomolecules relevant for wellbeing. In addition, point of care applications can benefit from implemented cloud-based data analytics.

Systems based on optical principles can provide new solutions for unmet demands in medical diagnostics, point of care testing, environmental analytics or production monitoring. They are particularly suitable for applications requiring non-invasiveness, high spatial or spectral precision, robustness or immunity against electric and magnetic fields.

Many of these applications generate large data sets in case of widespread use. These data sets can be standardized and combined to build a learning database for improved feature recognition or classification.

However, the connection between optical measurement systems, particularly integrated photonic devices and modern data science is still in its infancy. Yet, the trend is evolving quickly, and coined expressions such as the "thinking microscope" imply that precise measurement and supervised or unsupervised machine learning can lead to new system functionalities or better data mining.

Here, we briefly describe two of our promising research examples: We develop multimodal imaging technology for melanoma (black) skin cancer detection, figure top. Being among the most dangerous cancer types with ever-increasing incidence rates, early detection of the disease is crucial. Around 27,000 men and women are presently diagnosed each year with black skin cancer in Germany alone. To enable non-invasive, fast, and ultimately cheaper diagnosis, we develop a so-called optical biopsy to detect a lesion's benign or malignant nature and penetration depth. Three optical modalities are combined:

1. Optical coherence tomography (OCT) provides information about thin skin lesions.
2. Optoacoustic tomography analyses thick lesions.
3. Raman spectroscopy provides molecular information.

Incorporated concepts of artificial intelligence will continuously improve diagnostic accuracy so that non-medical personnel can perform examinations in the future.

In addition, we develop a smartphone-based surface plasmon resonance system to detect biomolecules (figure bottom). The simple concept relies on using a smartphone flashlight for interrogation, its camera for spectral evaluation, and a simple polymer waveguide with high sensitivity and specificity.

Combining digital signal processing with machine learning for the above applications is essential. It has to be implemented in a way not only to generate learning and a continuously growing database, but also to allow for essentially real-time analysis. For example, image and video analysis domains require multimodal data processing and time-series data analysis. Significant trends revolve around representation learning, semi-supervised learning, anomaly detection, sparse scene reconstruction, scene graphs, and multi-object tracking.

Further research on artificial intelligence in medical diagnostics and biological or environmental sensing is needed, for example, aiming to establish standardised data formats, implement data security and predictive data science, or to realise a digital twin on board the physical system for functionality checks and performance estimates.

Complex functional metal part produced with powder bed fusion (PBF-LB/M) comprising inner structures which could not be produced with conventional manufacturing.

The Laser – a Versatile Tool for many Applications

Stefan Kaierle

Since its first presentation in 1960 as a lab system, the laser has become an indispensable tool in today's industrial production. Lasers can cover applications from chips to ships, e.g. from the production of tiny structures that are needed for the manufacturing of computer chips or smartphones to welding heavy section steel plates for ships. The most important advantage of lasers is the wear-free use of the tool itself while applying only light to the component to be processed. At the same time, the high energy delivered by a laser applies only locally to the workpiece so that the environment will not be affected.

In the search for new applications, the laser has meanwhile become an important industrial device for additive manufacturing, often referred to as 3D printing: the fabrication of dental implants, weight-saving mounts for aircraft, or the repair of tools, especially comprising components with an almost unlimited degree of freedom of design (picture top). Beyond such established applications, there are still plenty of opportunities where the laser can be used. According to various forecasts (Frost&Sullivan (2016), Roland Berger (2014)), the potential for additive manufacturing is expected to reach about $20 billion in worldwide turnover within the next five years. Growth is expected in many different sectors such as medicine, tools, consumer products, the automotive industry, aerospace, maritime, agriculture and more. As a new area in production technology, additive manufacturing is currently also finding its way into national (DIN) and international standards organizations (ASTM).

At the Laser Zentrum Hannover e.V., a partner institution of PhoenixD, over ten different additive manufacturing technologies are currently being investigated for a variety of materials such as metals, polymers, and glass based on powder, wire, fibers and filaments. In the context of PhoenixD, the additive manufacturing of optical elements up to complete optical devices and systems is a challenge that is being addressed. To achieve this, a laser glass deposition process (LGD) is applied, using fused silica fibers as starting material. These LGD produced components include, for example, the manufacturing of functional waveguides, but also the fabrication of free-form optics during the course of the project.

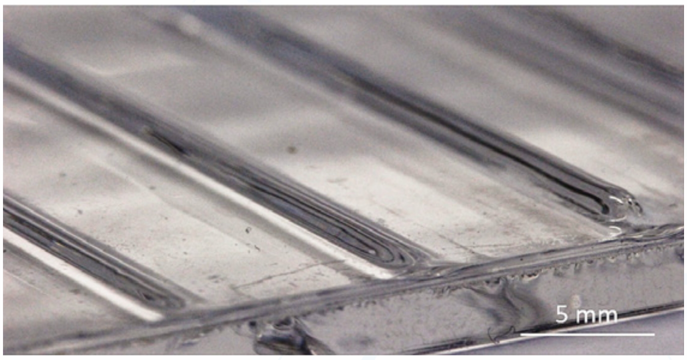
A major challenge is to produce elements of optical quality.

For structural components, this effect is not relevant as long as the required component properties, such as mechanical strength, are maintained. In the sandglass structure (picture right) the individual glass layers are still visible. As a result, the surface also exhibits waviness. By adjusting the process parameters such as the speed ratio between fiber feed and axis speed, as well as the laser power, it is possible to build wall structures consisting of up to 30 layers, which no longer have any visible boundary layers and show a homogeneous, smooth surface (picture bottom).

In conclusion, it can be stated that additive manufacturing is still in its early days, especially in the field of 3D printing of glass. During the course of the PhoenixD project, emphasis on further developing this technology will be set.

Sandglass structure printed with the LGD process.

Wall structure form without interfaces consisting of two, four and eight layers.



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.

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. From the winter semester 2022/23, Leibniz University Hannover will offer the 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

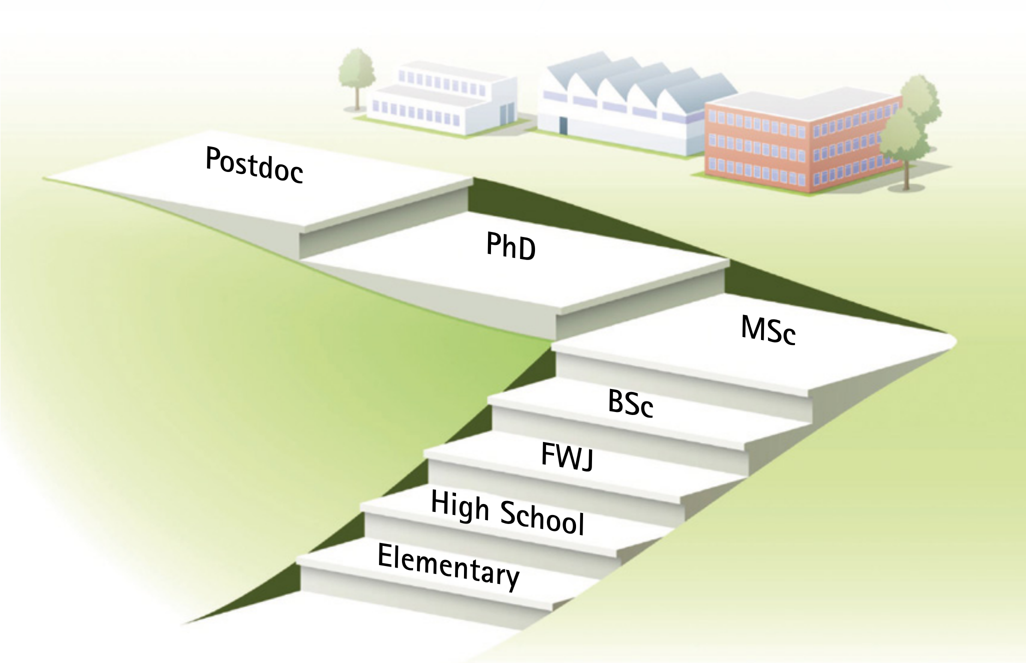
The PhD students are the heart of the PRS, since here interdisciplinary science is strongly supported. Doctoral students gain a profound insight into the broad range of different optic-related fields. In addition to monthly colloquia, where guests from Germany and abroad report on the current state of 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 net-working 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

Sabine Gersemann

Coordination of
PhoenixD Research School

Janna-Lee Steenblock

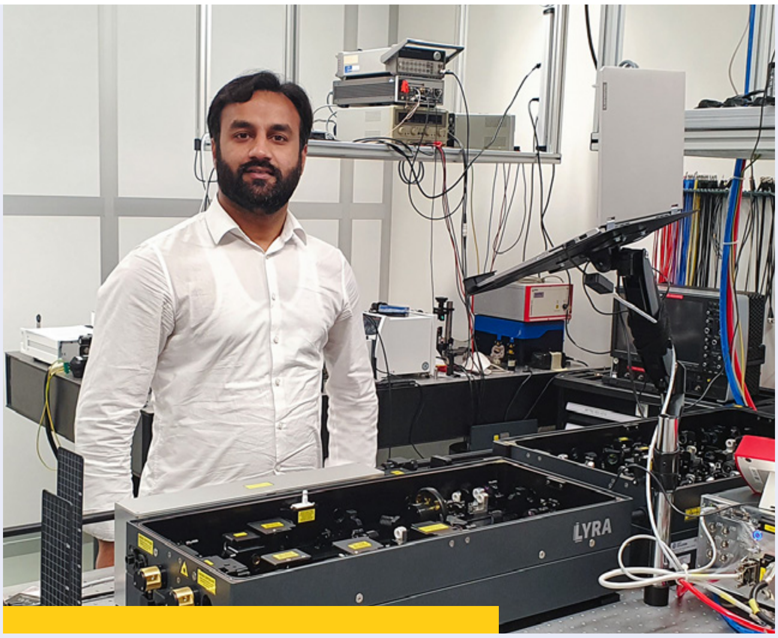
Coordination Diversity
PhoenixD Research School

Sarah Langhorst

Assistance
PhoenixD Research School

Voices of our Alumni

Yang Li works as a technical planning manager in the R&D department of Chengdu Pulse Optical Co., Ltd. in Chengdu, China. He was born in Chengdu, China.



Muhammad Shaukat Khan works as a scientist in the unit Heterogeneous Integration Technologies, under the Sensor Systems Division at Silicon Austria Labs (SAL) in Villach, Austria. He was born in Islamabad, Pakistan.

Sonja Smalian

Our alumni work in various fields of optical technologies. We asked four of them to tell us why they chose Leibniz University (LUH) for their PhD study and what crucial piece of learning they gained here. The four also reveal what they would do differently nowadays and share their advice for future generations of optical engineers.

*HOT – Hannover Centre for Optical Technologies;
IPeG – Institute of Product Development;
ITA – Institute of Transport and Automation Technology;
IQO – Institute of Quantum Optics;
LZH – Laser Zentrum Hannover e.V.

Why did you choose Hannover and LUH for your studies?

Yang Li: I wanted to choose a technical university in Germany for my studies, and TU9 universities are well known in China. Then I found IPeG Institute at LUH was recruiting, so I applied.

Muhammad Shaukat Khan: During my master's studies in laser and photonics at Ruhr University Bochum, I came to know about research centres and institutes, especially at LUH – HOT*, IPeG, ITA, IQO –, and LZH in Hannover and their excellence in the field of optics and photonics, which motivated me to pursue my PhD in Hannover.

Uliana Dudko: LUH in cooperation with Peter the Great St. Petersburg Polytechnic University offered a double degree Master's program in Mechatronics and Intelligent Systems. I found the combination of these two topics very interesting and applied for the programme.

Tim Wolfer: I wanted to study mechanical engineering and I liked what the LUH had to offer. In particular, the environment of the Hannover Centre for Production Technology in Garbsen with its interdisciplinary and cooperative approach excited me.

What did you study at LUH, and which degrees did you obtain there?

Li: I studied mechanical engineering, more precisely, opto-mechatronics at LUH, and I finally got a Dr.-Ing. degree.

Khan: I did my PhD (thesis submitted, defense in June 2022) in mechanical engineering at LUH with specialization in polymer micro-optics design and fabrication for automotive and sensing applications at IPeG/HOT.

Dudko: First, I received a double Master's degree in Mechatronics in 2016. Last year I successfully defended my dissertation in the field of Optics and Electronics and obtained a doctoral degree (Dr.-Ing.).

Wolfer: I gained a master's degree as well as a PhD in mechanical engineering with a specialization in production engineering.

What do you exactly do at work?

Li: Basically, I plan the technical and product roadmaps for my company. Besides, I also do research and sometimes product design.

Khan: Currently at SAL, besides writing proposals for funding acquisition and scientific papers, I am working on integration and packaging of photonic integrated

Uliana Dudko is a software engineer and works in the electronics equipment department of LPKF Laser & Electronics AG in Garbsen, Germany. She is from Penza, Russia.

Tim Wolfer is Project Manager Functional Printing, Department: Center for Functional Printing Technologies for Continental AG, Freiburg in Breisgau, Germany. He is from Bremen, Germany.

circuits (PICs), and electronic/photonic sensors. Also, development of pico-/femto-second laser processing system for various customer specific applications are among my responsibilities.

Dudko: At work I develop software for laser processing machines to control their parameters in cutting, drilling, and hatching tasks. I also develop concepts of what the user interface and production workflow should look like for these operations.

Wolfer: I work in research and development and use functional printing processes to digitise mechanical products. For example, sensors are integrated into fluid hoses so that these components can feel, analyze and communicate.

Does your work have anything to do with optical technologies? Please describe your work briefly.

Li: Yes, my company is an optical company :). I sort out the development route of this company and make suitable plans according to the route.

Khan: Yes, I am working on design and optical simulation of micro-optics (including refractive and diffractive optics) on the one hand, and fabrication of micro-optics using two-photon polymerization (TPP) and nanoimprint lithography (NIL) for photonic integrated circuits on the other. Also, I am working on pico-/femtosecond laser processing of different materials (silicon, glass, polymer) for various research and customer specific applications.

Dudko: To provide a user-friendly operation workflow for laser material processing, the self-explanatory human-machine interface can be achieved with the help of software. At work I develop and implement software concepts that make the work with a laser less complicated, help to avoid operating mistakes, and at the same time provide broad functionality and flexibility.

Wolfer: Functional printing can also be used to create structures that have an optical effect. These structures can be applied in communication, lighting or sensor technology.

What is the most significant difference between studying and working with optical technologies?

Li: In my opinion, my time for doing research decreases a lot, I have to deal with a lot of stuff from our customers now.

Dudko: Generally, the difference is the same as between theory and practice: you must be extremely careful with the equipment and understand what you are doing. Another difference is that in the university you have more freedom in your research, a stretch of the imagination. You can investigate freely under the trial and error principle. When you are working in a company you are more strictly bound by time and costs.

Wolfer: At the university there are experts, equipment and software for every conceivable question. So you have very quick access to the infrastructure you need. In a company, such structures sometimes have to be built up first. On the other hand, decisions are sometimes made more quickly in the company because the focus is more on the financial return.

What is the most crucial asset you gained at LUH from which you can benefit now in your working life?

Li: I think it is the strict ways of doing things.

Khan: During my studies at LUH, I gained simulation and experimental expertise in fabrication and replication techniques of micro-optics, and laser systems, which helps me in the current job.

The Welfenschloss is the main building of the Leibniz University Hannover. Here you will find the central administration of the university, the service centre for students, and a large number of lecture halls.

Dudko: How to structure complicated knowledge and represent it in a form other people can easily understand.

Wolfer: I think collaboration with different disciplines and people is a very important skill. Today, projects are carried out only in teams. If you have experienced social and professional exchange at university, you are well equipped for projects in companies.

What was the hardest lesson to learn when starting your job after university?

Li: Actually, I did not feel anything was hard to learn there.

Dudko: You learn the costs behind the industrial development within the framework of your company and its financial policy.

Wolfer: I have always tried to achieve good results. At the same time, however, I also specialized relatively strongly with the PhD. Following the doctorate, I then found that suitable positions were rare and required greater geographical mobility. That was a bit frustrating after all the efforts of my education. But now I am very happy with my job :-)

What advice would you give your younger self to do differently during your studies at LUH?

Li: Get in touch with more new things, new people, new thoughts and new methods. I just mean even playing games, watching comics and animations, doing sports, etc. which seems have nothing to do with the study and research, these activities usually give some good ideas for our work or fresh our minds.

Khan: The advice I give to my younger myself is to enhance competences in optical simulations, which surely would have increased my knowledge and made a huge difference.

Dudko: Study more, explore new things, and look at the broader picture.

Wolfer: Less emphasis on mechanics and materials and more on programming, artificial intelligence and project management. I think mechanical engineering would do well to become more agile, digital and international. As an external reviewer for the mechanical engineering curriculum, I am currently incorporating this perspective. I am glad to get an insight into these developments here.

What advice would you give young students who are interested in optical technologies? Into which fields should they stick their noses?

Li: I would suggest they should think more about the underlying logic when they see a phenomenon or encounter a problem; this will be beneficial in any field.

Khan: For young students, optical technologies are a promising field for the world of tomorrow. Optical technologies following More-than-Moore strategies are opening areas and applications which could not be imagined a couple of decades ago, for example, photonic chips (for computers, tablets, mobile phones), biomedical applications (non-invasive surgery, OCT), laser material processing (cutting, welding etc.), data transmission, lidar applications (automotive), lighting and illumination, energy (solar cells), to name a few from the infinite possibilities. As for students, quantum optics, optical spectroscopy, bio-photonics, optical design and simulation, micro-optics (MEMS) design and fabrication, laser material processing (including additive and substractive manufacturing), optical lithography are some of the fields which I recommend. In addition to this, simulation software such as ZEMAX for system design, Ansys for thermo-optical/thermo-mechanical simulation, COMSOL multi-physics simulation tool, and programming tools or languages such as C, Python, and MATLAB are highly recommended.

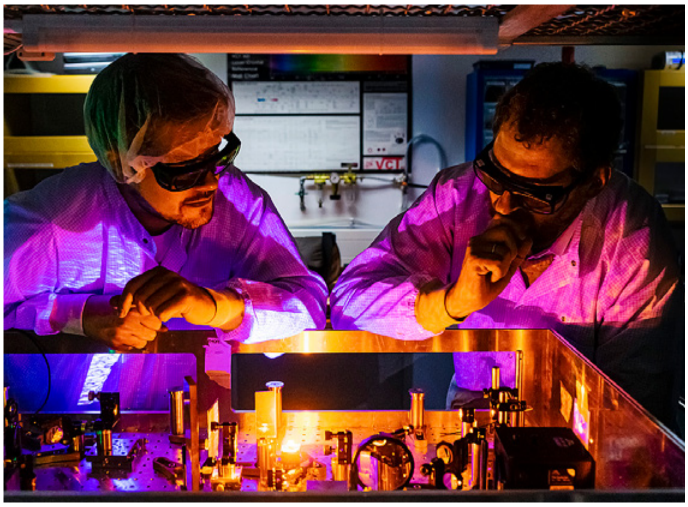
Dudko: Electronics and optics go well together. Production and integration of such components is a growing field now and will remain so in the future.

Wolfer: I would generally say: find out right at the beginning whether you want to work in science or in business in the long term. To become a scientist, I would then focus on the latest hot topics. If you'd prefer to go into a company after your education, you should also learn the latest working methods, but technologically you should know the traditional technologies as well. Most jobs in companies are perhaps not only in quantum computers but rather in materials processing, additive manufacturing and metrology. But the most important thing is always: do what you love, then you will be successful.

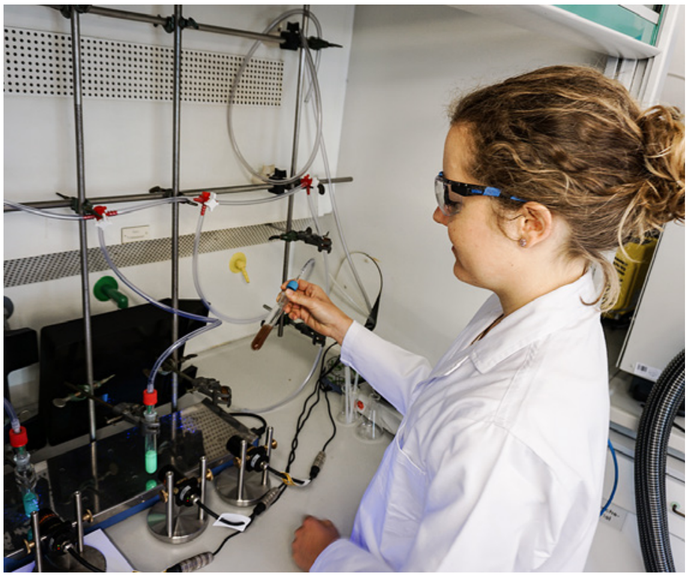
New Bachelor Programme in Optical Technologies starts in 2022

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 first intake is in the winter semester of 2022/23.



Laser technology (above) plays a crucial role in modern optics, as does chemistry. View into a chemistry lab (below).



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.

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 (HOT), the Leibniz School of Optics & Photonics and the Laser Zentrum Hannover (LZH) 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 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

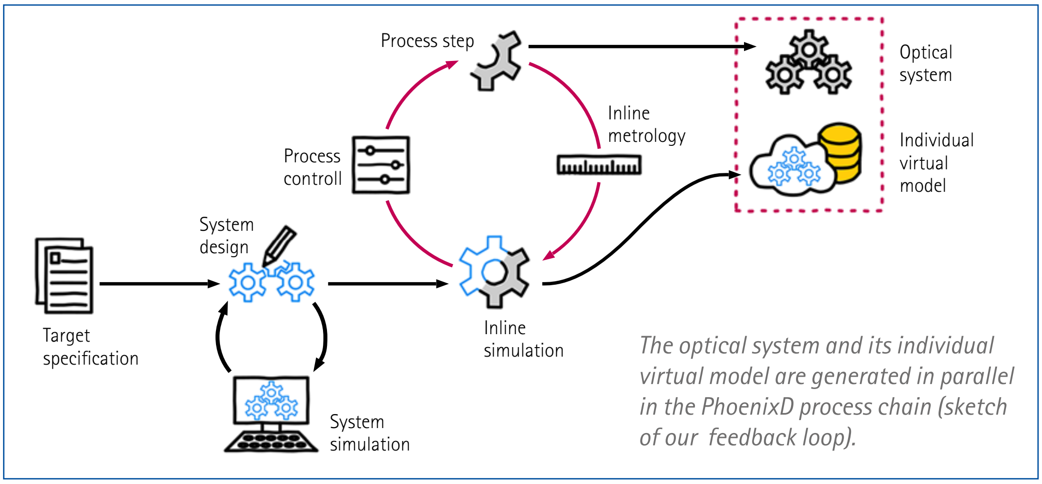
Course type:	Undergraduate studies (1 Subject bachelor)
Standard Course Duration:	6 semesters
Course Start:	Winter semester
Primary Language of Instruction:	German
Language Requirements:	Applicants with German University entrance qualification: none; International applicants: Proof of language proficiency 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/BA_Optical_Technologies

Digital Twins in Optics

Hauke Dierend
Alexander Wolf
Talash Malek
Hai Nam Nguyen
Roland Lachmayer
Berend Denkena



The optical system and its individual virtual model are generated in parallel in the PhoenixD process chain (sketch of our feedback loop).

Demands on optical elements and systems are constantly increasing, requiring individual and highly functional components, which are costly and complex to manufacture.

During system production and usage, a large amount of data is generated. These heterogeneous data sets can be used to gain valuable information for design optimization, manufacturing and the application itself. The amount of data generated requires new concepts for its structuring and management. At PhoenixD, we have established the concept of "Digital Twins" in our simulation and production processes (Figure 1). A Digital Twin is a virtual model of a physical product, process or system. It enables data management and exchange during different stages of the product life cycle (Figure 2). Real process data such as measurement results or machine data can be combined with simulation results to create a Digital Twin. In this way, the Digital Twin emulates an optical system as far as possible over its entire life cycle.

Holistic system description

After evaluating the user requirements, optical systems are designed, manufactured and assembled in several steps. The interactions between these stages and the application of the product are hard to consider and to control in the development process. Using a Digital Twin, the system and its dependencies can be described in a holistic way. For example, assembly and the resulting system performance can be simulated in advance, in order to optimize the preceding steps of design and manufacturing. Another usage of a Digital Twin is to enable computer-aided early detection of aging influences, damages, required maintenance or recalibration of an individual system. This often allows immediate recalibration of the system based on the evaluated data.

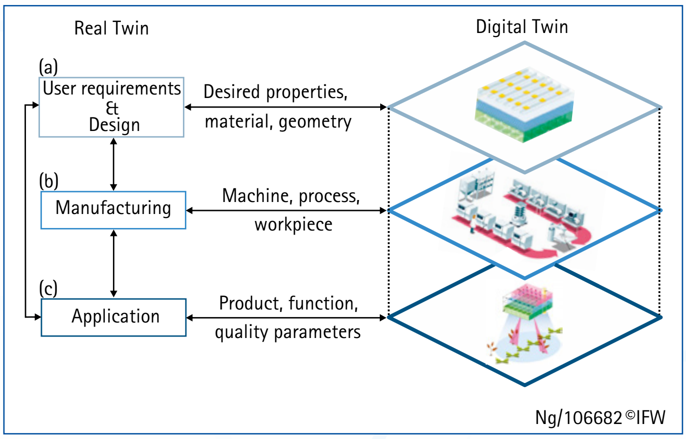
By integrating as much information as possible from all stages, a Digital Twin can also be used for product documentation. The benefit of a Digital Twin is the uniform representation of a wide variety of information, which is realized by structuring the information through metadata and ontologies. In this way, information is linked semantically, just like words in a language. This enables a Digital Twin to communicate with other data sources and Digital Twins as part of a data network.

PhoenixD is a partner in the Germany-wide network "National Research Data Infrastructure for Engineers" (NFDI4Ing), which is working on a uniform representation of the data to be processed across disciplines. In this context, the Digital Twin primarily serves as a management tool for the system data and enables the interpretation and subsequent use of data even years after its creation.

Information linking and structured data exchange

When the Digital Twin is made accessible to others, the linked metadata and the unique association of the data to physical sensors or their models and algorithms promote the traceability and subsequent use of the data once generated. This takes into account the FAIR data principles that (meta) data must be Findable, Accessible, Interpretable, and Reusable, making research and data generation sustainable.

Real and digital life cycle of optical elements.



Optics and Mobility

Alexander Wolf
Roland Lachmayer

To see and to be seen – road safety is based on this simple principle. Following this maxim, we, a team of scientists from PhoenixD and associated institutions, are actively involved in various research projects to increase road safety sustainably.

High-resolution vehicle headlamps can project symbols onto the street surface to communicate with the driver or other road users.

While pedestrians and cyclists have to rely on their eyes and ears as sensors to see other road users and the environment, today's cars support their drivers with detectors such as ultrasound sensors, cameras, radar and lidar systems.

Cameras and our eyes require sufficient illumination of the environment, and therefore an illumination system which provides enough light for the sensor without dazzling others. In addition, the limited dynamic range of the individual sensor system has to be considered. Neither cameras nor our eyes can correctly perceive information in dark areas in an otherwise bright environment or when subject to glare.

Adaptive illumination systems like matrix headlamps solve this problem as they use cameras to detect other road users and reduce the amount of light emitted in their direction. However, the capabilities of AI-based object detection are still limited. For example, oncoming vehicles are usually detected on the basis of their headlamp signature, and one's own illumination system needs a few moments to adapt the light distribution in the way that is intended. This time lag inevitably leads to dazzling other road users. If the vehicles to be detected also illuminate their environment, object detection can react to these light artefacts, allowing for a significantly faster response. In this way, the time lag can be eliminated, at least for curved-road scenarios.

Optimized street illumination

The detection of road users without any light sources (like pedestrians) is critical. While illuminating them with a low beam is often insufficient, a high beam dazzles the pedestrian. We want to solve this challenge and support camera-based object detection by developing an invisible near IR headlamp.

Today, regulations regarding headlamp illumination assume flat, straight roads. The next step to improving illumination quality is to consider the road's three-dimensional topology, including the number of parallel lanes, the position of sidewalks, cross-sections, and so on.

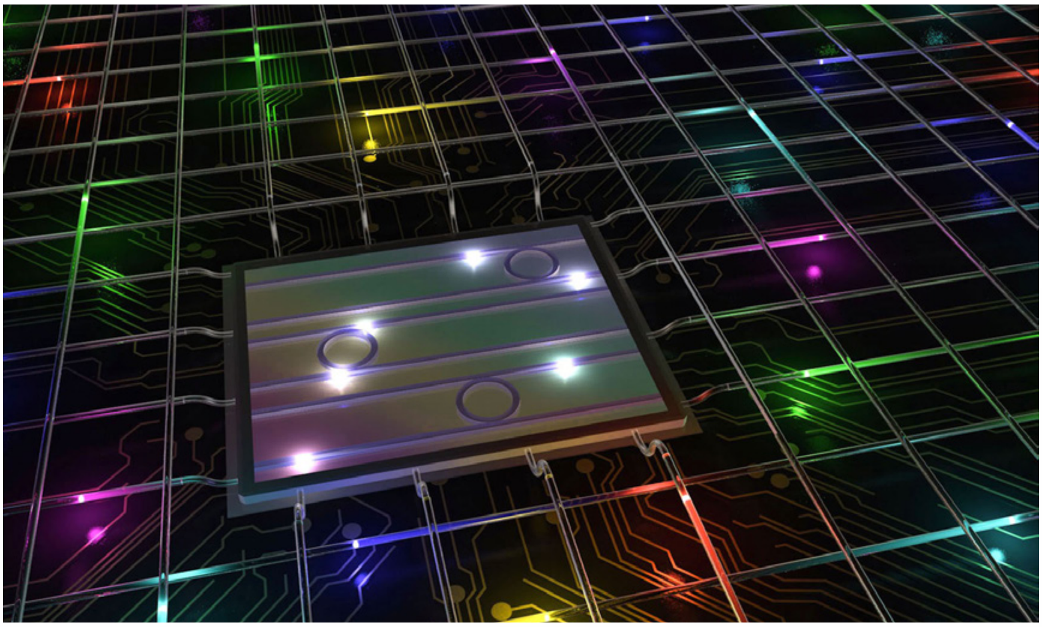
With this knowledge (and assuming correspondingly revised legal regulations), we can generate a theoretically ideal illumination of the traffic area. In addition, in a current research project, camera data identifies potential danger spots such as locations where pedestrians typically cross a road. Such dangerous situations can be prevented with adapted illumination and speed.

Light projections onto the road surface are currently in the approval process. In this way, a vehicle can communicate with its own driver and with other road users. A popular function is the projection of lines indicating the vehicle's width, assisting the driver when passing narrow construction sites.

Autonomous vehicle communication

In addition, an autonomous vehicle can signalize to a pedestrian that it is going to stop by projecting a crosswalk. Here, it is necessary to understand human vision more precisely, especially in the so-called mesopic range, the transition between day and night vision. So far, reliable statements can be made only about the boundary conditions (like the environmental illuminance) under which the projection can be perceived.

Photonic Quantum Technologies



Artistic representation of a photonic quantum network based on integrated chips and optical fibres.

Michael Kues

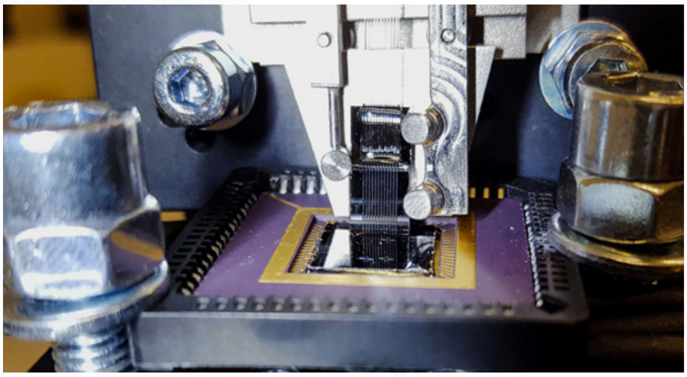
For more than 100 years, researchers have been exploring quantum physics, leading to major breakthroughs such as the laser, which is now in everyday use. In recent years, control over quantum systems has tremendously improved, allowing the fundamental performance advantages of quantum technology over classical approaches to be exploited.

Quantum systems can be used for example for quantum-enhanced metrology to improve length measurements, as it will be exploited in the next generation of gravitational wave detectors. Another example is quantum computing, which could accelerate computational tasks for specific problems and enable entirely novel solutions in e.g. medical drug development, material design and climate change simulations. However, current quantum computing technology is still in a proof-of-concept phase and needs to prove scalability to large-scale systems. More conceptually and technologically advanced is the realization of future-proof communication systems, i.e. communication techniques which cannot be decrypted by future advances in mathematical concepts or computing resources. Here, proof-of-concept systems in optical fibers, satellite configurations and even commercial devices already exist, which however require advances with respect to multi-user operation increased transmission rates and reduced complexity.

In PhoenixD we focus on photonic quantum technologies to transfer quantum technology out of the lab into real world applications. In contrast to other quantum systems that need cost-intensive cryogenic cooling, photonic systems can often work at room temperature. Photons come with the advantage that they are very robust to decoherence, i.e. they preserve the quantum state over long periods of time and distances. And photons are directly compatible with today's optical fiber communications networks, which allows us to exploit and make use of recent advances in this technology. Photonic quantum technologies can be used for optical communication in free space and in optical fibres, and are the only known way to realize secure quantum communication so far.

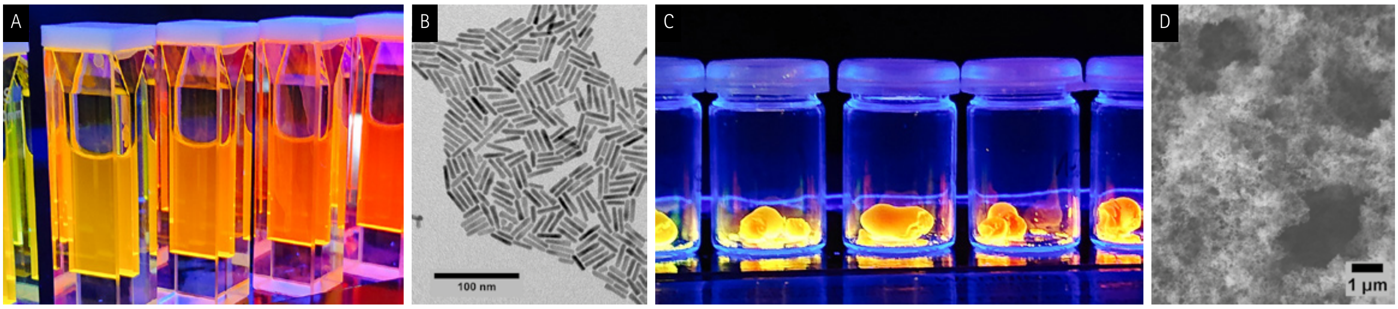
Integrated quantum photonic circuits

Bridging different disciplines in material research, photonic design and manufacturing, we at PhoenixD explore entirely new concepts for the realization of integrated, mass-producible and efficient quantum light sources of entangled states. We study the fabrication of waveguides for quantum circuits with advanced manufacturing techniques such as laser waveguide writing or flexo-printing. To realize more efficient and faster schemes to control quantum states, we exploit the modification of single photons using electro-optic and nonlinear effects in such waveguide systems. Our goal in PhoenixD is to develop devices with industry grade standards – bringing photonic quantum technologies to the next level of exploitation.



Integrated silicon chip for quantum information processing.

Functional Optical Materials



Photograph of highly emitting nanoparticles with different sizes (A); TEM micrograph of semiconducting cadmium chalcogenide-based nanorods (B); Photograph of highly emitting nanoparticle-based aerogels with different sizes (C); TEM micrograph of highly voluminous and porous semiconducting cadmium-chalcogenide nanorod-based aerogel (D).

Peter Behrens
Franziska Lübkemann
Nils Keppler
Nadja-C. Bigall

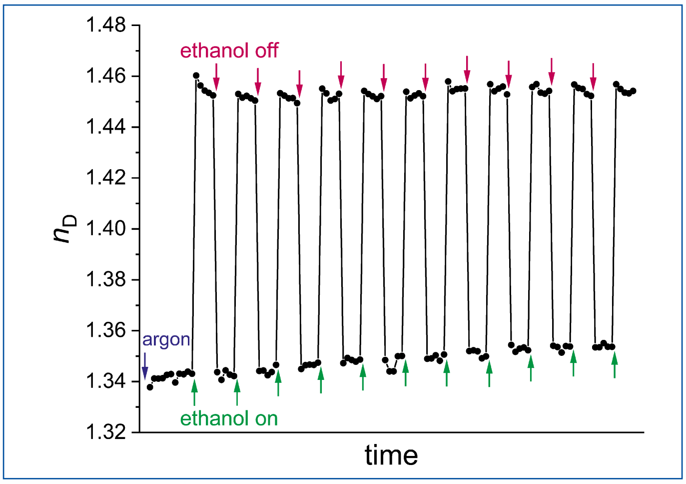
For centuries, glass was the optical material of choice. During the last decades this has been partially substituted by polymers. In order to access novel optical effects, the focus at PhoenixD is on novel types of materials, mostly nano-materials. On the nanoscale, novel properties emerge which can be utilized for modern optical components. Of special interest are dynamic, adaptive materials, the optical proper-ties of which can be influenced even after their preparation. Among the nanoscopic materials investigated are nanoparticles and their spatial arrangements as well as nanoporous materials.

Colloidal nanoparticles exhibit interesting properties which are strongly dependent on their materials composition, size, and shape (pictures top). By using different materials, like metallic, semiconducting, magnetic, or a combination of them, it is possible to tune the electrical, optical and magnetic properties of these materials. One way to further tune the properties of nanoparticles and to bring them into a manageable form is the controlled self-assembly of the individual nanoparticles into macroscopic gel structures. For this controlled self-assembly, different gelation techniques can be used, e.g. chemical oxidation, cross-linking, ice-templating and many more. The resulting so-called aerogels exhibit monolithic and nanoporous structure with a large specific surface area. By varying the nanoparticle building blocks and the type of gelation, aerogels with tailor-made properties can be produced, e.g. changes in optical properties like extending the exciton lifetime or changing the refractive index by varying the distance between the nanoparticles.

Metal-organic frameworks (MOFs) are crystalline nanoporous materials. These substances possess a modular construction, based on metal ions which are connected by organic linkers; together these two components build up a framework and so generate voids as the third constituent.

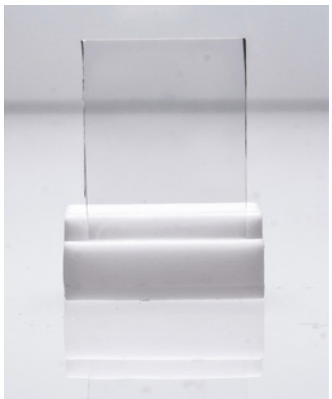
Changing the refractive index

Guest molecules can be introduced reversibly into these pores. By varying the different components, many different properties become accessible, for example dynamic changes of the refractive index (picture centre right). The research within this field is supported by simulation and modelling techniques, which form a cornerstone of the simulation efforts within PhoenixD, treating matter theoretically and essentially on the atomic scale.



Large reversible changes of the refractive index n_D can be obtained in a MOF material by adsorption and desorption of ethanol.

A focal point within functional materials chemistry at PhoenixD is the development of preparation processes that can be inte-grated into modern, fast and economic manufacturing tech-niques. These can be used within the Manufacturing Grid to be established at PhoenixD. Coating techniques are a way to imple-ment novel materials into these processes. For example, highly transparent coatings of MOFs can be obtained (picture bottom).



High quality coatings of crystalline materials – like the one of a MOF shown here – are often difficult to achieve (and hard to see, when the quality is really high).

Interview with Luc Bergé:

"Optical Megatrends will Change Humanity"

Sonja Smalian

Luc Bergé is President of the European Physical Society (EPS) since April 2021. Previously, he chaired its Quantum Electronics and Optics Division (QEOD) between 2013 and 2017, and he was a member of the EPS Executive Committee between 2016 and 2020. He is also a member of PhoenixD's International Advisory Committee. As a theoretical physicist, he has focused his scientific activities on nonlinear optics, laser-plasma interaction and terahertz pulse generation induced by femtosecond pulses in gases. With his team at CEA, the French Commission for Atomic Energy and Alternative Energies, he explores new ways of producing energetic terahertz waves using ultra-intense laser pulses operating at relativistic intensities. In the interview, Luc Bergé gives an overview of current market developments in optics and photonics.

What makes optical technologies a key technology of the 21st century?

Luc Bergé: You find optics everywhere. Our modern societies are in fact organized around optical technologies. Think of all the optical fibres that enable our communication requirements to be met. Light is used for imaging the nanoworld or biological systems like skin tissues. We use light for accessing ultra-short time frames and atom or even electron motions on attosecond scales.

What about our big hunger for energy? Can photonics help there, too?

Bergé: We can use light for building up large photovoltaic plants and the energy of the future – hundreds of powerful lasers are being used in giant facilities to produce thermonuclear energy through inertial confinement fusion. For example, in France, we have the MegaJoule Laser facility near Bordeaux, which is the European counterpart of the National Ignition Facility in the US. Its converged 176 laser beams can reproduce phenomena similar to those observed within stars.

Where else do we rely on optical technologies?

Bergé: We can use light for quantum computing so as to improve the performance of classical CPU computers by a factor of 1000. Light is the main tool for exploring the quantum world and increasing computational capabilities through quantum computers (qubits) in the future. Besides, the European Space Agency (ESA), NASA and the Canadian Space Agency launched the new James Webb Space Telescope in 2021, which will enable us to probe the universe into its first billions of years.

Light is an extremely versatile tool. Which megatrends are you expecting to arise in optics?

Bergé: There will certainly be significant break-throughs in the fields of quantum technologies, astrophysics and cosmology. Extreme laser light with a high level of intensity can also produce various harmonics and thus deliver new radiation sources, e.g., from the terahertz to the X- and gamma-waves ranges with numerous applications to probe all states of matter and even change some of their properties. On the other hand, we have high expectations of achieving the "break-even" - a kind of „holy grail" in thermonuclear fusion – that will lead to the next sources for clean energy generation. All these optical megatrends should change humanity.

Who are the leaders in the game?

Bergé: Optical instruments and devices have a long tradition in Germany with companies like Zeiss in Jena. Regarding laser technology, France is strong with the company Amplitude, but Germany is too with Trumpf. Regarding quantum technologies, Europe has had a head start. However, the world market in quantum technologies seems today to be led by China, followed by the U.S. and Europe.

Do you think the Excellence Strategy of the German Research Foundation DFG has had an impact beyond Germany?

Bergé: The DFG's strategy enables research groups to showcase their activities and contribute to impulse new heavy scientific infrastructures being supported both by the German „Länder" and the federal government. It seems to me that the German research funding system, in particular through the establishment of clusters of excellence, is crucial to pool skills and gain higher visibility in Europe and beyond. This is an excellence strategy that can attract creative researchers from outside Germany and that sparks the admiration of other nations.

Besides the megatrends, which fields of industry and research will have the most significant impact on optics and photonics now and in the future?

Bergé: The "Quantum Flagship Initiative", inspired by the second quantum revolution and launched by the European Commission in 2018 with a funding of €1 billion for ten years, will definitely have an impact. The flagship brings together research institutions, universities, industry, and policy makers, in a joint and collaborative initiative on an unprecedented scale. We'll see many new enterprises and spin-offs appear on the market. We already see many of them today. Other areas are biophysical imaging, applications of light in medicine, particularly UV-radiation and THz spectroscopy of viruses and proteins, and the fields of nano-photonics and metamaterials. In the future, I see four or five rising stars: the all-optical internet with high-rate data delivery, laser fusion, quantum computing using qubits, change matter with light, and deep learning applied to correcting the data of optical diagnostics.

We've talked a lot about the bright side of photonics. Where do you see significant problems?

Bergé: Science and industry have to recruit highly-educated young people having the appropriate knowledge both in science and entrepreneurship, which means knowing the market rules. These candidates are missing in large numbers. Following the Photonics21 PPP association, the global market value of optics and photonics represented around €450 billion in 2015, and is expected to reach €800 billion in 2023! The Leibniz School of Optics & Photonics (LSO) will play its part in meeting the demands. But we need many more university graduates. The Covid pandemic has shown us that we have to improve the capacity of the internet. And there is a demand for more light-based sensors and detectors in all branches of the industrial market, in the defence and security sectors. Highly competent people are needed everywhere, and opportunities are boundless in optics and photonics.

> Knowledge in science and entrepreneurship required

With such a high demand, it should be a good time to launch a spin-off. How can universities foster entrepreneurship?

Bergé: Universities should have a look at Télecom Paris Tech in France or the University of Groningen in the Netherlands. Both have established special schools to teach entrepreneurship within the university, offering courses on how to move from academia to the market side. In September 2021, I was a co-organiser with the EPS of the meeting "Rencontres Physique – Entreprise – Recherche" in Paris, where we proposed a special session on entrepreneurship followed by many young researchers. I am convinced that such initiatives to welcome representatives of the industrial world in academic campuses will help to increase the number of spin-offs from universities.

Info

The European Physical Society (EPS) represents more than 130,000 physicists in Europe and is an umbrella organisation for 42 national physical societies. The EPS advocates physics and its contribution to the economic, technological, social and cultural development in Europe. It promotes excellence in research and cooperation with physics-based industries, education and student mobility, publication and outreach. The EPS contributes to the advancement of physics, in particular through the promotion and the inclusion of young physicists at the international level. It also fosters scientific exchange, in particular in optics and photonics, through three leading conferences: CLEO/Europe in Munich, which attracts more than 2000 researchers and 35,000 engineers from optical industry, the Nanometa conference on metamaterials and plasmonics, and the Europhoton conference with a focus on fibres and solid-state lasers. The next Europhoton conference will take place from 28th August to 2nd September 2022 in Hannover, in cooperation with PhoenixD, Leibniz University Hannover and the Volkswagen Foundation.

Interview with Volker Pape:
"I Expect Great Developments in X-ray Technology"

Sonja Smalian

Together with his partner, Volker Pape founded the company Viscom, which today sees itself as a leading specialist in the inspection of electronic assemblies of all kinds. The 67-year-old has meanwhile joined the Viscom supervisory board and advises PhoenixD as a member of the International Advisory Committee.

Volker Pape discovered his interest in digital image processing while studying electrical engineering at the University of Hannover. He spent long nights at the university's computer centre testing the new technology and met Martin Heuser in the process. At the bicycle stand of the computer centre, the two students developed a business idea and founded an engineering office for image processing in 1984. At the beginning, they measured tree trunks three-dimensionally and inspected CDs and nicotine patches. Today, Viscom concentrates on the quality control of assemblies, components and batteries by means of optical inspection and X-ray technology, among others for suppliers to the automotive industry and manufacturers of smartphones and tablets. Today, Viscom has around 450 employees worldwide. The company's headquarters are in Hannover, where all production takes place. In an interview, Viscom Supervisory Board member Pape, who is a member of the PhoenixD International Advisory Committee, reveals which technological developments he expects in optics and photonics in the future.

Mr. Pape, what do you think makes optical technologies a key technology of this century?

Volker Pape: One important criterion is that they are used almost everywhere because of their breadth and diversity. Just three examples: A popular topic right now would be autonomous driving, which is made possible by cameras and laser scanners. Like humans, the cars orient themselves by optically recording their surroundings. The broad field of communication technology should also not be forgotten. Optical data transmission, especially via fibre optics, has long been an established standard. Laser technology also plays an important role here, but also in a completely different field: manufacturing technology, as lasers are used for welding, shaping and cutting.

The two of you founded Viscom some 38 years ago. What optical technologies does your company rely on?

Pape: At Viscom we use optical measuring technology. For this we traditionally work with camera technology and visible light, but for many years we have also been using X-ray technology. Even with X-ray technology, physicists are already talking about X-ray photons, i.e. light. Everyone knows X-ray images from medicine. We pass beams through products and produce a two-dimensional image. And from quite a lot of them we put together three-dimensional models as with the CT scan at the doctor's - and can detect many different effects.

What exactly do you examine with X-ray technology?

Pape: We check, for example, whether all the components are present in closed devices and whether they are in the right place. For example, a loose metal part in a mobile phone can exert pressure on the battery and thus cause the famous fire in your pocket - we prevent that. Such short circuits can also occur inside batteries due to assembly errors. By the way, at Viscom we also develop and manufacture our own X-ray tubes. These are so-called "open tubes" that are suitable for high power and are very easy and inexpensive to maintain.

What megatrends do you expect in optics and photonics?

Pape: In communication technology, optics will have to develop further because industry simply requires it. With the demand for higher data transmission rates, there is also social pressure. I am also counting on further progress in laser technology. I also expect that higher resolutions of fine structures such as semiconductors will continue to be possible at shorter wavelengths. But here we are already talking about extremely short wavelengths.

Will these developments also have an impact on your company?

Pape: Yes, we are very active in electronics testing with optical inspection devices, and this is clearly a growth area. If electromobility also expands more and more, we can expect an increase in the quantity and quality of our tasks, because both battery chargers and e-motors have many components from the field of power electronics. The finer and more precise optical technologies become in the future, the faster and more precisely we will be able to inspect the smallest structures of power electronics.

How are you doing that at the moment?

Pape: Take compounds like the sintering of electronic compounds. There we had to come up with a few special features to make testing possible. But the basis of X-ray technology will also provide us with steady growth in the next few years. There we are working on better options to control timing, and expect sensors with higher sensibility and higher resolution. We definitely expect further developments, but as a small company we can't get massively involved in basic research ourselves.

Is that why you are seeking contact with PhoenixD?

Pape: Yes, we interact well on the subject of X-ray technology. We can also contribute our own know-how in this area. Otherwise, due to the pressure of orders in the company, we have little capacity to follow the current trends in basic research. But if there are new, market-ready technological developments, we at Viscom look very closely to see if we have applications and customers for them. We hope, for example, that the lighting modules we manufacture discretely today can be made easily and cheaper with integrated or partially integrated solutions that PhoenixD is working on. When you're that close, it naturally helps when evaluating technological trends.

Where do you expect the greatest scalability in optics and photonics in the future?

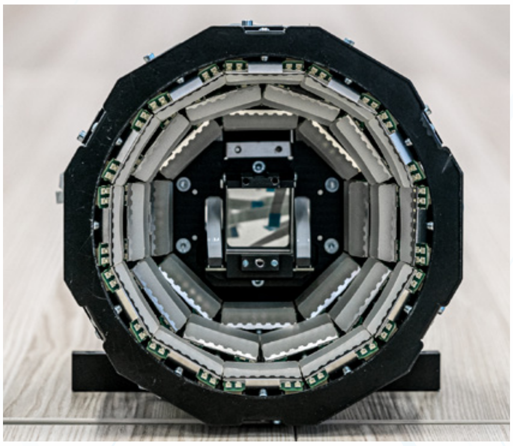
Pape: Clearly in X-ray technology, because in the exposure of semiconductors we will need ever finer structures. To build faster processors that are no longer 'thermal power plants'.

As an entrepreneur, where do you see the biggest problems in photonics research today?

Pape: I would like to see much more global cooperation in research than we are currently experiencing. Because it is becoming more and more difficult to keep track of even one subject area with the daily increase in knowledge worldwide. Every day the data situation becomes more complex and we build up a huge amount of knowledge, but there is no meaningful channelling system to be able to use the knowledge.

This trend is certainly furthered by the fact that the individual disciplines have to work together more and more. How important do you consider interdisciplinary research in optical technologies to be?

Pape: If I just look at the modest spectrum we work on, I see a variety of technologies in use. We have to answer questions from the fields of electronics, camera technology, software, hardware connection, 3D printing, mechanics, sensor technology, lighting technology, data transmission, and much more. Only in an integrated way can these technologies mature into a meaningful solution. This is why an interdisciplinary approach is so terrifically important, both in research and in application-oriented practice.



Volker Pape brought an illumination unit from Viscom with him to the interview, which can be used to inspect so-called bond connections (wire bonds) with highly reflective wires on reflective surfaces such as silicon chips. These bond wires are used, for example, in power electronics in vehicles (starters, e-mobility). Power peaks of 1,000 amps and more are not uncommon. Very inconspicuous in appearance, the precise coupling of the illumination and the beam path for the imaging prevents interference from a direct reflection.

Our First Three Years
Milestones and Selected Events

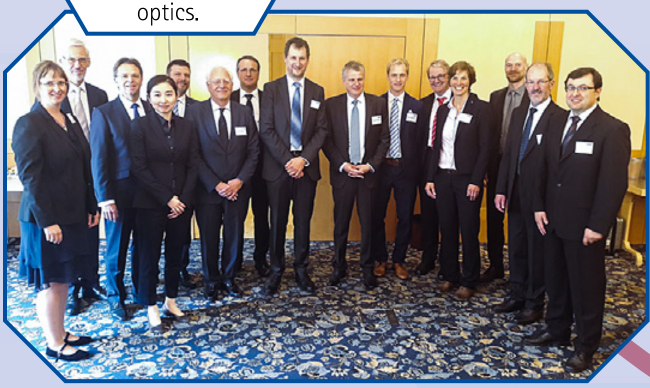
Sonja Smalian

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 DFG German Research Foundation invites PhoenixD to submit 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
DFG grants Leibniz University Hannover funding for PhoenixD and two further projects: 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 eriod 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

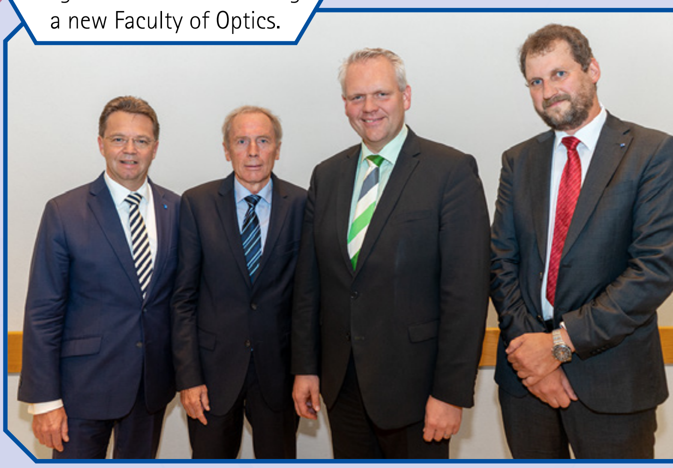
Stefan Muhle (left), State Secretary of Lower Saxony's Ministry of Economic Affairs, Employment, Transport and Digitalisation, presents the "Digital Venue Niedersachsen" award to the Laser Zentrum Hannover e.V. (LZH). Dr. Dietmar Kracht, Executive Director of LZH, accepted the badge of honour on behalf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

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.

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).

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

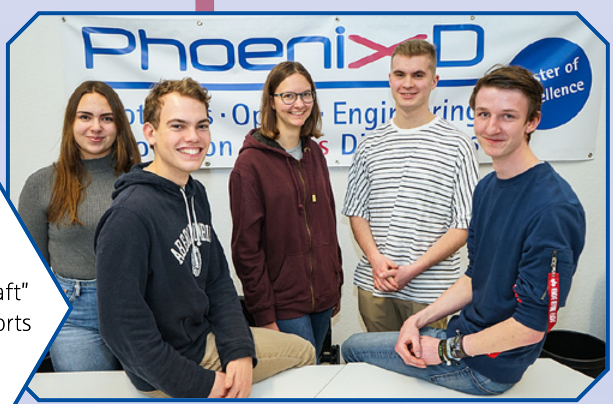
The Cluster holds its first retreat, an annual scientific plenary meeting and its first Summer School for the PhD students of the PhoenixD Research School at Hotel Schnuck, Schneverdingen.

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

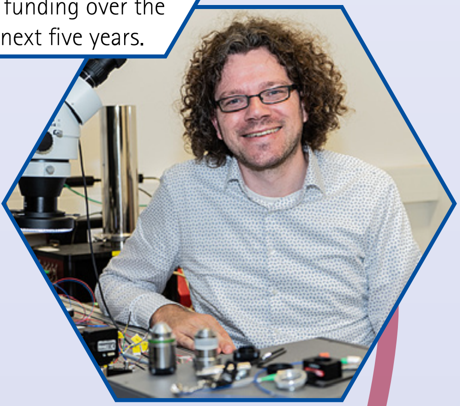
The Working Group of German University Professors of Chemistry in the German Chemical Society (GDCh) grants the ADUC award for excellent young scientists to Jannika Lauth for establishing her own field of research on 2D semiconductors.

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 euros 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 Lasertechnik 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 defends the proposal for the OPTICUM a second time in an online call with the German Council of Science and Humanities.

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
2nd July 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.

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
Marina Rosebrock (31) from the Institute of Physical Chemistry and Electrochemistry receives the first "PhD Award" of the PhoenixD Research School during a meeting of the PhoenixD General Assembly. The prize is a funded position to pursue one's research for one year.

19/04/2021
The School of Optics & Photonics (LSO) is granted permission to award doctorates.

28/04/2022

The state of Lower Saxony is supporting 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 euros 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 scientific workshops PhoenixD Laser Day 2022 and Hannover Materials Chemistry Symposium take place in person at LUH.

02-10/07/2022

PhoenixD is to present its educational programme at the LUH stand at the fair IdeenExpo in Hannover, including the new Bachelor's degree Optical Technologies: Laser and Photonics, the Voluntary Scientific Year (FWJ), and PhoenixD's project workshop PROTOYS. Uwe Morgner, Bernhard Roth and Anatoly Kukk will talk on stage. The IdeenExpo is Europe's largest youth event for technology and science, attracting more than 395,000 visitors from Germany and European countries.

28/08-02/09/2022

The 10th EPS-QEOD Europhoton Conference on Solid-state, Fibre and Waveguide Coherent Light Sources will take place at Herrenhausen Palace in Hannover. PhoenixD is the official partner of the European Physical Society (EPS) and Quantum Electronics and Optics Division (QEOD) of the EPS for organizing this international conference in collaboration with the Volkswagen Foundation. The General Chair of the event is PhoenixD spokesperson Uwe Morgner. In addition, Michael Kues will give a lecture at the two-day Summer School of the conference.

12-16/09/2022

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

You have not reached 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 to apply for follow-up funding.

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German Research Foundation

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