Leibniz ipht
LEIBNIZ INSTITUTE of PHOTONIC TECHNOLOGY

reflexion

Annual Report 2021

Solutions with Light

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From Ideas to Instruments

Leibniz Association

jenaphotonics®

PHOTONICS FOR LIFE
from Ideas to Instruments

Dear Readers,

Prof. Dr. Jürgen Popp © Sven Döring

Frank Sondermann © Sven Döring

Science is part of our society. The drive for knowledge, the generation of knowledge and its dissemination, as well as the creation of innovative solutions is closely interlinked with the history of mankind, and has contributed to improving our lives, making it safer and healthier, not just since the invention of the wheel. Innovations permeate our everyday lives and are valuable additions to our society in many ways. This mission for society as a whole is also reflected in the self-image of the Leibniz Institute of Photonic Technologies. We research light-based solutions for urgent issues of our time in the fields of medicine, health, environment and security.

In order for our work to meet these high standards, it is essential to transfer our knowledge, results and innovations and make them available for the benefit of the community. In our credo *"Photonics for Life. From Ideas to Instruments"*, this idea of transfer is firmly anchored.

So how can we succeed in turning findings from basic research into application-oriented solutions that are transformed into marketable innovations suitable for everyday use? How can we make our knowledge available to the scientific community and broad sections of society? How can we inspire younger generations from our work and spark their interest in a career in science? In this issue of the annual report, we would like to focus on these questions and present to you, dear readers, our approaches that bring us closer to these goals.

Knowledge and technology transfer must be actively pursued and thrive on interaction and exchange. The basis of our successful work and proven scientific excellence is our committed and motivated workforce. And it is the numerous partners from science, industry and politics, as well as friends and sponsors, with whom we have been working closely and trustfully for 30 years now. We would like to express our sincere thanks to all these people. The results and progress we present on the following pages of this issue would not be imaginable without their commitment and support.

We hope you really enjoy reading this issue!

Jürgen Popp
Scientific Director

Frank Sondermann
Administrative Director

Content

Happy Birthday!

Leibniz IPHT Celebrates its 30th Anniversary

For 30 years now, (Leibniz) IPHT has been an integral part of the research landscape. The academic roots of the institute, which was initially founded as a state institution under the name Institute for Physical High Technology, go back to the 1950s. Leibniz IPHT pursues the vision of using light to find solutions to questions and pressing problems in the fields of health, environment, medicine and safety that make life safer, healthier and cleaner. Today, the institute is one of the leading international research institutions in the field of optical health technologies.

Foundation
1992

2005-2006
Structural Commission headed by Prof. Dietrich Wegener (TU Dortmund)

Profiling with a focus on photonics in life sciences
2007

2011-2013
Evaluation process for admission to Leibniz Association

Admission to Leibniz Association
2014

2014-heute
Further profiling in the field of photonic technologies for system solutions in the areas of health, environment, medicine and security

Successful evaluation
2019

> "The work of the institute is not only scientifically but also socially highly relevant (...). IPHT meets the requirements of an institution of supra-regional importance and national science-policy interest."

Statement on the evaluation of Leibniz IPHT by the Senate of the Leibniz Association (July 15th, 2020)

From Basic Research to Clinical Use

Translation Paves the Way to Better Diagnostics

How can age-related diseases, such as Alzheimer's, be diagnosed better and at an early stage? How can a dangerous sepsis be recognized and treated acutely within a very short time? And how can antibiotic-resistant pathogens be reliably detected?

In order to find answers to these and similar questions and challenges of our time, Leibniz IPHT conducts research on new light-based solutions and technologies. They lay the foundation for faster and even more accurate medical diagnostics and improved therapy of diseases.

However, only when innovative approaches and processes are transferred into marketable products, doctors can accurately detect diseases and initiate target-oriented therapy measures for affected patients.

Translational infrastructures are required to pave the way from science to clinical application for the benefit of society. To this end, Leibniz IPHT cooperates closely with partners from research, industry, and medicine in various translation networks in order to transfer ideas and academic results into medically proven and patient-friendly products and systems:

29 partners from science and industry are working on tomorrow's infection diagnostics and research as part of the **InfectoGnostics research campus**. New methods will be used to reliably detect infectious agents and antibiotic resistance and to gain a better understanding of the immune response. Promising approaches in basic research are quickly translated into powerful diagnostic solutions and products thanks to the close collaboration between research, industry, and medicine.

At the **Center for Sepsis Control & Care (CSCC)**, sepsis and other dangerous infections, their causes, and long-term effects are intensively researched. Basic and clinical researchers work together intensively to develop effective diagnostic methods and acute treatment concepts.

The research of age-associated diseases such as Alzheimer's, Parkinson's or cancer is the focus of the **Center for Translational Medicine (CeTraMed)**. The aim is to elucidate the processes and procedures behind these diseases in order to derive modern diagnostic concepts as well as therapeutic measures for the benefit of those suffering from those conditions.

At the **Leibniz Center for Photonics in Infection Research (LPI)**, science and industry will work hand in hand in the future in a user-friendly translational infrastructure to quickly transfer light-based technologies and processes into application and thus achieve better diagnostics and therapy of infections. The transfer of new approaches into commercial products and processes should thus be significantly accelerated.

Leibniz ipht

InfectoGnostics
Research Campus Jena

CeTraMed

LEIBNIZ CENTER *for* PHOTONICS *in* INFECTION RESEARCH

Center for Sepsis Control & Care

A Look into the Inside of the Body: On the Trail of Cancer

In an initial field test of the *invaScope* system in Denmark, the fiber-optic Raman probe was inserted directly into the bladder in the operating room to detect bladder cancer.

© Iwan Schie

Around 19.3 million people worldwide are diagnosed with cancer every year[1]. The sooner a tumor can be detected and treated, the better the chances of recovery for affected patients. There is a great need in tumor surgery for new technologies that are able to precisely locate tumors in order to remove them as completely as possible, and that enable a reliable tumor typing and classification to quickly initiate an individual and customized therapy plan for a patient.

Leibniz IPHT is working on various endospectroscopic solutions to address these medical problems, which have been insufficiently addressed so far: A multimodal imaging endoscope concept (page 14) offers the potential to distinguish tumorous from healthy tissue directly during a surgery by generating spatially high-resolution tissue images containing both morphological and biochemical information. To further characterize tumors in terms of tumor grading and staging, the *invaScope* (page 12) – a Raman-based system – was developed to enable physicians to characterize conspicuous tumor tissue histopathologically with pinpoint accuracy, without markers and without taking a biopsy.

Compact and flexible: The *invaScope*, which Iwan Schie (right) developed together with his team, combines all the necessary components for the diagnosis of bladder cancer in a compact design. © Sven Döring

Characterize bladder cancer in-vivo using optical biopsy

Bladder cancer ranks tenth among the most frequently diagnosed carcinomas worldwide. Men suffer more often from this type of cancer than women. In 2020, 212,536 people with bladder cancer – almost 40 percent of those affected – died of the disease[2]. Bladder cancer ranks 13th in the death statistics, alongside lung cancer, cancer of the digestive tract and breast cancer. Improved diagnosis significantly increases the chances of a cure.

Until a clear diagnosis of bladder cancer can be made, it usually takes a few days up to several weeks, during which persons affected live in uncertainty. If cancer is suspected, doctors take a tissue sample from the urinary bladder to differentiate a harmless tissue change from a malignant carcinoma. The sample is then analyzed under the microscope in a histopathological examination. If the diagnosis is "cancer," further operations and accompanying therapeutic measures follow.

However, the histopathological examination only provides information on morphological tissue characteristics, such as structure and shape of the extracted cells. Important biochemical information is not covered. A molecular fingerprint of affected cells would allow a more precise diagnostic characterization of the tumor and help to better predict the course of the disease.

In order to improve bladder cancer diagnostics and at the same time shorten the time of uncertainty for persons affected, the EU project "MIB" (Multimodal, endoscopic biophotonic imaging of bladder cancer for point-of-care diagnosis) was launched in 2016.

Together with ten European partner institutions, Leibniz IPHT took on the task of developing a compact imaging endoscopic system for the detection of bladder cancer as part of the project. "The *invaScope* is intended to effectively support physicians in the characterization of bladder tissue. Tumor diagnosis will be possible in a quick and painless manner directly in the urinary bladder and in real time. Findings will be available within a very short time, and health risks for patients will be significantly reduced. Medical interventions, such as cystoscopies, can be associated with complications for those affected, for example with bleeding, bladder perforations or infections," explains Prof. Dr. Iwan Schie, head of the Working Group Multimodal Instrumentation in the Department Spectroscopy / Imaging at Leibniz IPHT.

A special challenge on the way to this system was the development of an endoscopic fiber probe suitable for clinical use. The aim was to make the fiber probe extremely thin, flexible, and robust to enable uncomplicated access to the bladder via the urethra. It was particularly important to ensure that no surrounding tissue would be injured, the examination would involved minimal risks and would be painless for patients. Moreover, the probe also had to be biocompatible and sterilizable. Thanks to the close cooperation with physicians from the Hovedstaden region in Denmark and the medical technology manufacturers Blazejewski MEDI-TECH GmbH and 2M Engineering, the application-related and regulatory requirements could be considered even during the research.

"The European Medical Device Regulation (MDR) imposes very high requirements in terms of documentation, functionality and safety on devices for clinical-investigative research. For us at Leibniz IPHT, the development of the *invaScope* is the first realization of a system for in-vivo use on humans – much in line with the motto *'From Ideas to Instruments'*," explains Iwan Schie.

In ex-vivo studies, the researchers first demonstrated on biopsies that Raman spectroscopy, in particular, is suitable for diagnosis of bladder cancer and tumor grade differentiation. It enables label-free biochemical characterization of tissue samples. With an accuracy of 92 percent, it was possible to distinguish healthy from tumorous tissue. In differentiating between highly malignant and less malignant tissue, the accuracy was 84 percent.

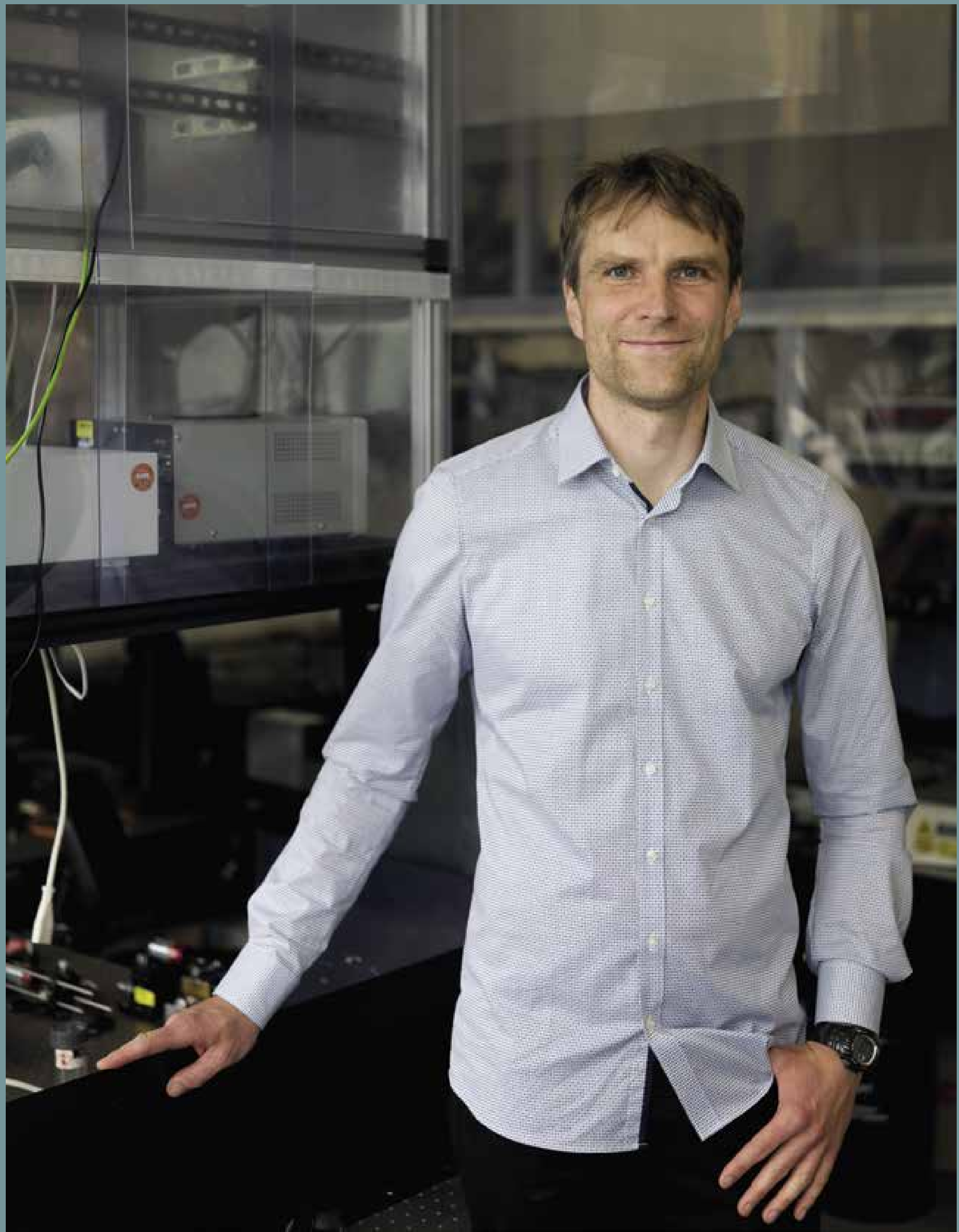
The diagnostic performance is improved by combining different optical methods. "In collaboration with the Medical University of Vienna, we were able to show that different optical methods can be well combined and complement each other in diagnosis. The combination of optical coherence tomography, or OCT, and Raman spectroscopy offers the advantage of being able to obtain both depth-resolved structural and molecular information from samples. Doctors thus obtain comprehensive and meaningful diagnostic information about the aggressiveness and stage of a bladder carcinoma," continues Iwan Schie.

Endoscopic, fiber-optic Raman probe that helps distinguish healthy and diseased tissue. © Iwan Schie

In 2021, the work on the endoscopic system with fiber-optic Raman probe was completed. The developed probe can be sterilized several times and is therefore reusable. All elements necessary for Raman spectroscopy, such as laser, spectrometer, and camera, are integrated in a compact and splash-proof housing, and are supplemented by software specially developed for clinical use. The Raman system is installed on a medical equipment cart and can be used flexibly in operating rooms or outpatient clinics.

At the Copenhagen Herlev Hospital in Denmark, the *invaScope* system was subjected to a practical test at the end of 2021 as part of a clinical study. Using the new instrument, physicians were able to examine the bladder wall of 20 study participants within a few minutes each using Raman spectroscopy. For this purpose, the probe was inserted into the bladder through the working channel of a nephroscope, the probe tip was brought into contact with the bladder wall, and the measurements were started. A brightfield camera connected to the system provided simultaneous images from inside the body and assisted in the selection of the tissue region.

"It was fascinating to see the results of our work from the past few years live in the clinical setting. The Danish physicians were convinced by the ease of use of the system and are interested in continuing the development towards a medical product," Iwan Schie summarizes. In addition to medical benefits, the *invaScope* could offer economic benefits: Expensive and time-consuming operations involving surgeons, anesthetists and nurses could be better planned due to improved diagnostics, and could be performed in



Dr. Tobias Meyer-Zedler wants to advance tumor diagnostics together with his team and with a newly developed endomicroscope. © Sven Döring

a more targeted manner. This could save costs in the healthcare system.

The endoscopic approach and the uncomplicated operation of the system will make other hard-to-reach regions of the body accessible for application. In a subsequent clinical study, the suitability of the system for the diagnosis of cancer tumors in the neck and head region will be demonstrated.

Tumor margin detection with triple imaging

Researchers at Leibniz IPHT, together with the company Grintech from Jena, have researched and developed a multimodal endoscope for improved tumor margin detection.

So far, surgeons have had to rely on the findings of frozen section diagnostics to be able to see whether a tumor has been completely removed during surgery.

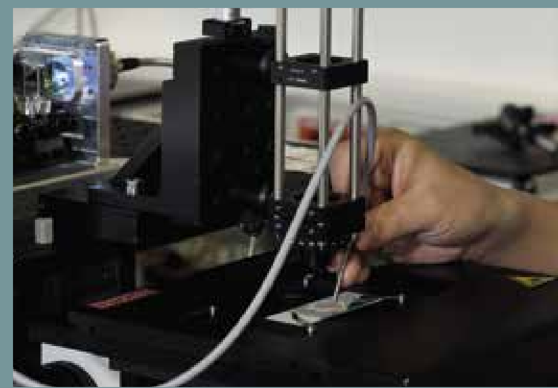
The evaluation of the results requires many years of experience and can sometimes be incorrect. Only a subsequent intensive pathological examination of the removed tissue provides certainty. It can take up to four weeks for an exact finding to be available. For patients, this is a time of agonizing uncertainty – during which any remaining tumor cells may already be multiplying again.

Scientists at Leibniz IPHT have researched a diagnostic method that could revolutionize the previous procedure: The endomicroscope is able to reliably distinguish healthy from tumorous tissue in real time in-vivo during a surgery. For this purpose, the system combines powerful laser, innovative optical fiber, and endomicroscopic lens.

"In the previous project 'MediCARS', we researched a method for multimodal tissue diagnostics. We have now transferred the experience gained here into a miniaturized flexible endoscope design. Together with our partner, the Grintech GmbH, this has resulted in one of the most compact and powerful endoscopes for gentle in-vivo imaging – an even smaller realization is hardly possible," explains Dr. Tobias Meyer-Zedler, head of the Molecular Imaging Group in the Spectroscopy / Imaging Department at Leibniz IPHT.

To be able to generate as much information as possible from the tissue to be examined, the researchers combined three imaging techniques: coherent anti-stokes Raman scattering, frequency doubling, and two-photon excited fluorescence microscopy. This multimodal approach visualizes tissue structures and their molecular composition as well as morphology down to the submicrometer scale without labeling. "The generated images can even compete with those of high-resolution, high-end microscopes," summarizes the researcher.

An important milestone in this development was the realization of the double-core double-clad optical fiber, which was designed for both laser guidance and signal acquisition. With expertise from several decades of experience, the fiber experts at Leibniz IPHT developed a microstructured fiber consisting of two cores for guiding the two excitation lasers for coherent anti-stokes Raman scattering, which are used to irradiate the tissue from both cores with light. The two cores are surrounded by an outer cladding that collects the tissue's response to excitation by laser light.



The endomicroscope is designed to precisely assist physicians in the removal of tumors. © Sven Döring

"In order to make the concept fit for clinical application, further challenges lie ahead: We will, for example, further refine the endoscope technologically and perform clinical tests. The approval as a medical device will be another important milestone. In a few years, our endoscope could contribute to optimally support cancer diagnostics in a minimally invasive manner," says Tobias Meyer-Zedler.

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Publication:
Schie, Iwan W. et al, Scientific Reports 11, 9951, 2021, https://doi.org/10.1038/s41598-021-89188-2

Pshenay-Severin, Ekaterina et al., Light: Science & Applications 10, 207, 2021, https://doi.org/10.1038/s41377-021-00648-w

[1] Cf. Statista: Number of new cancer cases worldwide by cancer type in 2020, 2022: https://de.statista.com/statistik/daten/studie/286545/umfrage/zahl-der-krebsneuerkrankungen-weltweit/ [17.01.2022]

[2] Cf. Statista: Number of cancer deaths by cancer type worldwide 2020, 2022: https://de.statista.com/statistik/daten/studie/286584/umfrage/zahl-der-krebstodesfaelle-nach-krebsart-weltweit/ [18.01.2022]

Automated high-throughput Raman system for the rapid characterization of cells.

Cutting-edge Research with Light

Market-ready Solutions in the Fight Against Infections

Leibniz Center for Photonics in Infection Research (LPI) is an open-user one-stop agency.

As a globally unique research infrastructure, the center will help revolutionize the development of market-ready light-based diagnostic procedures and novel therapeutic approaches for the treatment of infectious diseases. All development steps, from the concept to the certified medical product, will be considered in a holistic process. LPI is still under construction – but scientific preliminary work has already begun and management structures have been set up.

"We complement state-of-the-art technologies with new photonic methods that are not commercially available today. In the future, users from science and industry will have access to a broad spectrum of unique light-based and molecular biological methods in combination with all the necessary technologies to accelerate the translation of new methods for diagnostics and treatment of infectious diseases. We bring excellent research, technology development and clinical practice closer together. Thus, LPI will also enable small and medium-sized companies to achieve standardized results more quickly. After all, not every small company has to reinvent the wheel," says Jürgen Popp, LPI spokesman, describing the center's approach.

Since last year, researchers from the four supporting institutions have been working in inter-institutional projects to increase the technical maturity of the basic technologies (TRL – Technology Readiness Level) in order to prepare them for use in LPI.

Leibniz Center for Photonics in Infection Research (LPI)

The Leibniz Center for Photonics in Infection Research is a project funded by the German Federal Ministry of Education and Research. 124 million euros will be made available for the realization of the idea in the coming years. The supporting institutions of the LPI are the Leibniz Institute of Photonic Technologies (Leibniz IPHT), the Leibniz Institute for Natural Product Research and Infection Biology Hans Knöll Institute (Leibniz HKI), the Friedrich Schiller University, and the University Hospital Jena.

Modern Equipment for the Fight Against Infectious Diseases

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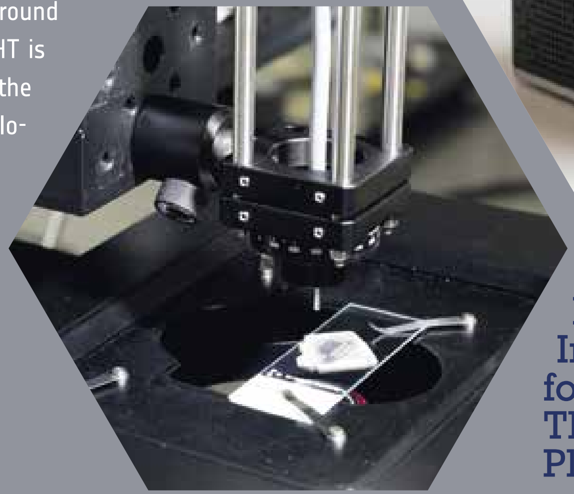
In the course of 2021, the development of the LPI's technological infrastructure started: The Federal Ministry of Education and Research is funding five projects designated as basic technologies with around 50 million euros. Leibniz IPHT is contributing its expertise in the field of optical health technologies to the projects.



Multidimensional, Multimodal, Intelligent Imaging Platforms

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The subject matter of the project is research and development of innovative imaging platform technologies for infection-relevant application scenarios combined with new concepts for sample preparation of cells, tissues as well as organ models and organs. The work at Leibniz IPHT includes methodological and technological realization and provision of multimodal imaging procedures with the aim of recording morphological and chemical changes in biological structures.

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Project coordinator:
Leibniz IPHT

Photonic Interaction Assays for POCT / High Throughput Platforms

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In the project coordinated by Leibniz IPHT, methodological and instrumental biophotonic platform technologies for point-of-care (POC) and high-throughput applications are researched and realized as basic technologies for LPI. Leibniz IPHT focuses on research and development of compact instruments, analysis strategies and methods for the preparation of liquid samples in particular.

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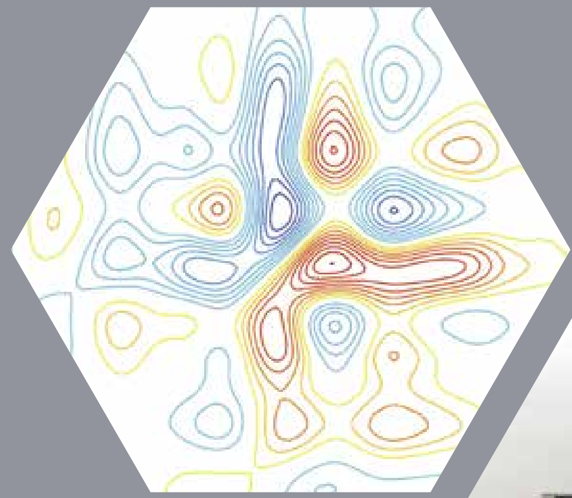
Project coordinator:
Leibniz IPHT



Artificial Intelligence for Diagnostics and Therapy

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Users of LPI should be able to rely on state-of-the-art analysis methods for the evaluation of diagnostic data sets when developing their own solutions. Within the framework of the project coordinated by Friedrich Schiller University Jena, methods based on artificial intelligence, machine learning and deep learning methods are being developed. Leibniz IPHT focuses on the creation of data infrastructures for photonic, molecular, genomic and biochemical data that ensure both data security and data protection while maintaining data reusability in accordance with the FAIR principle. Case number and experiment planning procedures will be developed to accommodate sufficiently standardized data.

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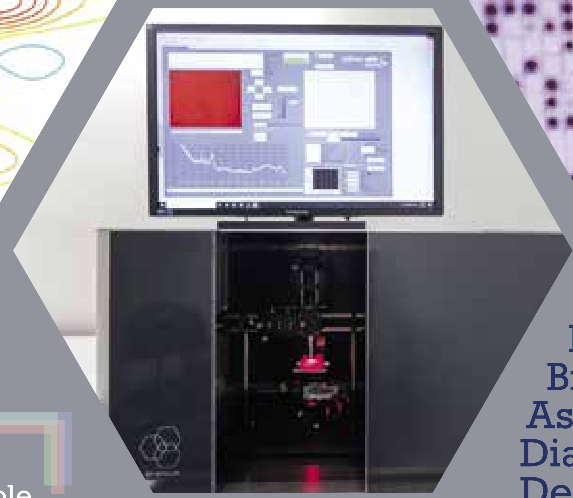
Project coordinator:
Friedrich Schiller University Jena



Highly Parallel Profiling of the Host Response to Life-threatening Infections

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In infections, the course of disease and reactions of the immune system, and thus a precisely fitting therapy, are very different and individual. In the project coordinated by the University Hospital Jena, light-based methods for accompanying diagnostics and monitoring of bodily functions are being researched in order to be able to quickly and precisely characterize the individual response to the pathogen, even when pressed for time in the intensive care unit. Leibniz IPHT focuses on photonic technologies that allow the characterization of the host response directly from the smallest amounts of sample material.

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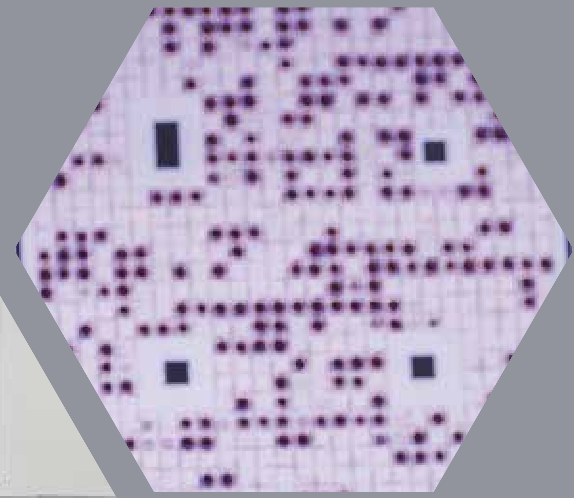
Project coordinator:
University Hospital Jena



Innovative Molecular and Biochemical Assays for Rapid Diagnostics, Drug Development and New Therapeutic Concepts

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In order to be able to develop novel individualized forms of therapy in the future, scientists are researching molecules and therapeutic microbes as well as certain proteins and antibodies, as an alternative to conventional antibiotics in the project coordinated by Leibniz HKI. Photonics-based molecular and biochemical assays are being developed for rapid diagnostics. The sub-project of Leibniz IPHT combines different methods of pathogen detection, mapping the complete diagnostic process from the sample to the detected pathogen and the resulting outcome.

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Project coordinator:
Leibniz HKI

Science Communication par Excellence

With the Comic „Lasergirl. Jagd auf den Killerkeim" ("Lasergirl. Hunting the Killer Germ"), Leibniz IPHT Has Chosen a Rather Unusual Way of Conveying Knowledge, and with Great Success.

Press conference on the occasion of the comic publication with Jürgen Popp, Federal Minister of Education and Research Anja Karliczek and Ute Neugebauer. © BMBF / Hans-Joachim Rickel

Batman and Iron Man have to invent the technologies that give them superpowers – and yet they remain science fiction. With Lasergirl, it's the other way around: her superpowers – photonic technologies – are real. Only the heroine had yet to be born. Her first adventure story is about an action-packed journey through the body, and provides a fascinating insight into the creation of a life-saving technology.

At a joint press conference on occasion of the publication of the comic in July 2021, Anja Karliczek, then Federal Minister of Education and Research, expressed her enthusiasm: "I am particularly pleased with this initiative because science communication should increasingly become part of scientific work. The researchers from Leibniz Institute in Jena are real trendsetters here."

The comic is "science communication par excellence," the concluding summary of the Federal Ministry of Education and Research states.

The magazine „Forschung & Lehre" ("Research & Teaching") was interested in the story of the comic's creation and invited Jürgen Popp, one of the idea providers and at the same time protagonist in the comic, together with the authors Lavinia Meier-Ewert and Daniel Siegesmund to a discussion about creative science communication.

Research and Teaching: Professor Popp, the science communication of Leibniz IPHT is innovative and creative, as is the new comic „Lasergirl. Hunting the Killer Germ" which was just published. How did it start?

Jürgen Popp: I think, if public money is used and topics of social interest are researched, efforts should also be made to bring this research to society, using a language that is generally understandable. At Leibniz IPHT, it was a matter close to my heart to organize public relations and research marketing after the insitute's foundation. We were pioneers in this area and continue to break new ground, as you can see from Lasergirl.

R&T: Mr. Siegesmund and Ms. Meier-Ewert, as head of department and editor, you implement public relations and research marketing at Leibniz IPHT. Why should research results be communicated creatively?

Daniel Siegesmund: In science communication, there are many different target groups. In order to find the right format depending on the message, creativity is needed when choosing the right means.

Lavinia Meier-Ewert: You need creative ways if you want to communicate not only the results, but also how they came about. If the process is made visible, how research works, then people can be fascinated. Young people can be inspired about how great it would be to do research themselves, and the broader society can be made aware of what the research topics mean to them.

R&T: With „Lasergirl. Hunting the Killer Germ" you stick to a text-based form of knowledge transfer. Why is it still innovative?

Meier-Ewert: The medium of comic combines text and images, opening up completely different ways of telling a story. Scientific topics can be linked with storytelling elements. A comic also offers different entry levels and can convey different levels of complexity. Even five to seven year old children are enthusiastic to follow stories of good versus evil. In our case, a heroine fights an evil monster. Depending on how much complexity you can absorb, you can always learn more, including how spectroscopic processes work

R&T: How did the release of Lasergirl come about?

Meier-Ewert: First there was the Ralf Dahrendorf Prize from the Federal Ministry of Education and Research. The prize is associated with the task of sharing research results obtained with society. We applied with a research project in which Leibniz IPHT scientists had collaborated with colleagues from both University Hospital Jena as well as from Greece, Denmark, France and Italy to quickly detect sepsis with the help of laser light. We incorporated the idea of making a comic out of this into the application and then won the prize with this communication concept.

R&T: As director of Leibniz IPHT, how did you react to the suggestion to write a comic? And what did the other scientists at the institute think?

Popp: I have a capacity for enthusiasm, so it didn't take much to convince me. For us researchers, it was very important that things are presented in such a way that they are also understandable from a scientific point of view and corresponded to reality in some way. Overall, I think everyone was very enthusiastic, otherwise we would not find the drawn likenesses of, for example, Professor Michael Bauer, Professor Ute Neugebauer, Dr. Anuradha Ramoji and me in the comic.

Lasergirl at Frankfurt Book Fair. According to Hessischer Rundfunk, one of the "10 highlights at the show you should not miss". © Daniel Siegesmund

Meier-Ewert: What we developed in conversation with the scientists was the concrete visual representation of the research. Sometimes we had to work with our illustrator sandruschka (Sandra Bach) on precise image proposals until the researchers were also satisfied. All participants were able to contribute their different perspectives.

R&T: One challenge of creative science communication seems to be the question of scientific accuracy. How do you communicate research results without completely neglecting important details and flattening the results?

Meier-Ewert: During the creation of the comic, we always clarified in dialogue with the researchers whether something could also be presented in a certain form within the scientific community. We wanted everything that worked in the story to be scientifically true.

Siegesmund: There are, of course, a few exaggerations due to the translation into the visual language: Our heroine Lasergirl travels in a nanometer-sized spaceship in the body. This is a small homage to various science fiction movies.

Popp: This is exactly the point where a lot of fiction is involved. We actually do laser spectroscopy, a light-based analysis method. To transfer this to Lasergirl, from whose eye a laser beam comes, is of course a matter of fantasy. But we have found a good level of abstraction: Lasergirl irradiates something with laser light. What comes back is analyzed using methods of artificial intelligence and not by herself. There is also an explanatory section in the comic that clarifies who has which role and how everything fits together with reality.

Jürgen Popp is one of the idea generators and, in his function as Scientific Director and Researcher, also one of the protagonists in the comic. © Sven Döring

Sundruschka (Sandra Bach): the illustrator from Weimar drew the comic with great attention to detail. © Daniel Siegesmund

Daniel Siegesmund, head of the Public Relations and Research Marketing Department, wrote the comic together with Lavinia Meier-Ewert. © Sven Döring

Lavinia Meier-Ewert brought Lasergirl to life as an author. She now works in the Press Department at Alfred Wegener Institute (AWI) in Bremerhaven. © Sven Döring

R&T: What would you recommend to scientists who would like to communicate their research results more creatively?

Popp: At Leibniz IPHT, we work together as equals. Scientists are not only the ones who deliver something. And the public relations employees are also not only the ones who accept and process something. Neither side has primacy. This is important for good cooperation.

Meier-Ewert: Communication should be considered from the beginning and not just when a publication is finished. Researchers should involve PR departments as early as possible. Talking to non-experts is the best way to find out what is worth telling, or exciting, where the message lies, or how to tell about your methods. I believe that today's doctoral students have already learned a lot and communicate in a very target group-oriented way.

Siegesmund: Exactly, there is a new generation of scientists who have grown up with the idea that you have to be able to communicate your research in 280 characters on Twitter, you have to appear eloquent and you have to be able to present it in a generally understandable way. It is a false conclusion that the more complicated science is presented, the more important it is.

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The interview was conducted by Charlotte Pardey. The full text of the interview can be found on the website of the magazine "Forschung & Lehre".

The comic is available free of charge as an e-book in the Apple Books Store, among other places.

Golden Highlight

Tiny Nanoparticles of Gold Creatively Showcase Science

They are only about 80 nanometers in size, and yet they are permanent fixtures in medical diagnostics as well as in food and water analysis: gold nanoparticles. In 2021, the metallic structures became shining actors in an Artist-in-Residence program that shed new light on nanoparticles.

"The history of gold nanoparticles goes far back to the early beginnings of mankind. Historical glass containing gold nanoparticles is already known from Roman times. This 'ruby red' glass was used for drinking vessels, for example, or was later used in church windows," explains Prof. Dr. Wolfgang Fritzsche, head of the Department Nanobiophotonics at the Leibniz IPHT, who works intensively on gold nanoparticles.

The electrons of the particles are set into oscillation by incident light, which can cause their colors to vary from red to green. The metallic structures are used in the field of bioanalytics to detect, e.g. pathogens, antibiotic resistance, or biomarkers. "If pathogenic germs dock onto the surface of gold nanostructures, the particles change their color. Due to their strong reactivity to light, pathogens can be quickly detected using light-based imaging methods. This principle can also be transferred to other diagnostic applications, such as the detection of tumor cells," continues Wolfgang Fritzsche.

Aesthetic staging

In 2021, the art project "Entstehung einer künstlerischen Tatsache" ("Emergence of an Artistic Fact") brought together Jena researchers and creatives from all over the world. Encounter, dialogue, and exchange as well as a look behind the scenes of research provided the art creators with the necessary inspiration for a creative examination by using scientific methods and questions.

The Italian-born artist Luca Spano staged the Leibniz IPHT and its research work in five creative 25 x 55-centimeter artworks. In gold on steel, he symbolically combined the institute's gold particle research with a poetic aspect intended to open up an exciting approach to science for a viewer.

Luca Spano combined the essence of his exploration of the precious metal gold with meaningful phrases such as "Gold is red but also green". In this way, the artist opens a door to nanobiophotonics: Due to the ability of gold nanoparticles to interact with light, and influenced by their size as well as the direction of the light, different color variations can be created. Gold nanoparticles that absorb light in the green wavelength range, for example, appear red in transmitted light, whereas they appear green when illuminated from the side.

"What the resulting artworks and our research have in common is that we work with numerous image data. However, images are only the first step in understanding physical phenomena, chemical reactions, or biological processes and procedures. In order to decipher them, we have to go beyond the purely visual information and interpret the data as well as derive correlations. Luca Spano also skilfully implements this in his artworks: his art only reveals itself at second glance – only then the whole story is told, and the scientific approach emerges. Seeing our research work creatively staged in this way was extremely exciting and inspiring," says Wolfgang Fritzsche.

The artworks, staged by artist Luca Spano, were presented to the public at a vernissage in the TRAFO cultural space in Jena.

© Leonie Lindl

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Arts & Science Residency Jena: "Emergence of an artistic fact". Exhibition TRAFO Jena. Summer / Autumn 2021

From Leibniz IPHT into the World

Leibniz IPHT Alumni are an Important Link to the Global Research Network

Transfer takes place not only through research topics, but also through minds. The promotion of young researchers is a central topic at Leibniz IPHT. Almost every fourth staff member at the institute is doing a doctorate or research as a postdoc. After their training at Leibniz IPHT, the young researchers usually pursue a career in science or industry. Some stay in the region, others move further away. A large number remain connected to Leibniz IPHT – through research collaborations, joint projects and ongoing scientific exchange. Thus, Leibniz IPHT alumni make an important contribution to networking in the scientific community – often worldwide.

In this portrait, four alumni talk about their time at Leibniz IPHT, what they learned here and how the experience they gained has helped them in their professional careers in Sweden, Canada, China and Australia.

Dr. Joachim Kübel

Optics and development engineer at Optoskand / Coherent in Mölndal, Sweden

From 2011 to 2016 as a diploma and PhD student at Leibniz IPHT

The most important thing I learned at Leibniz IPHT? The ability to grasp and analyze complex correlations and to develop creative solutions to problems. Practical work in the laboratory and planning and developing optical systems for my own research meant a lot to me. I gained a lot of insight and detailed knowledge about spectroscopy, lasers, nonlinear optics and photophysics. Crucial for me were the countless technical and scientific challenges that I could grow from.

With short distances between departments, Leibniz IPHT has made a great contribution to spark interest in topics that go beyond one's own nose. Looking back, I was lucky to have done my doctorate at an institute with strong expertise in optical fibers, even though it was not my main research area. During my time at Leibniz IPHT, I was able to gain knowledge about optical fibers through colleagues, seminars and lectures, which is very helpful today."

Dr. Mario Chemnitz

Postdoctoral researcher at the Institut National de la Recherche Scientifique, Quebec, Canada

From 2013 to 2019 as a PhD student at Leibniz IPHT

"I have had three key experiences at Leibniz IPHT that have decisively prepared me for my academic career: (1) In the scientific world, it takes clear data and precise communication to move forward. (2) When I first had the opportunity to supervise students, I learned how important it is to support them according to their strengths and interests. (3) You should always keep in mind that your research may have patent potential. Especially for the latter, I find the interdisciplinary and intertechnological research environment at Leibniz IPHT immensely inspiring, as you see so many basic physical concepts for biophotonics in application.

From my time at Leibniz IPHT, I have gained much positive experience in almost all important areas of research: scientific publishing, group communication, student supervision, laboratory and institute organization, and most importantly, human interaction. With this positive role model in mind, I arrived at my new job and was able to directly apply much of what I had learned."

Dr. Shuxia Guo

Assistant Professor at the Southeast University, Nanjing in China

From 2014 to 2020 at Leibniz IPHT as a PhD student and postdoctoral researcher

"Leibniz IPHT is a very interdisciplinary institute, which gave me access to many types of data to develop and test new methods as a statistician. I benefited a lot from the scientific exchange and participation in conferences and events, both scientifically and socially. I found the atmosphere at Leibniz IPHT to be very warm; my supervisors supported me at all times, and my colleagues were very friendly and helpful. All this was very important, especially since I come from a completely different culture.

After my time at Leibniz IPHT, I was able to start an academic career at one of the top universities in China. This would not have been possible without the knowledge and skills I acquired at Leibniz IPHT. And this is not only about knowledge in statistics, biophotonics and biology, but also soft skills of all kinds, such as effective interdisciplinary communication and good scientific practice. My connection to Leibniz IPHT remains, as I would like to continue the exchange and collaboration."

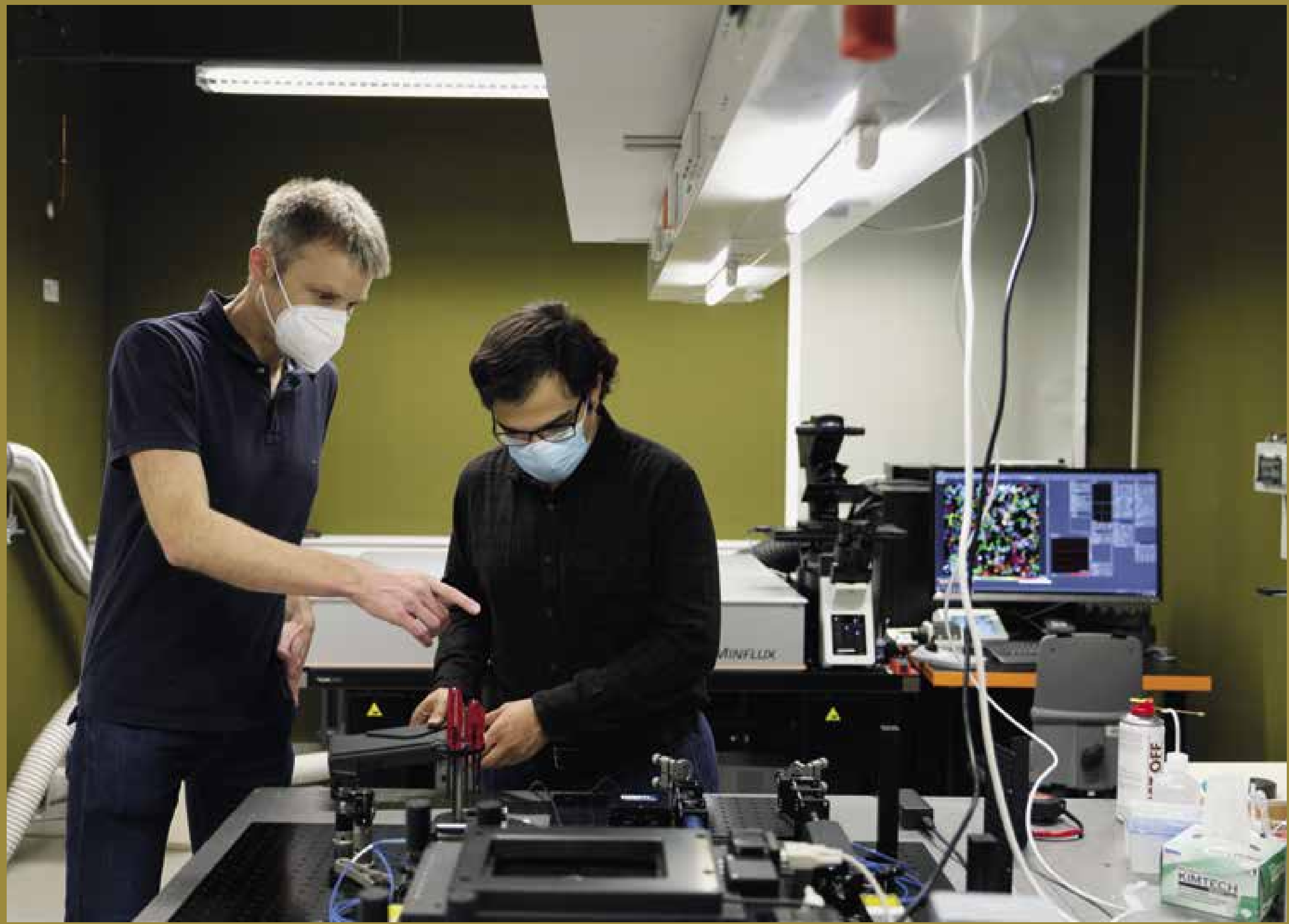
Dr. Alessandro Tuniz

Senior Lecturer at the University of Sydney, Australia

From 2015 to 2017 at Leibniz IPHT as a postdoctoral researcher and Humboldt Fellow

"I really enjoyed being part of the Leibniz IPHT family: there was a strong sense of community that made me feel immediately welcome and that I looked forward to every day. I am still in contact with many of the friends I made here. In terms of research, I really appreciated having access to state-of-the-art experimental instruments in-house. This is especially important when you are a junior scientist with limited financial resources. And it helped me to develop some of my ideas freely.

I was fortunate to receive two fellowships as a follow-up. Undoubtedly, the two productive years at Leibniz IPHT were a very important stepping stone for my research career. The collaboration with Leibniz IPHT continues to this day. My time at the institute showed me how important a friendly, open and collaborative environment is for research success."



Prof. Dr. Christian Eggeling and his colleague Dr. Francesco Reina want to use MINFLUX microscopy to help make the smallest details visible.

Sharp, Sharper, Sharpest

New Microscopy Method Sets Standards with Unrivaled Sharpness

MINFLUX microscopy allows the smallest building blocks of life to be observed with unprecedented accuracy. Researchers at Leibniz IPHT are further developing super microscopy and experimenting with photostable fluorescence probes to unlock new potentials of this novel microscopy technique for applications in life sciences.

How do viruses infect cells and overcome the barrier of the cell membrane? How can pathogens multiply unhindered in the human body and spread to cause an infection? What happens inside the cell during an inflammation? How are signals transmitted at the cell envelope? Biology and medicine are trying to find answers to these and similar questions using microscopy. However, optical light microscopy quickly reaches its limits when observing the smallest details. Already in the 19th century, the physicist Ernst Abbe recognized that structures can only be precisely resolved microscopically down to a size of 200 nanometers. "Smaller details can only be perceived in a blur under the microscope and cannot be clearly distinguished optically," explains Prof. Dr. Christian Eggeling, head of the Biophysical Imaging Department at Leibniz IPHT.

To overcome these physical limitations, researchers developed a super-resolution microscopy: Nobel prize winner and physicist Stefan Hell expanded the most established super-resolution microscopic methods STED and (f)PALM / (d)STORM to create the ultrahigh-resolution MINFLUX fluorescence microscopy. Instead of maximizing light intensities from the irradiated laser or detected fluorescent light, the MINFLUX approach minimizes light intensities. This enables razor-sharp insights into the inner of cells with a unique resolution of less than ten nanometers.

Observing three-dimensional insights into living cells with pin-sharp clarity

Scientists at Leibniz IPHT, among others, are researching the strengths of this supermicroscopy. In 2021, they received a MINFLUX device, which was acquired as part of the large-scale equipment initiative "Novel, Experimental Light Microscopes for Research" of the German Research Foundation.

"The MINFLUX technology allows completely new three-dimensional insights into living cells. With it, processes on the cell membrane can not only be made visible, it also significantly expands our understanding of the interplay of the cell components. Intracellular processes, such as the infection of cells with HIV or corona viruses, can thus be deciphered. In order to fully exploit the potential of MINFLUX microscopy, we are working on further technological developments, optimizing the hardware and methods of evaluation, for example, and studying its possibilities and limits. This paves the way to further improve the technology in order to enhance the support of biology and medicine in answering cell biological questions in the long term," explains Christian Eggeling.

Color makes the difference

To track dynamics at the cell membrane microscopically, fluorescent dyes are needed. "With these dyes, we insert a label into the cells to be observed. These dyes glow thanks to the microscope's excitation light. In this way, the movement of the molecules can be tracked in time and space, and their diffusion through the cell membrane can be precisely observed. Unfortunately, some of these dyes, the fluorophores, lose their ability to fluoresce in fractions of seconds due to photochemical processes, like a photograph whose colors fade," says biophysicist Christian Eggeling. The fading of the dyes is a problem, especially in long-term observations.

Novel photostable dyes, also known as fluorescent probes, offer the potential to overcome the disadvantages of photobleaching and enable observations on cell membranes in real time with high temporal and spatial resolution as well as long acquisition times. In 2021, the team of Christian Eggeling and his colleague Pablo Carravilla tested new fluorescent probes based on Nile red, which were synthesized by their collaboration partner Prof. Dr. Andrey Klymchenko from the Université de Strasbourg. These markers only accumulate in the cell membrane for a short time, and only there they begin to fluoresce when stimulated by light irradiation.

Fluorescence probes can be used, for example, to observe the fusion of membrane vesicles with the cell membrane, the so-called membrane fusion, as well as the union of lipid layers. The new dyes thus provide the opportunity to gain detailed insights into the molecular mobility on biological membranes via high-resolution time-lapse imaging or real-time imaging. Since MINFLUX technology requires low concentrations of fluorescent probe for its high precision, these dyes that only accumulate for short times would also be suitable for this technology.

"In the future, we want to further investigate the performance of super-resolution STED and MINFLUX microscopy techniques to make them useful for biomedical applications. The technology has the potential to inspire pharmaceutical research and modern medicine," says Christian Eggeling full of hope.

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Publication:
Carravilla, Pablo et al., Biophysical Reports, Vol 1 (2), 2021, https://doi.org/10.1016/j.bpr.2021.100023

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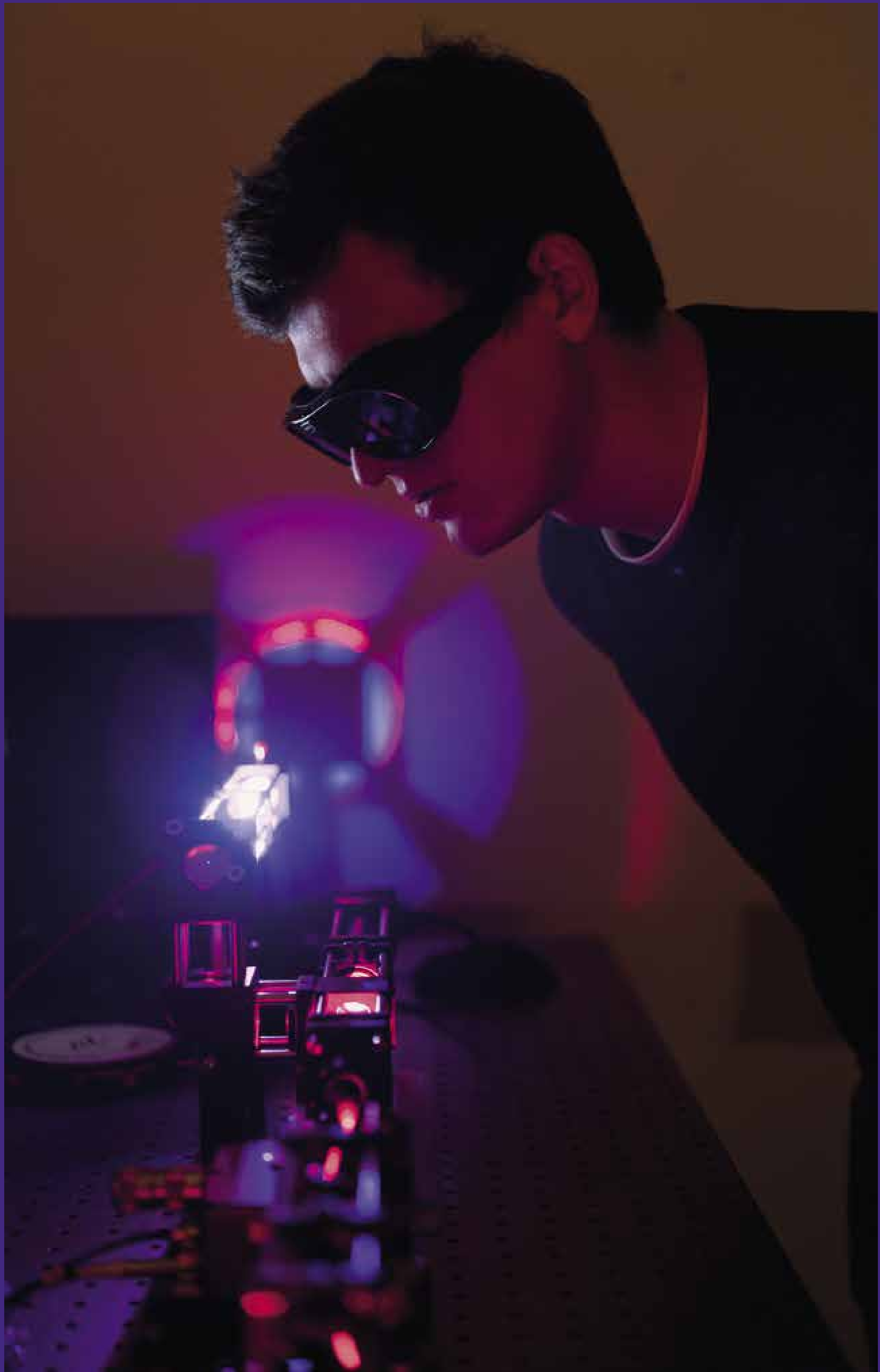


Scientists at Leibniz IPHT are investigating how agile cells can be studied even more precisely with optical traps. © Sven Döring

Trapped with Light

Lenses on the Tip of Optical Fibers Bring Tiny Objects into Focus

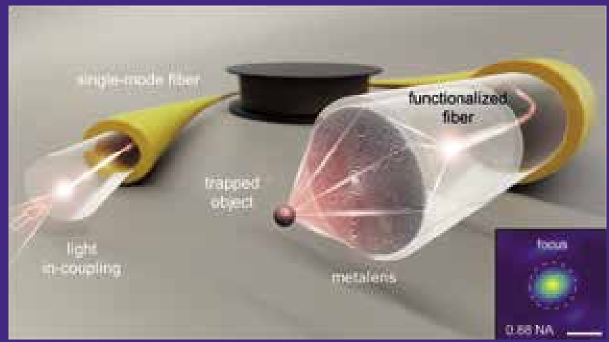
Scientists at Leibniz IPHT have succeeded in using 3D nanoprinting to apply an ultra-thin lens to the end of an optical fiber that is just as thin as the human hair. The combination of diffractive optics and fiber enables optical trapping of the smallest particles and offers novel possibilities for in-vivo applications.

If objects of only a few micrometers in size are to be examined microscopically in bioanalytical or medical applications, fixing of these objects is often useful. This is made possible by optical traps, also known as optical tweezers. They hold objects without contact and – combined with imaging or spectroscopic methods – enable high-resolution optical measurements during trapping.

An optical trap uses the power of light to capture objects at the center of a focused laser beam. Existing approaches rely on elaborate and complex optical systems that use, for example, microscope lenses to focus the laser beam. To overcome these disadvantages, researchers at Leibniz IPHT developed a flexible design to optically control microscopic and nanoscopic objects as precisely as possible.

To do this, the researchers used 3D nanoprinting to apply a diffractive optical lens with a diameter of 90 micrometers and a height of three micrometers to the end of an optical fiber. "This polymer lens on the tip of a flexible optical fiber allows us to focus the coupled laser light with high precision. By doing so, we were able to capture freely moving micro-objects, such as E. coli bacteria, with a single optical fiber in water and fix them optically in a stable manner for several minutes, which is unique to date," explains Dr. Malte Plidschun, scientist in the Hybrid Fibers Group in the Fiber Photonics Department at Leibniz IPHT.

Thanks to the smart design of the diffractive optical lens, also known as meta lens, an extraordinarily high numerical aperture (NA) of up to 0.9 could be achieved. The NA describes the magnification and focusing performance of optical systems. The higher its value, the more precisely details can be resolved microscopically and the better the light can be focused. Until now, an optical trapping with a comparatively high NA was only possible with elaborate and complex setups.



Miniaturized objects in micro- or nanometer size can be optically trapped by a focused laser beam using the flexible meta fiber. © Leibniz IPHT

"Optical traps based on flexible fibers offer completely new diagnostic possibilities, especially for regions that are difficult to access. A combination of optical trapping and Raman spectroscopy, for example, enables a molecular characterization of cells directly in their natural environment in living organisms during the time of optical fixation. In this way, among other things, the investigation of blood cells or the diagnosis of pathogens could be significantly accelerated and advanced," says Malte Plidschun.

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Publication:
Plidschun, Malte et al., Light: Science & Applications 10, 57, 2021, https://doi.org/10.1038/s41377-021-00491-z

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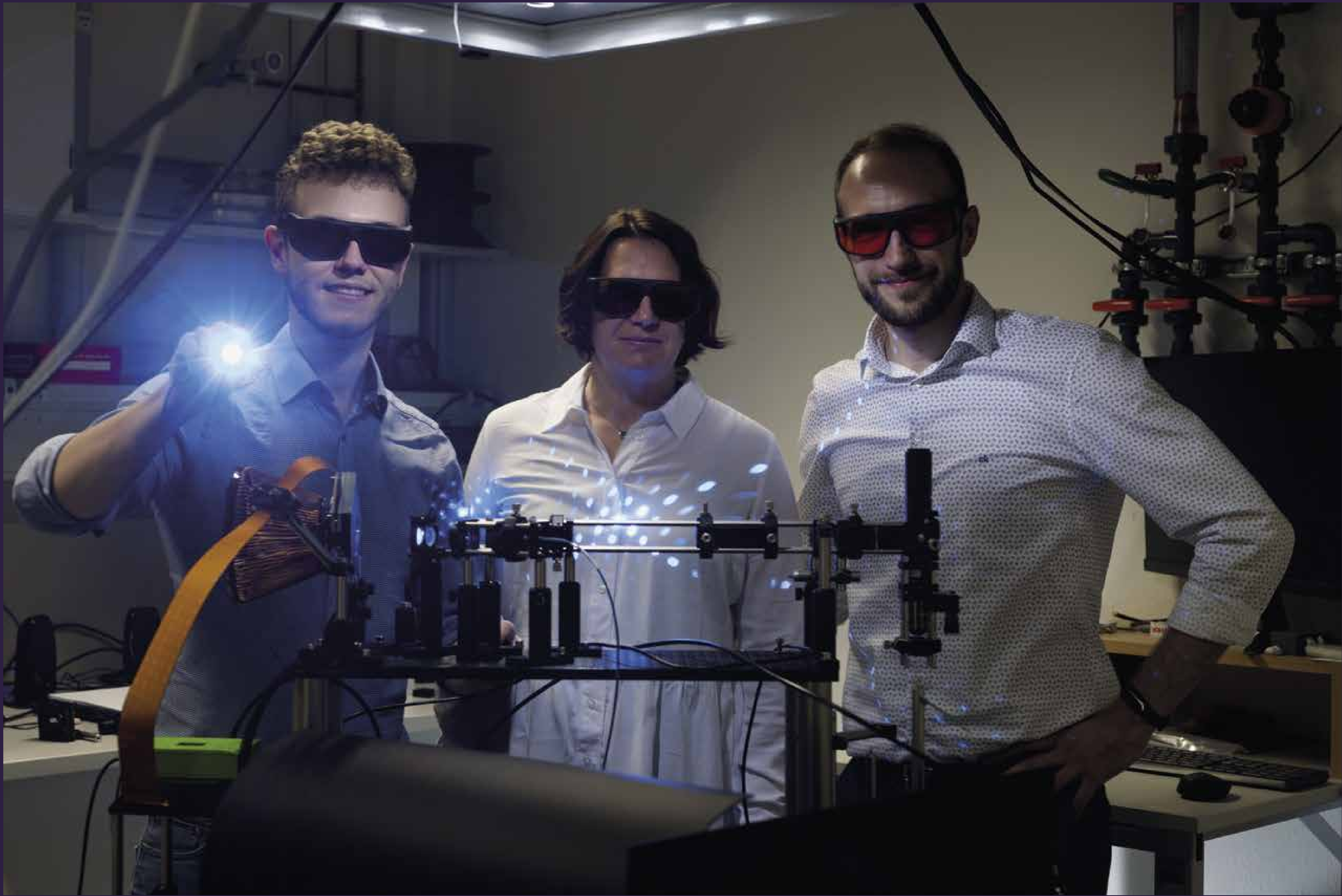
Deep Insights

With Minimally Invasive Endoscopes from Leibniz IPHT, it Will Be Possible in the Future to See into Deeper Regions of the Human Brain.



EXIST founder scholarship holders Patrick Westermann, Dr. Hana Čižmárova and Dr. Sergey Turtaev with an experimental setup of the hair-thin endoscope.

An innovative technology, a highly motivated team and a field of application that needs new solutions: Hair-thin endoscopes from Leibniz IPHT will advance brain research in the future. Dr. Sergey Turtaev, Dr. Hana Čižmārova, Dr. Jiri Hofbrucker and Patrick Westermann are working on this topic under the mentorship of Prof. Dr. Tomāš Čižmār: The interdisciplinary team is preparing their spin-off *DeepEn* from the Research Department Fiber Research and Technology. The project is supported with funds from the Federal Ministry for Economic Affairs and Climate Actions' EXIST research transfer program.

The brain as the most complex organ of the human body is still far from being researched in its entirety. Conventional methods used in in-vivo brain imaging cause tissue damage that severely limits research on internal brain regions. The *DeepEn* team aims to make hair-thin holographic endoscopes available to neuroscientists, which can provide insights into areas of the brain that have not yet been accessible. This should make it possible to investigate the causes of neurodegenerative diseases such as Parkinson's, Alzheimer's, or strokes even better.

Well positioned for transfer

"The timing is just right: the technology is ripe for transfer, and there is currently a worldwide trend to diagnose and treat diseases minimally invasively with light," says

The *DeepEn* team has 26 months to turn the lab setup into a market-ready solution. © Sven Döring

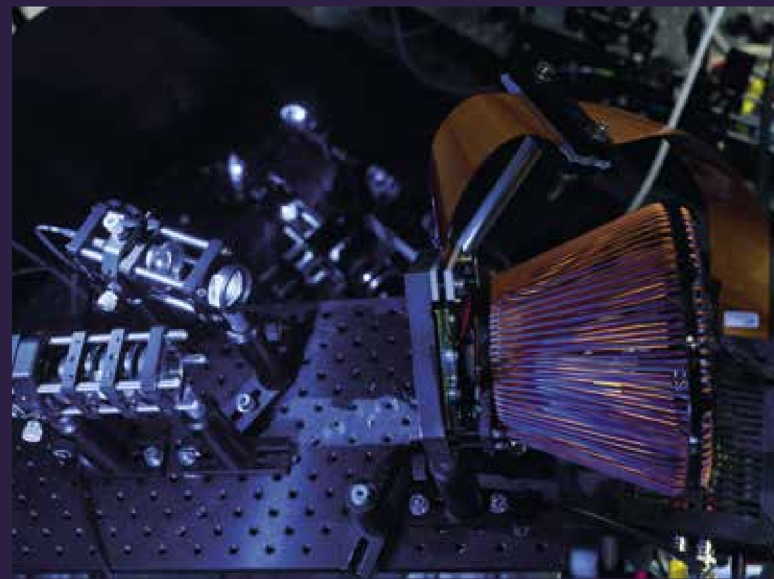
Tomáš Čižmár, leader of the Holographic Endoscopy Group and mentor of the team. *DeepEn's* goal is to stabilize and miniaturize the experimental setup so that in the end there will be an easy-to-use brain imaging workstation for neuroscience on the table – the *NeuroDeep*. "I'm driven by going beyond proof of concept in research and translating scientific knowledge into application," reveals Sergey Turtaev, leader and technology expert of the start-up project.

DeepEn's technological approach is based on a multimodal fiber – the narrowest known channel that can transmit image information. A fiber normally cannot transmit an image from one side to the other, as in conventional endoscopes. When light moves through an optical fiber, it doesn't come out on the other side in the same shape but is completely distorted. The Holographic Endoscopy Working Group team has researched a method for transmitting images in spite of this: "Using modern holographic modulators and intelligent algorithms, we manage to turn this hair-thin glass structure into a high-resolution imaging instrument," explains Sergey Turtaev. "The key advantage is that the frontal area of such a fiber is more than a magnitude order smaller than that of conventional endoscopes. Our fiber endoscope has the subcellular resolution of modern multiphoton microscopes, and can penetrate deeply into brain tissue without causing much damage."

For Hana Čižmārova the *NeuroDeep's* user-friendliness is the main focus. She is a physician, and her hands-on experience in geriatrics has taught her what symptoms of neurodegenerative diseases can look like. "Now I'm working on the other end and can contribute to being able to better research these diseases," she says. To do this, she works closely with research partners at the Institute of Scientific Instruments in Brno, Czech Republic. Her main task is currently to gather needs and feedback from potential users of the system. In the future she will work on the protocol, the design of the user interface and the training plan for the implementation of the *NeuroDeep*.

Market research, competitive analysis, estimation of market potential: Patrick Westermann took the lead in creating the business plan for the start-up. He completed his master's degree in management in Belgium and Spain in the summer of 2021, and now is responsible for the business management at *DeepEn*. He is in charge of organizational issues, rethinks work packages, prioritizes tasks, establishes contacts and talks to development partners and first potential customers at neuroscience institutes. "This is a real vision of the future: that later on our fiber endoscopes will be able to advance research and make human lives better, or even save them," says the young entrepreneur.

First successful steps in building up the start-up



With the help of this experimental setup, a hair-thin optical fiber will become a high-resolution imaging instrument. © Sven Döring

There have been many highlights in the start-up phase so far. First and foremost, the *DeepEn* team was completed by Jiri Hofbrucker, who contributes additional expertise with his background in physics and his passion for engineering. He is now working with Sergey Turtaev in the lab to configure a fully functional test system. "We are refining the test setup in close coordination with our research partners and future users. Initially, we plan to make the design very flexible in order to be able to respond to new suggestions at any time," explains Jiri Hofbrucker. "The possibilities offered by our endoscopes are new to the target group. Therefore, many feedback loops are necessary to accurately determine the needs of researchers in neuroscience laboratories," adds Hana Čižmārova.

From lab to market in 26 months – that is the goal of the interdisciplinary team. They can take recourse to a lot of experience from both internal and external sources. "With Leibniz IPHT, we have an excellent infrastructure and environment to push on our project. We received a lot of support from our scientific coordinator, Ivonne Bieber, the PR team and the colleagues from the personnel office," emphasizes Sergey Turtaev. Externally, the Leibniz Association's Start-up Support assisted by providing advice and support from the very beginning. At the kick-off meeting of the EXIST program organized by project sponsor Julich, the team exchanged ideas with other EXIST start-up scholarship holders in Berlin. They were also able to learn a great deal from their business coach, a consultant with over 20 years' experience in the microscopy and bio-imaging industry.

Another highlight was the workshop with research partners in Brno, which the *DeepEn* team attended together. "Presenting ourselves there made us grow closer even more," reports Patrick Westermann. He is pleased that many important steps have already been completed. The lab has been equipped, parts for the test setup are ordered, an office set up and a logo have been designed for *DeepEn*. "We are a good team and our competencies complement each other perfectly. I'm confident we can meet the challenge of bringing our advanced technology to the market."

Great potential for hair-thin holographic endoscopes

Once the *NeuroDeep* has gained acceptance in neuroscience, the *DeepEn* team plans to target the market for diagnostics and therapy in human medicine as the next stage. There, it can also enable in-situ imaging, for example during surgeries or for faster diagnosis. "In the future the holographic endoscope could be become a fitting device for delivering novel photonics-based methods such as photoablation and optical biopsy to specific body regions," explains Tomáš Čižmār.

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Initiative "IR4future"

Industry and Science Require Innovation Boost in Infrared Technology

Dr. Christoph Krafft, head of the Raman and Infrared Histopathology Group from the Spectroscopy / Imaging Department: "The potential of IR spectroscopy is in danger of not being used." © Sven Döring

Infrared spectroscopy enables a wide range of applications in medical diagnostics and analytics. However, the method is currently being used and taught mainly as a routine measurement procedure – methodological further development has stalled. With participation of scientists from Leibniz IPHT, researchers and industrial partners from German-speaking countries have launched the "IR4future" initiative. The aim is to intensify research activities in the field of IR spectroscopy and to develop application potentials.

Measuring blood glucose without pricking, detecting lung and kidney diseases or diabetes at an early stage based on the air you breathe, or determining the chemical composition of tissue to detect pathological changes: IR spectroscopy provides a wealth of information, especially for simultaneous determination of chemical and physical parameters, and enables analyses without the use of external labels. This makes it a key technology in the field of health technologies as well as in the areas of agriculture and nutrition.

Prof. Christian Huck from the Leopold-Franzens University in Innsbruck, together with his colleague Prof. Jürgen Popp from Leibniz IPHT, initiated the interdisciplinary interest group "IR4future". Together with eleven other representatives from industry and science, they have published a position paper in which they critically analyze the current status of IR spectroscopy and show current trends. Dr. Christoph Krafft, head of the Raman and Infrared Histopathology Group from the Spectroscopy / Imaging Department at Leibniz IPHT, is one of the authors of the position paper. He warns: "The potential of IR spectroscopy is in danger of not being used. I see the danger that research institutions and equipment manufacturers in German-speaking countries will fall behind on international level." He is not alone in his opinion: colleagues from the "Leibniz Health Technologies" Research Alliance, Freie Universität Berlin and University of Innsbruck, as well as from spectrometer and optoelectronics manufacturers in German-speaking countries have joined the appeal. Together, they call for a stronger commitment to research and development of new radiation sources, sensor technologies and detectors as well as AI-supported evaluation, especially for biomedical issues.

Appeal to politicians: Invest in the development of new methods

Public funding agencies should be encouraged to increasingly support projects for the development of methods. "There is an urgent need to secure and expand the existing potential of methodological research in the long term," experts appeal in a jointly published position paper. "In order to be able to translate new approaches into products and services for the benefit of society, there is an essential need for suitable research and development infrastructure."

In their statement published in April 2021, the authors outline concrete proposals for solutions to enable an innovation boost. Existing competencies should be bundled and made accessible in an IR spectroscopy technology hub. It is necessary to combine IR-based methods with enabling technologies such as micro- and nanotechnologies, microfluidics and fiber technology. Deep-learning approaches for the evaluation of IR spectra have to be newly or further developed.

In order to better and more efficiently develop the potential of IR spectroscopy as a whole, it is essential to improve the framework conditions, especially in the continuous qualification of scientific and technical personnel at universities and research institutions. "This is crucial for progress in research and for its economic connectivity," the researchers emphasize.

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Position paper at: www.ir4future.de

Physicist PD Dr. Thomas Bocklitz is working on training AI algorithms so that, in the long term, they learn to distinguish quickly and efficiently healthy from diseased tissue, for example – both on images and in complex Raman spectra.

© Sven Döring

Second Opinion Computer

Smart Algorithms Detect Details

Artificial intelligence (AI) has long ago arrived in our everyday lives, and has become a valuable addition to the lives of many people: Whether it´s self-controlling drones, intelligent room lighting or smart voice assistants – AI permeates almost all areas. In addition to logistics, the automotive industry and the entertainment sector, the smart support from AI also finds its way into medicine, providing valuable information about cancer and infectious diseases. Leibniz IPHT researchers are working together with Biophotonics Diagnostics GmbH on the AI-supported analysis of Raman spectra and image data.

"The aim is to use computer-assisted algorithms to identify abnormalities in imaging diagnostics and in spectrally measured data within a very short time. This would allow physicians to confirm their suspicion of a disease or an infectious agent in the sense of a second opinion. It would also be possible to pay special attention to conspicuous areas of a tissue sample and clarify them further medically," explains PD Dr. Thomas Bocklitz, head of the Photonic Data Science Department at Leibniz IPHT. Together with his team, he researches the smart algorithms to achieve exactly this aim, and the benefits they can provide to medicine. The expert is convinced that AI-based methods will not replace physicians in the future, but will offer real added value: With their ability to quickly recognize patterns in pathological findings, computer-assisted methods support therapy decisions.

Competent innovation

Raman spectroscopy, in particular, can usefully support diagnostics and analytics through biochemical and molecular characterization of samples. However, due to the complexity and volume of the data, its potential is not fully utilized in clinical applications. With its intelligent and AI-supported software solutions, Biophotonics Diagnostics GmbH demonstrates that analysis of even comprehensive spectroscopic data can succeed easily and without specialized knowledge.

The spin-off, which emerged from a cooperation of Leibniz IPHT with Friedrich Schiller University Jena and the University Hospital Jena, successfully combines the intensive research of the three institutions in a user-friendly product: The RAMANMETRIX software developed by the company accelerates fast and intuitive evaluation of Raman spectra.

Future ideal solution

In order to further advance application of Raman spectroscopy in the medical environment, uniform procedures, and measurement methods, such as standardized measurement conditions and setups, are also required for generation and evaluation of comparable measurement data. Thomas Bocklitz's team has therefore written a manual to Raman spectral data analysis using AI. With it, the researchers would like to contribute to the international standardization of data collection, processing, and AI-supported evaluation.

"In the future, we want to increasingly use AI for inverse modeling of measurement processes. With the support of AI, conclusions about the sample and possible errors in measurement will be drawn from measurement data that has already been generated. This will allow us to improve the initial data and further optimize diagnoses," says the scientist, who also heads the network "AI for Diagnostics and Therapy" as part of the Leibniz Center for Photonics in Infection Research (LPI) at Friedrich Schiller University Jena.

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Publication:
Guo, Shuxia, Nature Protocols 16, 5426–5459, 2021, https://doi.org/10.1038/s41596-021-00620-3

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Artificial Intelligence

AI stands for artificially generated intelligent behavior of machines by means of mathematical algorithms. Thinking, solving problems and learning are its characteristic features. One subdomain of AI is machine learning, whose algorithms are trained by data sets. Thanks to pattern recognition, machine learning can solve tasks better and better. Deep learning as a sub-discipline of machine learning is mostly modeled on the human brain. It is able to learn from large complex amounts of data using artificial neural networks, to recognize regularities intelligently and to draw logical conclusions.

Record-breaking: Black Coatings from the Clean Room

A surface appears black when practically no light is reflected, but instead all the colors of the incident light are absorbed. In the past, photographers used a black setting cloth on their apparatus to focus, in order to keep ambient light away from the sensitive photographic plate. Today, black surfaces are also used to trap light: In the optics lab, for example, black surfaces minimize distracting stray light when lasers are used in optical setups.

But black is not just black. Dr. Mario Ziegler, a scientist at the Center for Micro- and Nanotechnologies at Leibniz IPHT, and his team colleagues have succeeded in producing black coatings in the clean room that surpass the absorption properties of all previous thin-film solutions. Applied to a profiled sheet from the hardware store, it swallows up all contours visible to the human eye. The profile can only be seen through an extremely steep angle of incidence.

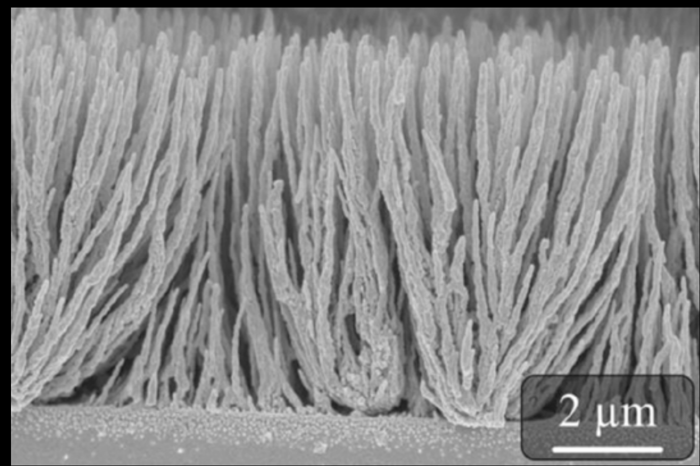
Valentin Ripka holds a wafer with a structured Dark Mirror surface.
© Sven Döring

The black coating from the cleanroom is proven to be darker than the blackest black, which holds the world record in the Guinness Book of Records. "Our 'Dark Mirror' achieves peak light absorption values. And it does so in a very broad wavelength range. This means that our black absorbs more light than comparable thin films such as 'Vantablack' or the current record holder 'Dark Chameleon Dimers'," reports Mario Ziegler, who described the process in detail in his doctoral thesis. The black layer is produced using the novel metastable atomic layer deposition (MS-ALD) process, which was developed and patented at Leibniz IPHT. In this process, a silver thin film is transferred to the metastable phase silver oxide. This metastability is used to produce complex 3D nanostructures of silicon dioxide and silver nanoparticles in a self-assembled growth. The record-breaking black is created by the interplay of two optical effects: On one hand, light is trapped by the silicon dioxide nanostructures (light trapping); on the other hand, the silver nanoparticles formed on the nanostructures absorb the incident light due to their special optical properties.

The black coatings are already being used at the institute to minimize stray light in spectroscopy setups. "A novelty is that the black layer is chemically stable. This means it can be used for many applications," explains Valentin Ripka, a laboratory technician in the clean room. "Right now, we are preparing everything for space qualification. For this, the layer must be further stabilized; after all, it has to survive requirements such as a rocket launch. The plan is to apply the black coating to our infrared light sensors, which have been tested for many years, so that they can be used for contactless measurement of heat in space exploration missions." In parallel, the team of scientists is working to coat the substrate material with a semiconducting substance such as zinc or titanium oxide. This could enable use of the black layer as a photocatalytic surface. In combination with sunlight, it would thus be possible to decompose harmful chemical components and filter them out of the contaminated water. In the future, this effect could be used, for example, in wastewater treatment of textile factories.

Name	Dark Chameleon Dimers	Dark Mirror
Institution	King Abdullah University of Science and Technology	Leibniz IPHT
Material thickness	10,2 µm	9,0 µm ± 0,2 µm
Maximum absorption	99,2 % @ 497 nm wavelength	99,77 % @ 1646 nm wavelength 99,69 % @ 497 nm wavelength
Wavelength range of absorption > 99 %	400 bis 800 nm wavelength (VIS)	220 nm to 2500 nm wavelength (UV, VIS, NIR)

Comparison of the black coating of the current record holder for the category "Darkest manmade substance" at the Guinness World Records and the "Dark Mirror" developed at Leibniz IPHT.



Scanning electron microscopy image of the silver-silica hybrid nanostructures (Dark Mirror).
© Leibniz IPHT

"The element hydrogen is a key component for global energy transition. In a next step, we want to explore our black coatings with view to synthesizing green hydrogen," Mario Ziegler gives an outlook. Plasmon induced photocatalysis should make it possible to split water by means of sunlight and thus obtain hydrogen. "Hydrogen as a synthesis gas and energy carrier could then be produced decentralized and used directly without costly storage, for example in mobility concepts of the future."

Scan this code to access the YouTube post.

The researchers investigated the mechanisms for the electrochemical growth of nanoporous platinum layers.
© Sven Döring

Cauliflower, Fern, or Ball?

How Porous Platinum Catches the Light

Surfaces and structures of porous platinum could not be more different. Thanks to its distinctive properties and composition, the precious metal is indispensable in many fields, such as astronomy, physics, or medicine. Researchers at Leibniz IPHT are studying the chemical element and its design on a nanometer scale.

Measuring fever in the ear, exploring the weather on the Red Planet, or monitoring critical processes in industrial environments – non-contact radiation thermometers are used in a wide variety of applications. Their IR sensors, hidden inside, capture incident infrared radiation, convert it locally into heat, and generate a thermoelectric signal that scales with the temperature difference and can be measured. Thus, IR sensors make heat and temperature parameters visible. These sensors are reinforced by locally applied broadband absorber layers consisting of nanoporous platinum. This sophisticated surface finishing can support the sensitive IR sensors in the subtask of converting IR radiation into heat.

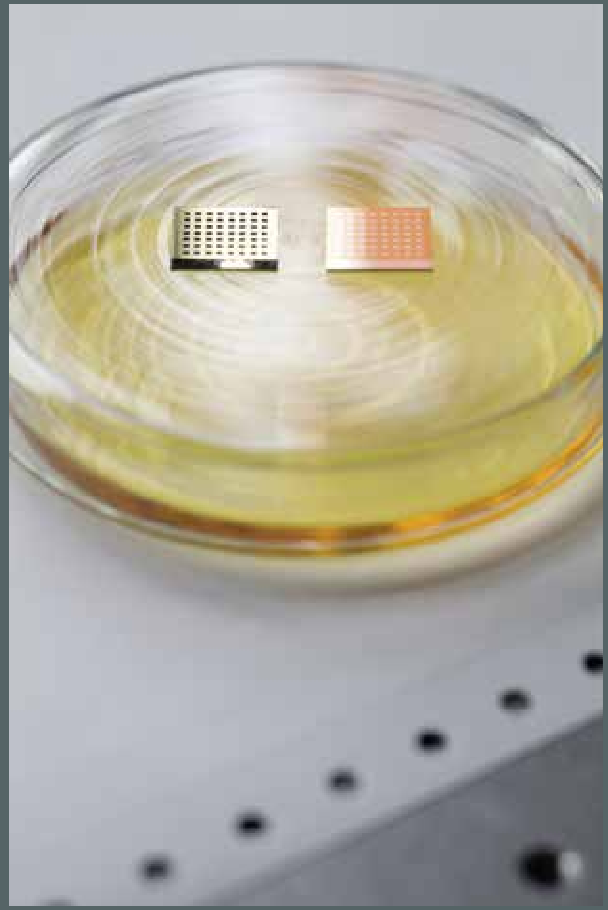
Captured light

"Non-porous platinum normally only absorbs a small proportion of the incident light, while a large part is reflected. Highly porous platinum, on the other hand, has completely different optical properties. It is very absorbent and can absorb almost all of the incident radiation. In contrast, its reflectivity, that means its ability to reflect radiation like a mirror, is extremely low," explains Dr. Gabriel Zieger, head of the Thermal Sensors Group in the Quantum Detection Department at Leibniz IPHT.

This property makes porous platinum attractive as an optical absorber material over a broad wavelength spectrum. "Its fine structure, which can look cauliflower-like, fern-like or spherical with its different pore sizes and pore distributions under the microscope due to its elevations and depressions, increases its surface enormously. This special surface structure means that the incident radiation has hardly any chance to escape," Gabriel Zieger continues.

Layer by layer

The absorption capacity of porous platinum mainly depends on its structure and thickness. To precisely control the growth of nanoporous platinum layers, researchers in Jena investigated the mechanisms behind the deposition process in 2021. "In order to electrochemically produce highly localized platinum layers, conductive patterns must first be created, for example on a substrate on which the coating is to be deposited. The coating itself takes place in an electrolytic bath containing platinum chloride. By applying an electric current, metal ions dissolve in the bath and accumulate selectively on the previously defined structures. Thus, the nanoporous platinum layer grows exactly there," explains Dr. Sarmiza Stanca, scientist in the Thermal Sensors Group.



Nanoporous platinum is characterized by its high absorption capacity.
© Sven Döring

The researchers observed that the development of the platinum layers can be specifically manipulated: Decisive factors for the platinum layer thickness are applied voltage and electrolyte composition. An increase in temperature can also influence the electrochemical process and thus the layer thickness. Time also plays an important role, because the longer the initial material remains in the electrolyte solution, the more the platinum layer grows. Emerging hydrogen during electrolysis also influences the porosity of the platinum. "The special thing is that we can grow platinum with the help of water-free electrolysis. This is particularly advantageous for water-sensitive sensor materials, and offers great potential for optoelectronic and many other applications," says Sarmiza Stanca.

With the knowledge gained on the precise control of platinum growth, its surface structure, porosity and thickness, even more sensitive IR sensors with optimal absorption characteristics can be created. Due to the platinum refinement, these IR sensors are able to almost completely absorb the radiation to be detected and convert it into heat, allowing to perceive even finer details.

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Publication:
Stanca, Sarmiza-Elena et al., Communications Chemistry 4, 98, 2021, https://doi.org/10.1038/s42004-021-00535-w

Scan this code to access the YouTube post.

Following the Footsteps of Mongolian Rulers by Using Magnetic Field Sensors

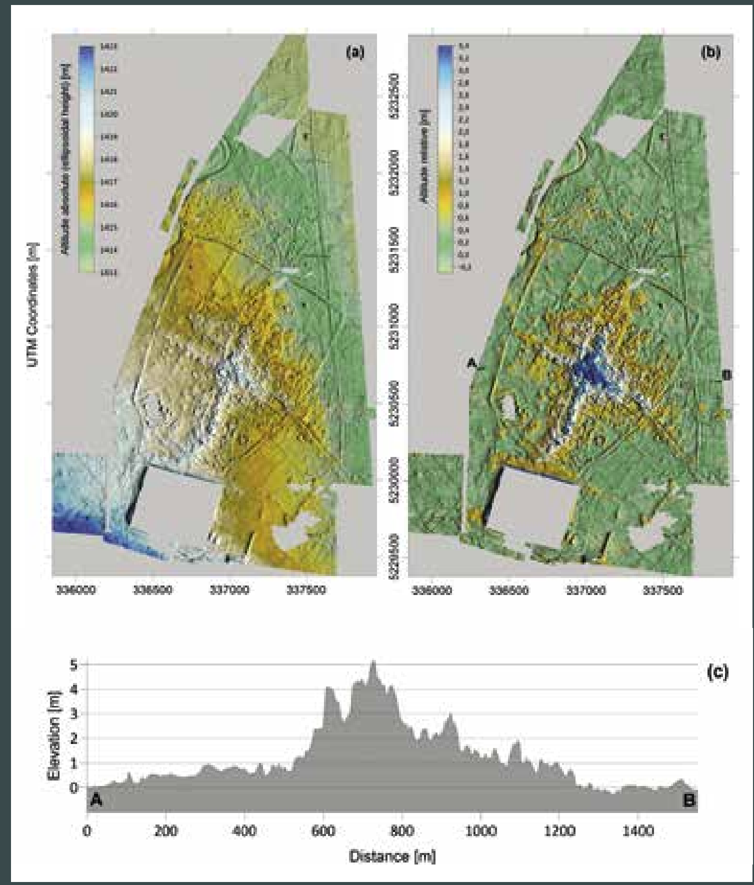
The measurement vehicle is equipped with three cryostats filled with liquid helium, in which the SQUID magnetic field sensors are located. © Leibniz IPHT / Sven Linzen

Hidden under steppe and farmland in the Orkhon Valley of central Mongolia lies the 800-year-old ancient capital of Karakorum, center of the former Mongolian Empire and now a UNESCO World Heritage Site. Researchers from Jena and Bonn have surveyed the city and the surrounding terrain and discovered that the former metropolis was significantly larger than previously thought.

Using a jeep, the researchers dragged their measurement system of magnetic field sensors – called SQUID (superconducting quantum interference detectors) – and a differential GPS system over an area of more than 650 soccer fields to map the remains of the ancient city. The system measures minimum changes in the Earth's magnetic field with very high resolution and, through this non-destructive geomagnetic scanning, can survey in great detail anthropogenic ground structures that are not visible above ground.

Dr. Sven Linzen, Dr. Ronny Stolz and the team from the Quantum Systems Department, together with colleagues from the Institute of Archaeology and Cultural Anthropology at the University of Bonn, were thus able for the first time to create a comprehensive geomagnetic and topographic survey plan for this area. From this, they gained insights into how the city was structured, how it developed, and which traffic routes and trade routes led to it.

During the expeditions to central Mongolia, the researchers had to overcome several challenges: The measurement system had to be transported overland to Asia due to installed lithium batteries, and the scientists were accommodated in yurt tent camps without a stable power supply. The expedition team as well as the sensor technology had to withstand air temperature fluctuations from -5 to up to 40 degrees centigrade. Sven Linzen is proud of the team's success: "For measurements and interpretation of the large amounts of data, physics and archaeology have to work closely together." The successful cooperation was rewarded in 2021 by an accentuation of the published research results as a "Research Highlight" in the journal Nature [2].



Centimeter-precise terrain model of the city complex, calculated from the measurement data of the SQUID system in a) absolute and b) relative elevation representation. A profile section through the city center is shown in c). Figure from Antiquity [1] © Leibniz IPHT / Sven Linzen

SQUID: Versatile

Research on SQUID in Jena dates back to 1968. Initially, the hair-thin structures of SQUID were scratched by hand under a microscope. Today, SQUID with structures in the nanometer range can be produced in the clean room using thin-film and lithography techniques. They are among the most sensitive in the world and enable magnetic field measurements with low noise and very high magnetic field resolution. SQUID from Leibniz IPHT are used in many applications – on earth, in the air and also under water. For example, to detect magnetic anomalies in the earth's crust, to search for mineral deposits or geothermal potentials, or to identify contaminated sites, old ammunition and unexploded ordnance device in the ground.

The researchers were accommodated in yurt tent camps during the expedition. © Leibniz IPHT / Stefan Dunkel

Together with Supracon, a company founded in 2001, Ronny Stolz's team is working on commercializing such systems, for example for building ground investigation. "Through the cooperation with Supracon, our sensor technology is being used across the board. This is a good example of the successful transfer of scientific findings into practice. In research, we are currently working on further developing our measuring system with the aid of optical magnetic field sensors," says the head of the research department, giving an outlook.

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Publication:
[1] Bemmann, Jan et al., Antiquity, 2021, https://doi.org/10.15184/aqy.2021.153

[2] Nature 599, 182, 2021, https://doi.org/10.1038/d41586-021-03013-4

In the Rhythm of the Heart

How Optically Pumped Magnetometers Make Even the Faintest Signals Visible in Biomedicine.

Measurement setup for characterization of OPM cells and research of new readout methods. © Sven Döring

For many, the smallest is often the greatest happiness: When couples are expecting a child, the anticipation of an exciting time in a new phase of life increases. This is often accompanied by uncertainties, namely whether the child's heart is beating in the right rhythm. One way of examining the rhythm of the heartbeat from the outside while the baby is still in the mother's womb is known as fetal magnetocardiography. This can provide information about the heart activity of the unborn child without pain or contact. The heartbeat of adults can also be measured quickly and easily using magnetocardiography. Thus, doctors can detect abnormalities that indicate pathological changes in the cardiac activity.

Optically pumped magnetometers for tiny biomagnetic signals

At the heart of this diagnostic procedure are highly sensitive quantum sensors, in this case optically pumped magnetometers (OPMs), which can detect the smallest magnetic fields. Each contraction of the heart muscle is associated with electrical currents in the human body and thus a secondary magnetic field. OPMs are able to measure and visualize those very weak biomagnetic signals non-invasively. By using these sensors, cost-intensive use of commonly used superconducting sensors, so-called SQUID, with complex cooling by liquid helium or nitrogen, can be circumvented. This provides a broad range of application of this diagnostic method far beyond individual research institutions and special clinics.

Measuring heart and brain activity

Not only the human heart, but also the brain generates biomagnetic signals that are much smaller. The sources of brain activity can be mapped in three dimensions with OPM, for example, to study neuronal diseases such as epilepsy. In addition, OPM are also attractive for a number of other potential fields of application, such as magnetomyography, a method for studying nerve conduction, or for cancer research.

Microfabricated OPM cell array with central reservoir, two measurement volumes and integrated heater and temperature sensor structures in thin film technology. © Sven Döring

"In particular, miniaturized OPMs provide interesting possibilities in neurodiagnostics, as the sensors can be attached extremely flexibly to the head of affected individuals to measure neuronal activities. The head of a child, for example, is much smaller than that of an adult. Consequently, the sensors used for children must follow a different design than those used for adults. Measurement of the signals must always take place very close to the source, in this case the head, in order to provide meaningful results. With small OPMs, such flexible arrangements can be realized very well," explains Dr. Theo Scholtes, head of the Quantum Magnetometry Group at Leibniz IPHT, who is working intensively on the sensors.

His group researches and develops quantum sensors for biophotonic applications. "Our aim is to replace SQUID more and more by OPM in the future, as they overcome the disadvantages of superconducting sensors and do not require extremely cold temperatures for their use. At the same time, it is our vision to be able to do without magnetic shielding, which is necessary when using these highly sensitive magnetometers in order to exclude the earth's magnetic field as well as technical interference factors from the measurement," Theo Scholtes continues.

Good to know: How do optical magnetometers work?

OPMs are integrated optical devices that can spectroscopically measure the effect of an ambient magnetic field on an atomic vapor. The core is a cell with atomic vapor, which is microsystem-manufactured in the clean room of the Leibniz IPHT and filled with the element cesium. If the magnetic field surrounding the cell changes, this affects the optical properties of the atoms of the vapor, which are detected with laser light. The research group is investigating various aspects of OPM, including advantages and disadvantages of different readout principles, in order to customize them for use in a range of applications.

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Publication:
Oelsner, Gregor, Physical Review Applied 17, 024034, 2022,
https://doi.org/10.1103/PhysRevApplied.17.024034

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Excellence Needs Diversity

International and open-minded – that's what Jena is, the City of Light. Many renowned high-tech companies and research institutes work in the hometown of optics and photonics on pioneering key technologies of the present and future.

Year after year, specialists from all over the world choose Jena as a center for business and academics. With their know-how and experience, they help to develop new ideas and transform them into valuable solutions. Thus, photonic technologies pave the way for new diagnostic procedures and therapeutic approaches, raise industrial manufacturing to a new level, enable us to explore unknown galaxies, or lay the foundation for future mobility.

Leibniz IPHT also has an international character due to its employees coming from 35 countries, worldwide research collaborations, exchange programs and partnerships. It is precisely this diversity that spawns groundbreaking innovations, international projects, global networks, and research at the highest scientific level.

In order to ensure this excellence in research in the long term, excellence in scientific education and training is needed. Supporting researchers at all career stages, allowing them room to develop, permitting them to dive deeper into their research field and gaining intercultural experience, is of central importance to Leibniz IPHT.

To strengthen its research performance, innovative strength, and international cooperation, the institute also participates in EU funding programs such as the **European Research Council** and **Marie Skłodowska-Curie** measures to address scientific issues with global social relevance.

Three PhD students of Leibniz IPHT give an insight into their story and their experiences in their portraits, in which they tell of their passion for international research that creates pioneering solutions for greater safety, health, and a cleaner environment.

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The globally visible European funding program for cutting-edge research of the European Research Council (ERC) supports excellent scientists with groundbreaking interdisciplinary research projects.

With the Marie Skłodowska Curie actions, the European Union aims to promote academic careers of scientists. Established by the European Commission, scientific careers should become more attractive for researchers.

Julia Sophie Böke

Doctoral candidate in chemistry

Since 2020 at Leibniz IPHT

Department Nanobiophotonics

"Working on highly sensitive topics of great global impact such as the pollution of our waters by microplastics, and thus contributing to the protection of our environment and nature is incredibly exciting. In particular, close integration of microfluidics and photonics makes research in this field fascinating."

From the Wide World Right into the Heart of the Town on the Saale

After working in Spain, Belgium and Asia, Julia Sophie Böke (born in Braunschweig) detects microplastics based on their properties as part of her doctoral thesis in Jena. For this purpose, the tiny plastic particles are dyed and made visible in quantity and size with the help of microfluidic processes, optics, and image processing. This approach could be used to analyze drinking water, wastewater, or seafloor for plastic residues. Julia Sophie Böke contributes the results of her research to the interdisciplinary and EU-funded "MonPlas" project. In this network, young scientists from European research institutions and universities work closely together on tomorrow´s technologies and processes in order to be able to identify microplastics even more reliably and quickly in the future.

Internationality, equality, and diversity are particularly important to the **Marie Skłodowska-Curie** fellow being the equal opportunities officer at Leibniz IPHT. Respect and tolerance are the cornerstones that enable a successful collaboration across all borders and give rise to cutting-edge research. Julia Sophie Böke is particularly passionate about encouraging young people to pursue their preferences and interests, and motivating them to follow their path, especially in the field of natural and engineering sciences.

> **It is extremely inspiring and motivating to recognize the potential of our research already today and to see what impact the results will have on all of our lives in a few years.**

From Porto to the Optical Valley Jena

Dr. André Gomes

At Leibniz IPHT since 2016

PhD student since 2017

Post-doctoral researcher since 2020

Doctor in physics in 2021

Department Fiber Research and Technology

Born in Portugal, Dr. André Gomes came from Porto to Jena during his studies in 2016 thanks to a scholarship from the German Academic Exchange Service. At Leibniz IPHT, he followed his passion for optics and was able to deepen his knowledge in the context of his master's thesis. The enthusiasm and fascination for optical technologies remained and again brought him to the city of light for his dissertation in 2018. With his doctoral thesis on novel fiber sensor technologies in optical fibers he laid important foundations for a new generation of highly sensitive sensors. They are suitable for applications such as temperature and pressure measurements with improved properties such as increased sensitivity and resolution.

Above all, the positive evaluation of the international research community for his scientific achievement and publication in the renowned journal "Laser & Photonics Reviews" in 2021 were both confirmation of his previous work and a motivation to continue on his path.

After completing his PhD in 2021, the scientist focuses on biomedical imaging for minimally invasive brain examinations as part of a project funded by the **European Research Council**. With hair-thin endoscopic fiber probes, he contributes to observe neuronal structures in the deepest parts of the brain even better.

> **If physicians can diagnose diseases within the shortest possible time and choose the right therapy, we could really save people's lives. Contributing to such groundbreaking technologies to overcome challenges in medicine – that was and is my dream.**

From Israel to Jena and Back Again

Amir Nakar

Doctoral candidate in chemistry

At Leibniz IPHT from 2018 to 2022

Department Spectroscopy / Imaging

At Leibniz IPHT, biochemist Amir Nakar has dedicated himself to pathogenic infectious agents and their treatment. In his doctoral thesis, he succeeded in distinguishing enteric bacteria from other pathogens using Raman spectroscopy, as well as identifying bacteria that are resistant to antibiotic treatments. Such resistance is a major problem, as medications are becoming increasingly ineffective. That's why it is particularly important for him to enable doctors to assess more quickly which bacteria are causing an infection and prescribe medication in a targeted manner in the future. This would reduce antibiotic resistance and save human lives.

But it is not only in the context of his dissertation that the Israeli-born scientist is committed to social issues. He also gave the doctoral students at Leibniz IPHT a voice as a doctoral student representative. Supporting them in their professional development and in their exchange with the international scientific community was a matter of concern to Amir Nakar.

Moreover, he has a special passion for science communication. Whether blogging, tweeting, or posting – smart ideas and brilliant international minds fascinate him.

Amir Nakar will continue on his path in the fight against pathogens and antibiotic resistance in 2022 as he is moving from Jena back to Israel to work in the industry.

Closely Interwoven Excellence Research

Unleashing Potential Together for Scientific Excellence

In order to jointly advance research projects with cooperating universities and regional networks and to set accents for its own research, Leibniz IPHT works closely with partners in various Collaborative Research Centers and Clusters of Excellence.

Dr. Carolin Müller, scientist in the Department Functional Interfaces at Leibniz IPHT, uses spectroscopic methods to investigate how photocatalysts can help to split water into hydrogen and oxygen. © Sven Döring

"Green Energy for the Future"

Green plants convert water and carbon dioxide into oxygen and glucose through photosynthesis and with the help of solar energy. Inspired by this, scientists are trying to imitate this natural biochemical process in the laboratory: The **CRC CataLight** is working on novel materials that can perform artificial photosynthesis and, for example, split water into oxygen and hydrogen, as green energy carriers. To this end, photocatalysts are developed and incorporated into innovative materials that use the energy of sunlight to split oxygen and hydrogen from water. Within the framework of the CRC CataLight, Leibniz IPHT examines photocatalytic processes with the help of spectroscopic methods and thus contributes to a better understanding of the reactivity and stability of the novel materials.

"Extinguishing Fires Exactly Where they Burn"

As a scientist in the Functional Interfaces Department at Leibniz IPHT Dr. Maria Sittig researches nanostructures that react to light. © Sven Döring

Inflammations can spread rapidly in the human body and, in the case of a sepsis, lead to multiple organ failure. Medication used to treat these inflammatory trouble spots usually do not act exactly where they are needed, but are distributed throughout the whole organism via the bloodstream. Unwanted or sometimes even harmful side effects are the result. Researchers in the **CRC PolyTarget** are therefore working on a turnaround: They are developing polymer-based nanostructures that are inserted into the body and release their active ingredients in a controlled manner, precisely where it "burns". The body is less burdened with drugs due to the targeted administration of active ingredients and symptoms can be better treated. Leibniz IPHT is dedicated to, among other things, light-activated particles, their spectroscopic characterization, and the mechanisms of light-controlled reactivity. In addition, work is being carried out on the investigation of the nanoscale composition of polymeric nanoparticles and the factors influencing the release of active substances. Other subprojects are being worked on by the professors of Leibniz IPHT in their affiliation with the Friedrich Schiller University of Jena.

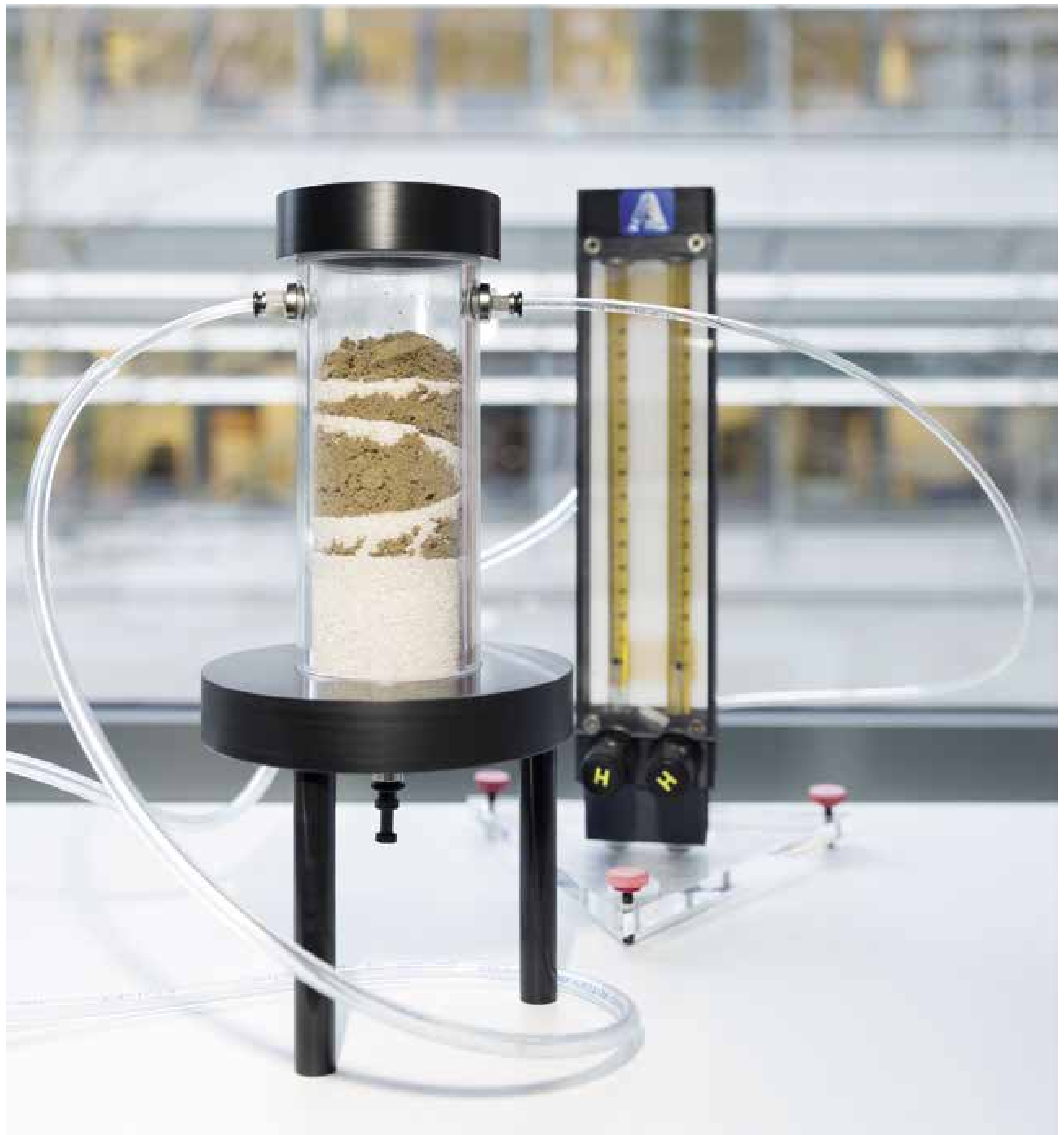
Collaborative Research Centers

Collaborative Research Centers (CRC) are long-term research projects at universities in which scientists work together with researchers from non-university institutions to examine and research globally significant topics. They are funded by the German Research Foundation for a period of up to 12 years. Leibniz IPHT works together with renowned researchers, for example, in the **CRC PolyTarget**, **AquaDiva**, **NOA** and **CataLight** on the challenges of the future.

Clusters of Excellence

Clusters of Excellence combine the strengths of different scientific players in close cooperation with industry to create a synergetic research culture that gives rise to new groundbreaking ideas. Clusters of Excellence are funded by the German Federal and State Governments as part of the Excellence Strategy. Leibniz IPHT is part of the **Cluster of Excellence Balance of the Microverse.**

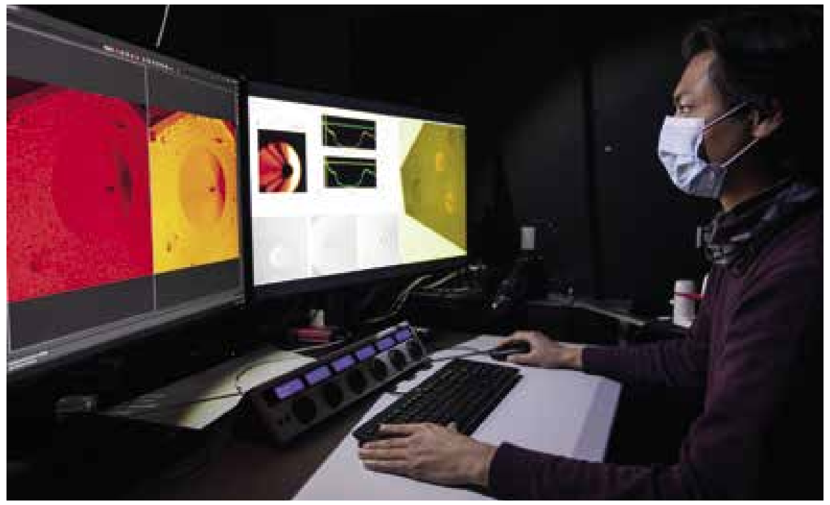
Deciphering What Holds the World Together at its Core



The Fiber Spectroscopic Sensing Group in the Spectroscopy/Imaging Department at Leibniz IPHT is conducting research to help analyze gases below the ground with new technologies. © Sven Döring

Protecting our nature and environment with its incomparable biological diversity and maintaining it in a healthy balance for future generations is of utmost importance. But biodiversity includes not only aboveground habitats, but also hidden ecosystems underneath the earth's surface. Unraveling the interaction of these two habitats and exploring how they shape biodiversity is the aim of the **CRC AquaDiva**. The researchers want to gain a deeper understanding of, among other things, the effects of intensive agriculture, the use of pesticides or extreme weather conditions on subterranean habitats and the groundwater reservoirs found here. Leibniz IPHT is researching optical gas sensors, which help to decipher metabolic and exchange processes underground. The knowledge gained in the CRC AquaDiva will be used to derive recommendations for the protection of these habitats.

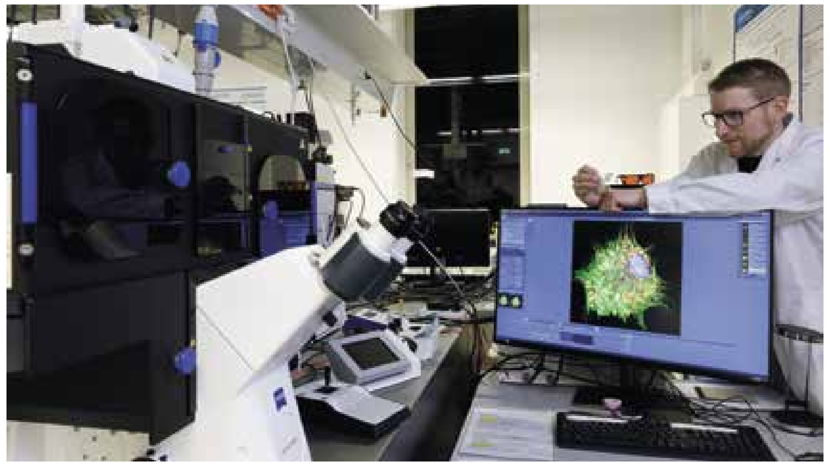
Bringing the Secrets of Nonlinear Optics to Light



Parijat Barman, PhD student in the Department Spectroscopy/Imaging at Leibniz IPHT, is conducting research on the optimization of Raman spectroscopy. © Daniel Siegesmund

The special feature of nonlinear optics is that the light-matter interaction effects caused by them do not show a linear but a nonlinear dependence on the intensity of the incident light, and can therefore generate completely novel light-matter phenomena. Researchers in the **CRC NOA** (Nonlinear Optics on Atomic Scales) are investigating nonlinear light-matter phenomena in nanostructures and how these phenomena can be used to manipulate light, for example to generate high harmonics. A better understanding of these processes should help to develop novel materials (such as metamaterials) characterized by specific nonlinear effects by means of nanostructuring. Thus, the scientists want to contribute, among other things, to the development of highly sensitive sensors, or the generation of highly efficient, compact X-ray sources for future applications. Within the framework of the CRC NOA, Leibniz IPHT is conducting research, among other things, to better understand and use surface-enhanced Raman spectroscopy, for example, to study chemical reactions of single molecules and their interactions with unprecedented precision.

Listening to the "Whisper" of Microorganisms



Scientist Dr. Patrick Then from the Department Biophysical Imaging at Leibniz IPHT and the Microverse Imaging Center is helping to understand how microorganisms communicate by exploring microscopic methods. © Sven Döring

Microorganisms, such as bacteria or fungi, are found on our planet in all areas of life – from soil to water to air. They often live and work together in close microbial communities. In this way, they fulfill important tasks in the environment and as a microbiome in larger organisms, such as humans. If this microbial universe is unbalanced, this can have fatal consequences for flora and fauna – destabilized waters or diseases are the consequences. The **Cluster of Excellence Balance of the Microverse** investigates how these microbial communities communicate and interact with each other and with their environment. The knowledge gained in the Cluster of Excellence will contribute to the long-term maintenance or re-stabilization of microbial communities. Together with its partners, Leibniz IPHT contributes to this aim by researching state-of-the-art imaging methods. The doctoral program "Jena School for Microbial Communication" (JSMC), which unites researchers from a wide range of disciplines and serves to promote young researchers, has been a graduate school of the Cluster of Excellence since 2019.

News

Jürgen Popp Re-elected as Director of Leibniz IPHT

Chemist Prof. Dr. Jürgen Popp will continue to head Leibniz IPHT for the next five years. The institute's advisory board unanimously reappointed him as scientific director, effective as of June 1st, 2021. Jürgen Popp has been heading Leibniz IPHT for 15 years, which researches light-based technologies for medical diagnostics and therapy, health, environment and safety, and pushes on the translation of research results into application in numerous national and international collaborations.

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Scan this code to access the online article.

2,000 Meters Below Ground-level: Jena Flight Probes Deliver Signals from the Depths

In the western part of the Harz mountain, research partners of Leibniz IPHT are testing novel measurement methods for worldwide use. They provide geological findings from depths never reached before. To this end, they use a new type of measuring instrument that researchers at Leibniz IPHT have developed together with Jena-based Supracon AG. The highly sensitive sensors use electromagnetic signals and make it possible for the first time to explore the terrain at depths of up to two kilometers. Until now, this was only possible stationary at individual locations and up to about 300 meters.

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German-British Research Team Develops Quantum Optical Light Cage on a Chip

The novel hollow-core light cage for nonlinear and quantum applications overcomes disadvantages of previous photonic structures and could serve as a basis for quantum memories in the future. Scalable integrated technology platforms for targeting the coherent interaction between light and atoms are essential for exploring new applications in quantum technologies. The light cage on the chip behaves stably even in the atmosphere of chemically highly reactive alkali atoms, and could in the future provide an integrable, cost-effective and versatile basis for delaying single photon pulses in atomic vapors. The researchers published their results in the journal Light: Science & Application.

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Leibniz Association Continues to Fund Health Technologies Research Alliance

The Research Alliance "Leibniz Health Technologies" will receive funding of 1.2 million euros from the Leibniz Association until the end of 2024. Leibniz Health Technologies is thus starting its second development phase with new projects in which competencies from 14 Leibniz institutes complement each other for research into innovative health technologies.

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Advancing the Energy Transition

Working together to adjust the set-screws that Thuringia can use to reduce its climate-damaging CO_2 emissions: This is how Jonathan Plentz formulates the aim of the SolarInput association. Since December 2019, the scientist from Leibniz IPHT has been executive board member of the association and network, in which more than 30 companies, research institutions, universities, colleges and municipalities are committed to strengthening the solar industry in Thuringia and advancing the topic of sustainability.

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Scan this code to access the online article.

Maria Wächtler is the New yPC Spokeswoman: "An Ideal Platform for Networking"

Two young female researchers have been at the top of the Bunsen Society's young researchers' organization since May: Maria Wächtler from Leibniz IPHT and Katharina Meyer from Georg August University Göttingen. The "young Physical Chemists" (yPC) is an ideal platform for researchers at the beginning of their careers who want to build up a network, says their newly elected spokeswoman Maria Wächtler – both within the scientific community and in industry.

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Scan this code to access the online article.

Progress in Phage Therapy: Researchers Demonstrate Broad Effectiveness against MRSA Bacteria

Bacteriophages are special viruses that only attack bacteria and can therefore be an alternative to antibiotics. Researchers at Leibniz IPHT, together with a team of Austrian, German and Swiss researchers, were able to show for the first time that specifically cultivated phages are significantly more effective against multi-resistant germs than known wild types.

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Excellent Performance

Successful Founding: Funding through EXIST Transfer of Research

Hair-thin endoscopes from Leibniz IPHT are to advance brain research in the future. Dr. Sergey Turtaev, Dr. Hana Čižmárová, Patrick Westermann and Dr. Jiri Hofbrucker from the Fiber Research and Technology Department are working towards this goal. In order to make this a reality, the team received the financial support "EXIST Transfer of Research" from the German Federal Ministry for Economic Affairs and Climate Action. With the help of the seed capital, a spin-off company is to be founded by 2023 to bring the endoscopy technology developed at the institute under the leadership of Prof. Tomáš Čižmár to market maturity. Thus, they want to contribute to even better research into the causes of neurogenerative diseases such as Parkinson's or Alzheimer's.

Excellent Idea: Leibniz Start-Up Award

Dr. Benedict Diederich, René Lachmann and Barbora Maršíková from the Microscopy Department at Leibniz IPHT received the Leibniz Start-up Award of 25,000 euros for their idea to develop a microscope for everyone. The prize is awarded to smart start-up projects from Leibniz institutes to help ambitious and promising ideas achieve a breakthrough and to support the company founding. With the developed "UC2" (You. See. Too.) optical toolbox powerful microscopes can be produced customized and cost-effectively by using a 3D printer enabling high-resolution images for research and education.

Award-winning Research Marketing: DFG Community Prize

The German Research Foundation has awarded Leibniz IPHT the Community Prize for its concept of telling in a science comic how researchers develop light-based solutions for space exploration. The prize money enables the realization of the comic, in which the superheroine "Lasergirl" travels to Mars to search for extraterrestrial life with the help of her technological equipment. Thus, Leibniz IPHT shows how its technologies contribute to the success of the scientific goals of the Mars mission "ExoMars": With participation of the Jena researchers, a Raman laser spectrometer has been developed that supports the mission in the search for signs of life through molecular fingerprints.

Top-class Honor: Changjiang Scholarship Award

Prof. Dr. Volker Deckert, head of the Nanoscopy Department at Leibniz IPHT, received the prestigious Chinese Changjiang Scholarship Award, the highest academic honor given by the Ministry of Education of the People's Republic of China to leading scientists in higher education. Considered a pioneer in tip-enhanced Raman spectroscopy, he will receive a Yangtze River Visiting Chair at the School of Physics and Information Technology at Shaanxi Normal University in Xian, China, for a funding period of three years to conduct research, and teach in the field of nano-optics. The fellowship also allows an exchange of scientific experience and the performance of optical experiments.

In the Golden Rain: iENA Gold Medal

For their invention "Augmented Reality (AR) in the operating room – real-time imaging for marker-free molecular tumor detection", the Leibniz IPHT researchers Prof. Dr. Iwan Schie, Dr. Wei Yang and Prof. Dr. Jürgen Popp received the gold medal of iENA, the trade show for ideas, inventions, and new products. The award-winning method could be used in the future in operations for tumor resection. The combination of Raman spectroscopy, fiber-optic probe, real-time data processing and imaging makes it possible to determine tumor boundaries and thereby remove the tumor as completely as possible. The use of AR serves to display the results in a user-friendly manner on a monitor, or by projecting them directly onto the tumor.

Convincingly Presented: Student Research Achievement Award

The Biophysical Society awarded Anindita Dasgupta, PhD student in the Biophysical Imaging Department at Leibniz IPHT, with the Student Research Achievement Award (SRAA) for her outstanding scientific performance. The doctoral student conducts research in the field of 3D super-resolution microscopy to visualize cellular structures with nanometer accuracy to be able to precisely investigate even the smallest details. The Leibniz IPHT scientist received the prestigious prize for her excellent presentation of her research results in the Biophysical Society's poster competition. The winners of the poster competition are selected annually by a jury from among hundreds of submissions.

Publication Highlights

Multimodal Nonlinear Endomicroscopic Imaging Probe Using a Double-core Double-clad Fiber and Focus-combining Micro-optical Concept

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Light: Science & Applications, 2021, 10:207, Official journal of the CIOMP 2047-7538, https://doi.org/10.1038/s41377-021-00648-w

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Pshenay-Severin et al.

Spatially Resolving the Enhancement Effect in Surface-Enhanced Coherent Anti-Stokes Raman Scattering by Plasmonic Doppler Gratings

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Spatially Resolving the Enhancement Effect in Surface-Enhanced Coherent Anti-Stokes Raman Scattering by Plasmonic Doppler Gratings, ACS Nano, 15, 809-818, 2021, https://doi.org/acsnano.0c07198

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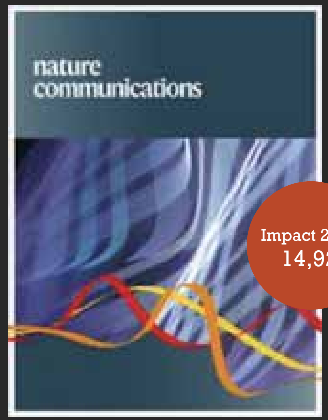
Ouyang et al.



Direct Supercritical Angle Localization Microscopy for Nanometer 3D Superresolution

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Nature Communications, 2021, 12:1180, https://doi.org/10.1038/s41467-021333-x

–

J. Ries et al.

Memory Effect Assisted Imaging Through multimode Optical Fibres

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Nature Communications, Volume 12, 2021, Article number: 3751 (2021), https://doi.org/10.1038/s41467-021-23729-1

–

S. Li et al.

Characterizing Photocatalysts for Water Splitting: from Atoms to Bulk and from Slow to Ultrafast Processes

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Chemical Society Reviews, 2021, 50, 1407-1437, https://doi.org/10.1039/D0CS00526F

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C. Kranz et al.

Time-of-flight 3D Imaging Through Multimode Optical Fibers

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Science, 9 Dec 2021, Vol 374, Issue 6573, pp. 1395-1399, https://doi.org/10.1126/science.abl3771

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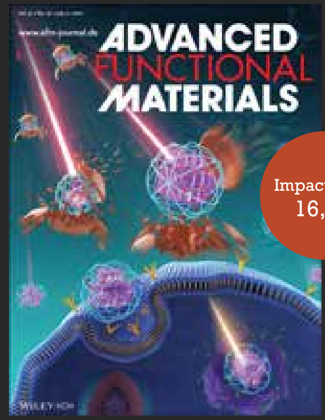
D. Stellinga et al.



1D p–n Junction Electronic and Optoelectronic Devices from Transition Metal Dichalcogenide Lateral Heterostructures Grown by One-Pot Chemical Vapor Deposition Synthesis

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Advanced Functional Materials, Volume 31, Issue27, July 2, 2021, 2101086, https://doi.org/10.1002/adfm.202101086

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E. Najafidehaghani et al.

Ultrahigh Numerical Aperture Meta-fibre for Flexible Optical Trapping

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Light: Science & Applications. 10, 57, 2021, https://doi.org/10.1038/s41377-021-00491-z

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M. Plidschun et al.

Silicon Sub-oxides as Driving Force for Efficient Light-enhanced Hydrogen Generation on Silicon Nanowires

–

Silicon suboxides as driving force for efficient light enhanced hydrogen generation on silicon nanowires, Small February 24, 2021, 2007650, https://doi.org/10.1002/smll.202007650

–

T. Ming et al.

Chemometric Analysis in Raman Spectroscopy from Experimental Design to Machine Learning-based Modeling

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Nature Protocols, 2021, 05.11., https://doi.org/10.1038/s41596-021-00620-3

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S. Guo et al.

Coherent Interaction of Atoms with a Beam of Light Confined

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Light: Science & Applications, Volume 10, Article number: 114, 2021, https://doi.org/10.1038/s41377-021-00556-z

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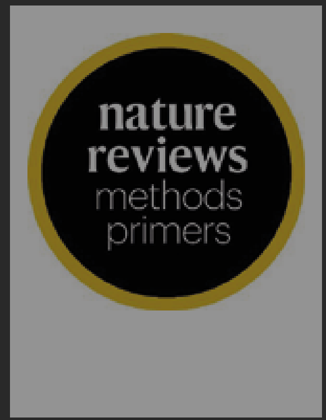
F. Davidson-Marquis et al.



Raman Microspectroscopy for Microbiology

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Nature Reviews Methods Primers, Volume 1, Article number: 80, 2021, https://doi.org/10.1038/s43586-021-00075-6

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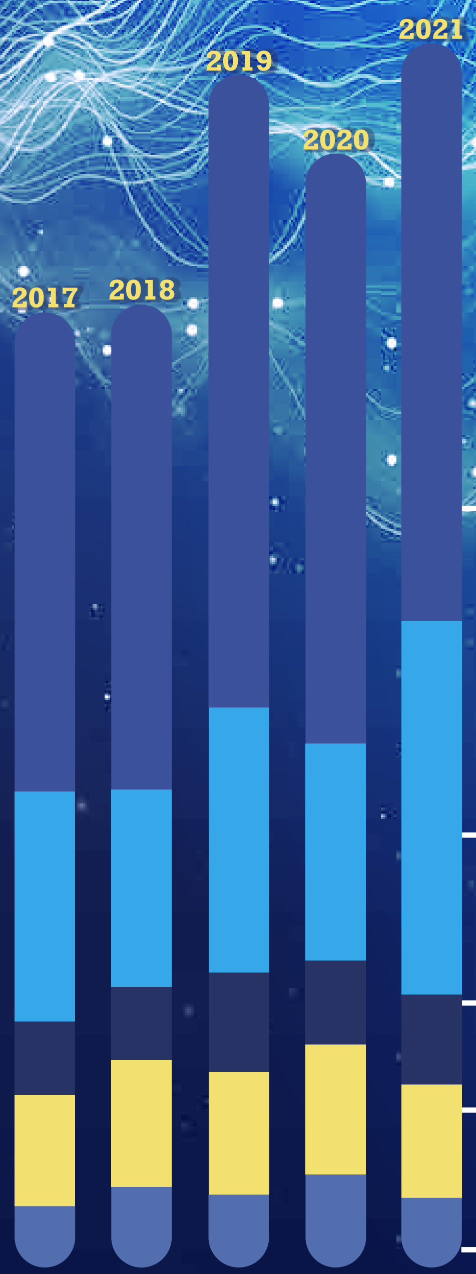
K. S. Lee et al.

Key Figures of 2021

15 Patent applications
9 thereof patent applications serving as priority

37 Patents granted
4 of which giving rise to priority



15,110,599 €
Institutional funding

9,809,588 €
National projects, **3,690,501 €** thereof for Leibniz Center for Photonics in Infection Research (LPI)

2,275,454 €
DFG funding

3,045,554 €
Industrial projects

1,789,627 €
EU third-party funding, **255,914 €** thereof from ERA-Net / ERA-NetPlus, JPI etc.

32,030,821 €
Total budget
= **52.82 %** Third-party funding

413 Employees

44 % Proportion of international researchers and doctoral students

Employees from **35** countries

30 Talks | Posters
8 thereof Invited Talks
1 thereof Keynotes
2 thereof Plenary Talks
19 thereof Contributed Talks

25 EU financed projects
5 of which coordinated by Leibniz IPHT

3 EU co-financed projects (ERA-Net, Eurostars, JPI etc.)

15 Doctorates
6 thereof earned by women

7 Trademark applications
3 thereof national

247 Publications in peer-reviewed journals

10 Trademark registrations
10 thereof IR trademark / European Union

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Dr. Uwe Hübner

Competence Center for Specialty Optical Fibers
Dr. Tobias Habisreuther

Sensor Systems and System Technology
Dr. Walter Hauswald

Junior Group

Ultra Fast Fiber Lasers
Dr. Maria Chernysheva

Institute Personnel 2021

	Full-time Equivalents				
	Institutional Funding	**Third-Party Funding**	**Professors**	**Total**	**Persons**
Scientists	39.57	68.82	8.00	116.39	130
Visiting Scientists[2]	–	–	–	–	27
External Funded Scientists[1]	–	–	–	–	13
External Funded Employees[1]	–	–	–	–	1
External Funded Doctoral Students[1]	–	–	–	–	48
Doctoral Students	7.24	34.85	–	42.09	66
Technical Staff	39.24	37.95	–	77.19	83
Administration	13.07	10.43	–	23.50	25
Scientific Coordination	3.25	5.88	–	9.13	10
PR and Research Marketing	3.38	1.75	–	5.13	6
Executive Committee	1.00	–	0.50	1.50	2
Trainees	2.00	–	–	2.00	2
Total Personnel	**108.75**	**159.68**	**8.50**	**276.93**	**413**

[1] Employees, not financed from Leibniz IPHT payroll or employees, financed by another institution (e.g. University Jena), who have their main working place at Leibniz IPHT.

[2] Scientists, who worked in the legal year 2021 longer than one week at Leibniz IPHT and who are financed by another institution. Key date regulation December 31st, 2021 does not apply.

Budget of the Institute 2021

	spending in T Euro
Institutional Funding: Use	
Free State of Thuringia, Federal	15,110.6
Third-Party Funding	16,920.2
total	**32,030.8**

Institutional Funding: Use

Staff	9,729.5
Materials	4,250.2
Investments	1,130.9
total	**15,110.6**

Third-Party Funding

Federal Ministries of which 348.9 T€ for projects financed by the Leibniz Association of which 3,690.5 T€ for Leibniz Center for Photonics in Infection Research (LPI)	7,442.0
DFG Additionally IPHT scientists at the University Jena used DFG-funds of 1,725.0 T€	2275.4
Free State of Thuringia of which for restructuring in the frame of EFRE 696.9 T€	2,268.0
EU of which for EU-Initiatives such as ERA-Net / ERA-NetPlus, Joint Programming Initiatives and more: 255.9 T€	1,789.6
Assignments from Public Institutions	173.7
Other Contributions	99.6
Subcontracting in Joint Projects	137.3
R & D Contract incl. Scientific-Technical Activities	2,734.6
total	**16,920.2**

We Thank for the Financial Support

Imprint

Publisher: Leibniz Institute of Photonic Technology

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PHOTONICS FOR LIFE
from Ideas to Instruments

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