

reflexion

Annual Report 2019



Solutions with Light

—

Biophotonics for Future

From Jena into the World

From Oxford, Dundee and California to Taiwan and China, Indonesia and Australia: Leibniz IPHT provides impulses in numerous regional, national, and international networks. As a high-profile player in the field of photonics in the life sciences, the institute is an attractive employer for international scientists and promotes collaboration with cooperation partners all over the world.

PHOTONICS FOR LIFE
from Ideas to Instruments

Dear Readers,



Prof. Dr. Jürgen Popp © Sven Döring



Frank Sondermann © Sven Döring

why is the sky blue? Why is water wet? Why is the banana crooked? Why, why, why, why ...? From the age of three to four, children start bombarding us with questions. They are driven by an almost insatiable curiosity. They look for answers and want to understand – they want to know. In the end, it is all about understanding the world around us and also the world within us. We do not know an answer to every question. Instead, the search, for knowledge reveals a multitude of new questions, which in turn raise further questions – a never-ending story. If the natural philosophers had already found all the answers in antiquity, there would be no need for science today.

We live in a time that raises many questions, in which everything is constantly being questioned and in which the demands and expectations of research are enormous. The corona pandemic is a very impressive illustration of this at present. We are facing challenges that affect society and therefore also science in all its diversity. In the search for solutions, natural and life sciences as well as social and behavioural sciences are equally in demand.

In a global and networked world, pathogens can spread rapidly and require new approaches for diagnostics and therapy. Although modern medicine is reducing the risk of dying at a young age, we are confronted with an increase in age-related diseases such as cancer, Alzheimer's or cardiovascular diseases. At the same time, climate change presents us with challenges that will occupy us for many generations to come. The number of problems to which we urgently need answers seems endless.

Curiosity and the search for answers to urgent questions motivate us at the Leibniz Institute of Photonic Technology again and again. We want to contribute to making life safer and healthier. Our mission is to research photonic solutions for faster and more accurate medical diagnostics, for safe drugs for a new quality of food and environmental analysis and for innovative safety technology.

In this issue of "reflexion", we would like to tell you about the questions we are pursuing and what our approaches to solving them look like. We hope you enjoy reading this issue.

Stay thirsty for knowledge, stay curious and above all: stay healthy.

Jürgen Popp
Scientific Director

Frank Sondermann
Administrative Director

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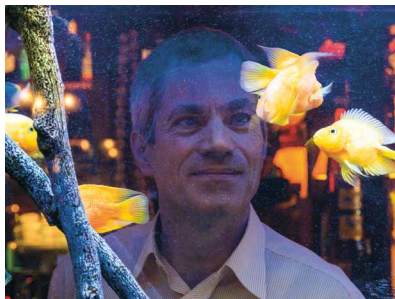


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The staff of Leibniz IPHT in autumn 2019

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We do Research for the Future

The corona pandemic is spreading around the world and aggravating the medical, social and economic challenges we face. While the virus is keeping us on our toes, the climate crisis is fading into the background – yet it is as urgent as ever.

No less pressing is the threat posed by multidrug resistant bacteria. At the same time, people in industrialized affluent societies are getting older and older; more and more of them are contracting cancer or Alzheimer's disease. Our way of life puts a strain on the environment. Plastic waste endangers water bodies. Fossil resources are running out. The devastating consequences of man-made climate change are already visible.

This makes it necessary for us to change our way of life. To live and work sustainably without health, environment and climate paying the price. To preserve our ecosystems for future generations in such a way that they too can use them as a basis for life.

Scientists at Leibniz IPHT are working on solutions that help us to shape this change. They are researching technological processes to improve the diagnosis and therapy of diseases, for example, to detect microplastics in water bodies and to safeguard the quality of our groundwater. They are developing approaches on how climate-friendly energy production could look like. By doing so, the researchers are laying the foundations today for how we want to live in the future.



Here's Looking at You

Clara Stiebing sends laser beams into the eye – and gets valuable information back. They reveal whether the retina is diseased, much earlier than with current examination methods

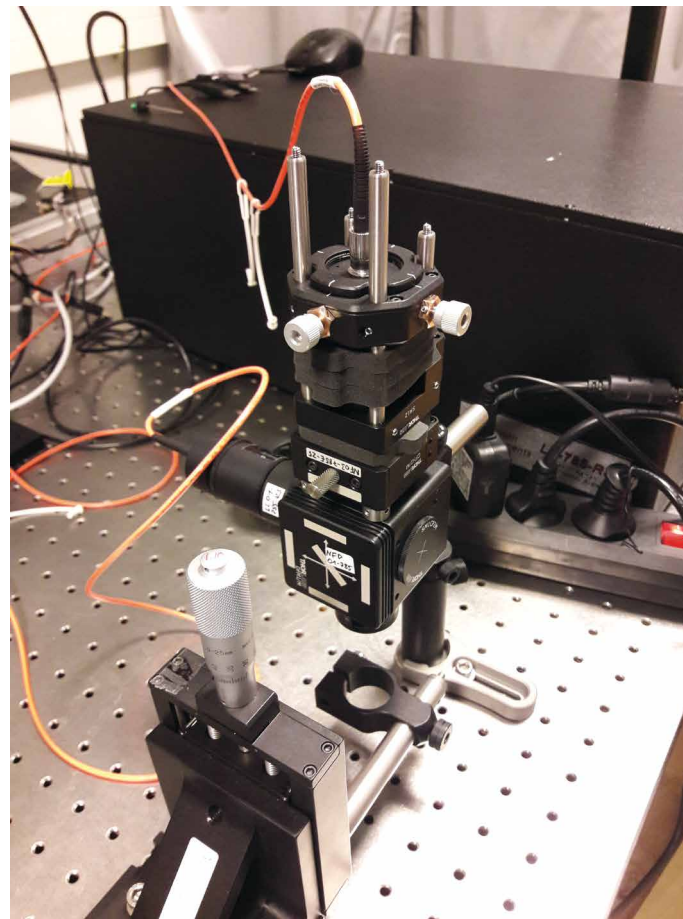
By Laser Beam into the Window to the Brain

A team from Leibniz IPHT shows for the first time how Raman measurements in the eye are possible. Research partners in Vienna are now building a device that will be able to detect Alzheimer's disease

The "laser" sign above Clara Stiebing's lab is lit up red. Only to be entered with protective goggles, it means. It doesn't mean a laser beam will hit your eye. Meanwhile, inside, Clara Stiebing is experimenting with exactly that: What happens if she aims a laser at a human eye? To be more precise, what must this beam be like so that it does not harm the eye, but helps to make visible signs of diseases that cannot be detected otherwise?

"We use the laser light to obtain comprehensive information about the biochemical composition of the retina," explains Clara Stiebing, who has been working as a postdoctoral fellow at the Leibniz IPHT for three years. "These are important, for example, for the early detection of age-related macular degeneration." The disease, which shows hardly any symptoms in its initial stage, is the most common cause of severe visual impairment or even blindness. In most cases this could be avoided if the changes in the macula were detected as early as possible.

Clara Stiebing is part of a team from Leibniz IPHT and the Friedrich Schiller University Jena, working together with the Medical University



With this Raman facility, the researchers reconstructed the optical path in the eye to simulate the parameters inside the eye.

of Vienna, the Netherlands Organisation for Applied Scientific Research in Leiden and Radboud University in Nijmegen to research the technology that this improved diagnostics will be able to provide in the future. The researchers combine two optical methods to deliver high-resolution, non-invasive images from the eye:

Raman spectroscopy and optical coherence tomography.

The idea with which the researchers from Jena started the joint project is to obtain a molecular fingerprint of the retina using Raman spectroscopy. To do this, the back of the eye is irradiated with laser light, which stimulates the molecules of the retina to oscillate. The scattered light shows characteristic patterns which decipher the chemical structure of the retina – without touching the eye or using special markers. From the content of lipids, proteins, carotenoids, and nucleic acids, physicians can then derive important health information. Measuring at the eye with a laser is a great challenge: Eyes are sensitive, aiming a laser at this organ can be dangerous.

"A laser with too much power could cause burns on the retina and, in the worst case, lead to blindness or clouding of the lens," explains Clara Stiebing. Moreover, the conditions in the eye are not ideal for optical measurements. Using international safety standards, the researchers calculated how strong their laser beam

should be at a wavelength of 785 nm. The result: one milliwatt – twenty times weaker than lasers that they normally use for their spectroscopic measurements. "We were skeptical whether this would work," admits Clara Stiebing.

It worked very well: Raman measurements on human retinal samples provided significant spectra that allow precise conclusions about the condition of the retina. "This was a great pleasure for us," reports Rainer Leitgeb from the Medical University of Vienna, who coordinates the European research project MOON (Multimodal Optical Diagnostics for Age-related Diseases of the Eye and Central Nervous System). According to Leitgeb, these promising results have decisively advanced the project.

To prove for the first time that Raman measurements in the human eye with a wavelength of 785 nm are theoretically possible, the researchers constructed a setup in the Jena laboratory that simulates the optical conditions of the eye. It simulates the conditions under which light is excited and collected in the eye.

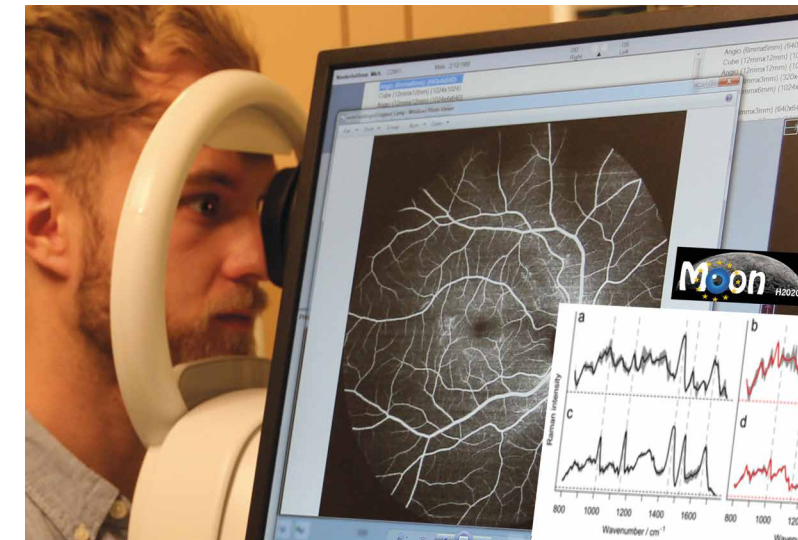
Based on these results, the team of scientists at the Medical University in Vienna is developing a device that will enable fast and contact-free diagnosis via eye scan in the future: "We scan the eye with light and measure the light that comes back

from the eye. And this returning light contains all the information I need for diagnostics," explains Rainer Leitgeb. "Optical coherence tomography very quickly maps the morphology of the fundus of the eye. This enables us to identify suspicious areas, which can then be analysed more precisely on a molecular level, i.e. chemically, using Raman spectroscopy.

The researchers hope to use the device to carry out initial measure-

Before the researchers can show this in experiments on humans, they have the planned study carefully examined by the ethics commission at the University Hospital in Vienna. For ethical reasons, only Alzheimer's patients in whom the disease does not yet limit the ability to make rational decisions may participate in clinical studies. Because the optical procedure is so sensitive, the researchers are convinced that the eye scanner could already provide meaningful results at such early stages and detect characteristic deposits in the brain.

Publication: Clara Stiebing et al., Nonresonant Raman spectroscopy of isolated human retina samples complying with laser safety regulations for in vivo measurements, *Neurophotonics*, 6(4), 041106 (2019), <https://doi.org/10.1117/1.NPh.6.4.041106>



Demonstrator at the Medical University of Vienna © Ewald Unger/Med. Uni Wien

ments on humans. Rainer Leitgeb is convinced that this will enable doctors to not only identify eye diseases, but also signs of deterioration in the brain. "It is always said that the eye is the window to the brain. The eye itself is nerve tissue that is directly connected to the brain. This means that all changes, all diseases affecting the central nervous system can also be seen in the retina."

So neurological diseases like Alzheimer's could leave their mark on the retina. Nowadays, the typical protein deposits in the brain of Alzheimer's patients can only be detected after their death. With the help of the Raman scan one could make them visible in the back of the eye earlier.

MOON: Multimodal Optical Diagnostics for Age-Related Diseases of the Eye and Central Nervous System

Medical University of Vienna (Coordinator) | Leibniz IPHT | The Netherlands Organisation for Applied Scientific Research TNO | Carl Zeiss AG | Innolume GmbH | Horiba Jobin-Yvon, S.A.S. | Funded by the European Union in the Horizon2020 program

moon2020.meduniwien.ac.at



Ralf Ehricht and his team examined samples of Viennese rats in the laboratory and found multidrug-resistant bacteria.

© Sven Döring

Carriers

Ralf Ehricht and his team are investigating urban rats as a source of multidrug-resistant bacteria

Multidrug-resistant bacteria are a global threat. Even now, certain antibiotics are no longer effective against many bacteria. Rats could accelerate the spread of such multidrug-resistant pathogens in cities. This is the conclusion reached by a German-Austrian research team after examining rat populations in Vienna. Ralf Ehricht and Stefan Monecke from Leibniz IPHT analysed the rats' genes and showed that the animals carry high-risk pathogens that are resistant to most antibiotics.

Every seventh rat caught in the city center of Vienna between 2016 and 2017 carried multidrug-resistant enterobacteria, whose most important representatives are also known as coliform bacteria. This corresponds to a proportion of 14.5 percent and is comparable to the frequency of previous studies in Berlin, for example. In more than half – almost 60 percent – of the rats in Vienna, the researchers identified dangerous, multidrug-resistant staphylococci.

"We found bacteria that were already resistant to up to four classes of antibiotics," reports Ralf Ehricht, whose team worked on the study with researchers from Vetmeduni Vienna, the Austrian Agency for Food Security, and Freie Universität Berlin. "These highly resistant pathogens pose a great danger because they

can transfer their resistance genes to other bacterial species.

The Jena scientists examined samples from the intestinal tract and nasopharynx of 62 animals. Among other things, they used a molecular resistance test developed at the InfectoGnostics Research Campus. They identified antibiotic-resistant bacteria in 39 rats (62.9 percent), 12 of these animals showed multivariate resis-



Bacteria in a Petri dish

© Sven Döring

tant variants of the pathogens.

Although the interaction between multidrug-resistant bacteria in rats and the risk to human health has not yet been clarified, the main authors of Vetmeduni Vienna consider the frequency of multidrug-resistant bacteria to be of concern. "For example, one of the rats we examined was caught in a green area that homeless people use as a sleeping place in summer," the veterinarians report. "This particular situation increases the risk of transmission of the resistant bacteria." In principle,

however, a number of other scenarios could also be considered for a transfer. The control of rats and other rodents, such as mice, is therefore still very important for public health in cities.

In order to investigate how multidrug-resistant bacteria spread and develop, migratory rats (*Rattus norvegicus*) are of particular interest, explains Ralf Ehricht. "They adapt extremely well, they reproduce rapidly, they feed on human waste and colonise the sewage system. As a result, they often come into contact with human faeces and can take up and spread multidrug-resistant bacteria. However, little is known about the role of rats in the epidemiology of multidrug-resistant bacteria.

The researchers assume that increasing urbanisation might in future lead to an increase in the spread of pathogens. More than half of the world's population currently lives in cities, and this proportion will have risen to 60 % by 2030. High population density, closer contact with urban wildlife and a warmer urban microclimate favour the development of zoonoses – diseases that are transmitted from wild animals to humans.

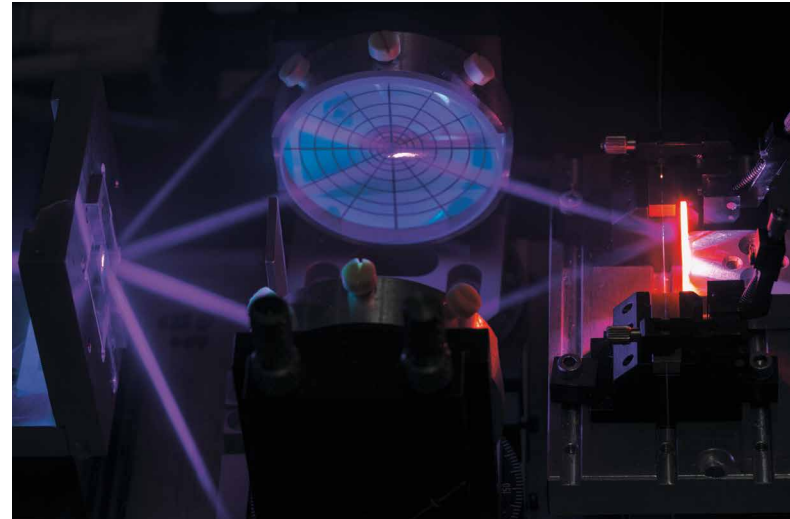
Publications: Desvars-Larrive, Amélie et al., Urban brown rats (*Rattus norvegicus*) as possible source of multidrug-resistant Enterobacteriaceae and meticillin-resistant *Staphylococcus* spp., *Eurosurveillance*, 24, 1900149 (2019), <https://doi.org/10.2807/1560-7917.ES.2019.24.32.1900149>

Health

Gently Diagnosing Esophageal Diseases

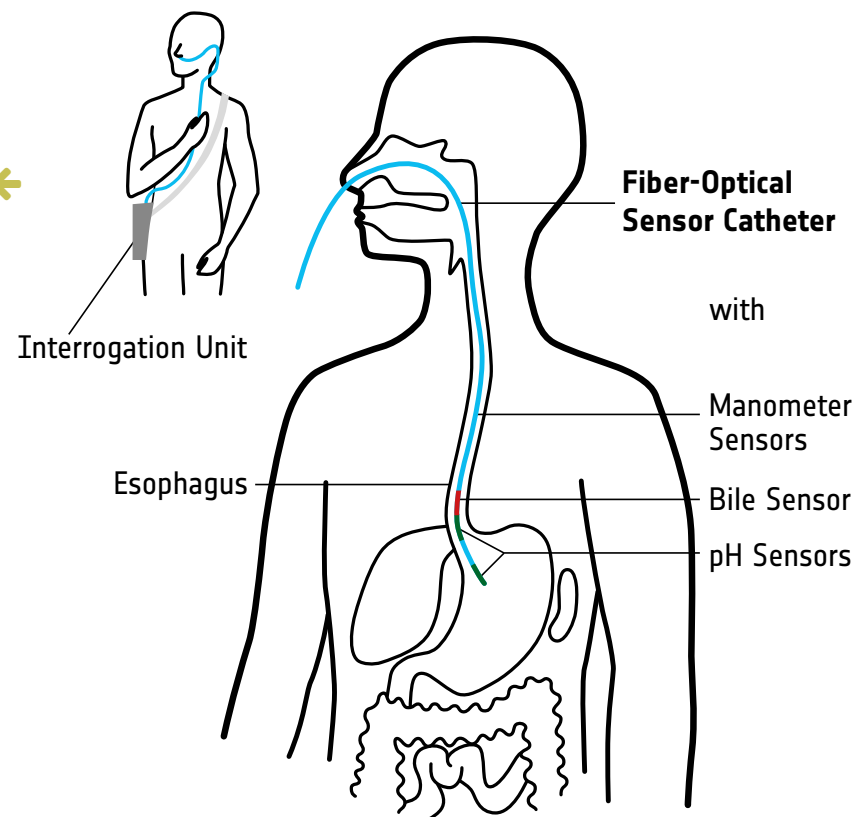
Almost everyone knows discomfort like heartburn or burping. For 10 up to 20 percent of the people in the Western world a reflux disease is behind that, in which acidic stomach contents flow back into the esophagus. To find out where the causes lie, patients have to undergo a long and not a very pleasant examination. The research team of the working group "Passive Fiber Modules" is now working on a new diagnostic device, which makes this procedure faster, more meaningful, and less burdensome for the patients. The device should also be used for screening examinations for esophageal cancer.

"We already showed several years ago that our pressure sensor catheter works," reports fiber researcher and technologist Manfred Rothhardt, who coordinates the "Optimo" project. Based on this, his team, together with two Thuringian companies and partners from Florence, is now developing a handy device that patients can use for long-term measurements at home. Two types of sensors are now being used: pressure sensors determine the interaction of the esophageal muscles and fiber optic sensors in the area of the stomach and just above it measure pH and bile values. By determining the values simultaneously and relating them to each other, they enable new insights into medical relationships and causes. In two years' time, the researchers hope to present the diagnostic device, which will then be tested on patients for over a year.



Interferometer used to write fiber Bragg gratings into the fiber core. They're in the sensors that measure pressure in the oesophagus.

© Sven Döring



The catheter with fiber-optic sensor determines the pressure distribution over the entire length of the esophagus.

© Leibniz IPHT

David Vasquez Pinzon does his PhD in the work group Multimodal Instrumentation

Our Probe Examines the Heart

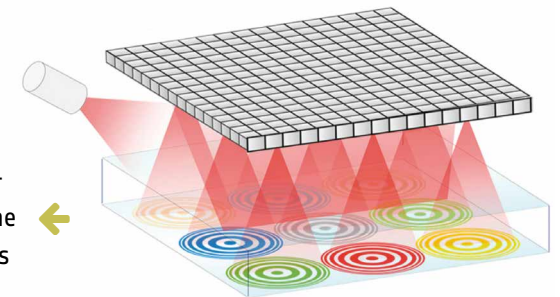
We are researching an endoscope that can be used to diagnose heart tissue optically. My vision is to use it to reach every part of the heart. Surgeons would then receive such precise information that they could operate more effectively and patients would no longer have to fear that the disease will reappear after treatment.

For a Better Heart Check

A team from Leibniz IPHT is researching a multimodal imaging fiber probe to diagnose critical sites in the human heart for the development of cardiac arrhythmia. These are regarded as one of the main causes of sudden cardiac death. In the project "Multimodal fiber optic probe for highly resolved in vivo localization of cardiac fibrosis" (MultiFib) Iwan Schie, Ines Latka, and David Vasquez Pinzon are working together with partners from the Universities of Bordeaux and Vienna. "We want to develop special catheters that monitor during surgery whether an ablation therapy in which the critical areas are sclerosed is successful," explains Iwan Schie, who coordinates the European research project.

Optical-holographic Methods for Significant Diagnostics

Record several diagnostic parameters simultaneously in a few minutes: this is the aim of the optical-holographic procedure, which the research group "MultiHoloDiag" from Leibniz IPHT and the University Hospital Jena works on. The scientists are researching a broadly applicable optical-holographic analysis platform, which should significantly increase the sensitivity and speed for label-free applications in molecular diagnostics and serology. "For this purpose, we use interference and diffraction effects of light to isolate the measurement signal from impurities," explains Karina Weber, who is working on the research together with Ralf Ehricht, Walter Hauswald, and their team. Using a special phase grating with a functionalized surface, it should be possible to measure several parameters simultaneously with up to 25 times greater sensitivity. Within the framework of the InfectoGnostics Research Campus, an industrial advisory board with companies from the region is accompanying the research of the novel diagnostic procedure and regularly checks results for their usability.



On the chip of the digital-holographic sensor for the detection of biomolecules, capture molecules for pathogens or germs (colored) are arranged. They are structured in such a way that the light of the illuminating laser diode is reflected, diffracted, and finally imaged in a defined way on the image sensor above. The sensitivity of the detection system can be significantly increased by holographic amplification.

© Leibniz IPHT

Detecting and Removing Tumors with Light

Tobias Meyer is investigating how laser light can be used to precisely identify cancer tissue and treat it gently



Cell by Cell in Focus

Diagnosis and therapy in one: A new endoscope is to make tumor edges visible and remove the cancerous tissue layer by layer

Progress can be measured in two steps in Tobias Meyer's laser laboratory and can be seen at a glance. In the background is a silver trolley, on top of it two black boxes and a monitor. The matt black compact device on the optical table in front of it is not even a fourth of it in size. Two Medicars, version 2015 and version 2019: a compact microscope for rapid cancer diagnosis during surgery.

"Good news from German cancer research" was the announcement by the German government in August 2019, referring to the "precision through laser light" with which the microscope researched at Leibniz IPHT makes cancerous tissue visible, enabling surgeons to remove tumors even more precisely in the future. The black box contains a light-based tool that can be used to examine the chemical and morphological composition of the tissue. This information is evaluated with artificial intelligence and immediately indicates whether the tumor has been completely removed – in other words, whether the operation was successful.

Tobias Meyer and his team from Leibniz IPHT, Friedrich Schiller University Jena, Jena University Hospital and the Fraunhofer Institute for Applied Optics and Precision Engineering are already continuing their research. They are combining the imaging procedure with a minimally invasive surgical precision tool: for laser-based microsurgery – and a

new way to treat cancer in a gentle way. "Our vision," as Scientific Director Jürgen Popp describes it, "is to use light not only to identify the tumor, but to directly remove it."

For this purpose, the research team combined CARS imaging with a femtosecond laser for tissue ablation for the first time. Femtosecond laser ablation in which tissue is ablated using pulsed laser radiation, i.e. vaporized, is currently the most



The improved microscope Medicars designed in 2019. © Sven Döring

precise surgical tool established in ophthalmology, explains Tobias Meyer. On the basis of high-resolution, label-free CARS imaging the researchers were able to selectively ablate smaller, pathologically altered areas in different tissue types with micrometer precision.

The research team is now further developing this approach together with long-standing partners from the University Hospital Jena, the Jena optics companies Grintech and Active Fiber Systems and the globally operating endoscope manufacturer Karl Storz. The aim of the Thera-Optik project (Multimodal Endoscopic

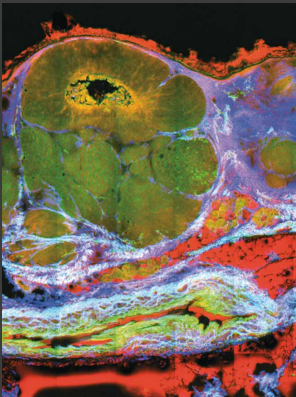
Visualization and Laser Surgery for the Diagnosis and Therapy of Head and Neck Tumors), which is funded by the German Federal Ministry of Education and Research, is to develop a flexible endoscope with which tumors in the head and neck region can be displayed in high resolution and removed directly in a microsurgical procedure: Diagnosis and therapy in one step.

Accompanied by the fiber technologists at Leibniz IPHT, the team is now researching solutions to increase the ablation rates and make the lasers even smaller. At the end of the project, a device is to be developed which, using a combination of endoscope, ablation laser, and hyperspectral wide-field imaging, will make it possible to treat tumors at sensitive sites gently and precisely. "With

this method, we can achieve resolutions in the range of a single cell," explains Tobias Meyer. "This means that we can selectively remove one cell layer without touching the next one and thus ablate the tumor layer by layer". Especially in the case of tumors at functional sites in the head and neck area, for example on the vocal cords or along the nerve tracts, this could significantly improve current treatment options and the chances of cure for patients.

Publications: Tobias Meyer et al., CARS-imaging guidance for fs-laser ablation precision surgery, Analyst, 2019, 144, 7310. <https://doi.org/10.1039/C9AN01545K>

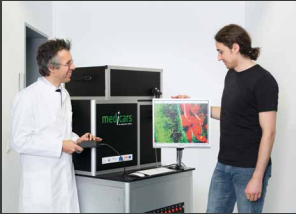
From the Idea to the Laboratory Sample



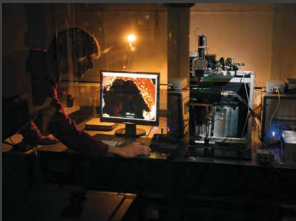
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2019

The Theraoptik Project Starts

Together with partners from application and industry, the research team is developing an endoscope for multimodal visualization and laser surgery for the diagnosis and therapy of head and neck tumors.

2019

Compact Microscope

It makes cancerous tissue visible with laser light and arouses great interest at the "Laser: World of Photonics" trade fair.



© Leibniz IPHT

2019

Improved Laboratory Sample in New Design

Medicars



© Leibniz IPHT

2018

New Highly Compact Electronics & Software

The laser scanning microscope can be controlled from a laptop.



© Sven Döring

2015

From Microscope to Endoscope

The follow-up project Endocars* for the research of an imaging CARS endoscope starts.



© Leibniz IPHT

2013

Thuringian Research Award 2012

for the multi-contrast microscope for clinical use to the research team from Leibniz IPHT, Fraunhofer IOF, the University of Jena and Jena University Hospital



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* All the above-mentioned projects were and are funded by the Federal Ministry of Education and Research.

I Can See a Solution Here

Aikaterini Pistiki got to know Leibniz IPHT from Athens, as a research partner in the joint sepsis project. Today, she works in Jena and wants to find out how to track down multidrug-resistant bacteria



Aikaterini Pistiki visualizes the properties of bacteria.

© Sven Döring

"Guests don't do the dishes", Aikaterini Pistiki orders warmly and takes the cup out of the visitor's hand at the Center for Applied Research. Two days ago the young German-Greek scientist returned from Athens. And she is just getting used to the tranquil city of Jena again. "The noise is missing." She laughs.

Nine months ago, Katerina – as she briefly introduces herself to her German colleagues – started as a post-doc at Leibniz IPHT. Her research area: multidrug-resistant germs. She wants to find out how sensitive germs can be quickly differentiated from resistant ones. So how can we quickly identify which germs doctors can treat with common antibiotics and against which only very few preparations still show an effect – if at all. Aikaterini Pistiki uses UV-Raman spectroscopy to examine the bacteria. The way in which a bacterial cell scatters the light enables her to visualize its chemical composition – to obtain its optical fingerprint. The light analysis method is highly sophisticated and Leibniz IPHT is one of the world's most distinguished institutes that is advancing its research for applications in the life sciences.

This was a reason for Aikaterini Pistiki to move from Athens to Jena. "I have a background in clinical research and routine," she says. "I know the problems in diagnostics. And here I see a solution." She has already worked on part of this solution in Athens – together with a team from Leibniz IPHT. A biologist by training, she was a doctoral student at the University Hospital in Athens when she joined the Euro-

pean research project Hemospec. Together with a research team from Jena and Athens and partners from France, Italy, Denmark and Portugal, she developed a new method for diagnosing sepsis.

The dissertation was finished, Aikaterini Pistiki defended it and then things went quickly. "On Monday I got my certificate, on Friday I flew to Jena to start at the hospital." At the Center for Sepsis Control and Care (CSCC) she spent three months researching how to examine white blood cells with Raman spectroscopy. "In the case of an infection, the blood's own immune cells try to fight the pathogen," explains the scientist. "To do this they mobilise



The Hemospec-Team in Athen.

© Leibniz IPHT

molecular mechanisms that lead to a change in their chemical composition." This can be detected with Raman spectroscopy and provides a key to finding out what kind of pathogen causes a sepsis.

Back in Athens, Aikaterini Pistiki tested a sepsis detection device built by the Hemospec team in Jena and Italy in two clinical trials. A third followed in Jena. With their new analyzing technique, the researchers were able to determine within a very short time whether sepsis was present or not. The project was successfully completed in early 2018 and the biologist's enthusiasm for

the spectroscopic analysis method continued. "Microbiological analyses need time," she says, "I see a great potential for more effective diagnostic procedures here."

This is what the scientist is focusing on in her new project. Her goal is to identify multidrug-resistant bacteria using Raman spectroscopy faster than the laboratory tests that have been used up to now. In order to achieve this, she moved from Athens to Jena in autumn 2019 as a fellow of the European postdoctoral program Multiply. She is investigating multidrug-resistant bacteria in a further study in the Carbatech project with the University of Thessaly in Larisa. Her measurements are going well, says Aikaterini Pistiki. The results show that her approach could deliver meaningful results. She will soon be working at the hospital again, then for a few months in a medical technology and biotechnology research center with close ties to industry. "It pays off," she says, "to always have an immediate connection to the application."

And Jena? She likes it, she feels she has already been well received, says Aikaterini Pistiki on the roof terrace of the Center for Applied Research. Especially since Germany is not new to her. She was five years old when she moved with her family to Metzingen, at the foot of the Swabian Alb. "Nothing for me", she remembers and laughs. She went back to Greece to study. Now it's time to turn the page. "Only the weather could be better," says Aikaterini Pistiki, looking at the cloudy panorama of the Saale valley. "But in Jena it's beautifully green."

Translating Research

Federal Minister of Education and Research honors Leibniz IPHT with European Dahrendorf Prize

Being able to draw a light bulb, a rocket, and a skull and crossbones: the preparation for this award ceremony looked a little different than usual for the scientific director of the institute this time. The Federal Ministry had assigned homework to the winners of the European Dahrendorf Prize. The scientists had to explain what they had researched – in a clear, entertaining way and keep it brief enough to fit on 33 x 33 centimeters. For Jürgen Popp and Ute Neugebauer this meant: HemoSpec on a napkin.

In the EU funded project, the team of scientists from Leibniz IPHT, together with Jena University Hospital and European partners, researched a method for the rapid diagnosis of sepsis. In doing so, they had shown "how European cooperation can improve the lives of citizens," says Federal Education Minister Anja Karliczek who awarded Ute Neugebauer and Jürgen Popp the Ralf Dahrendorf Prize for the European Research Area on 14 May 2019 in Berlin.

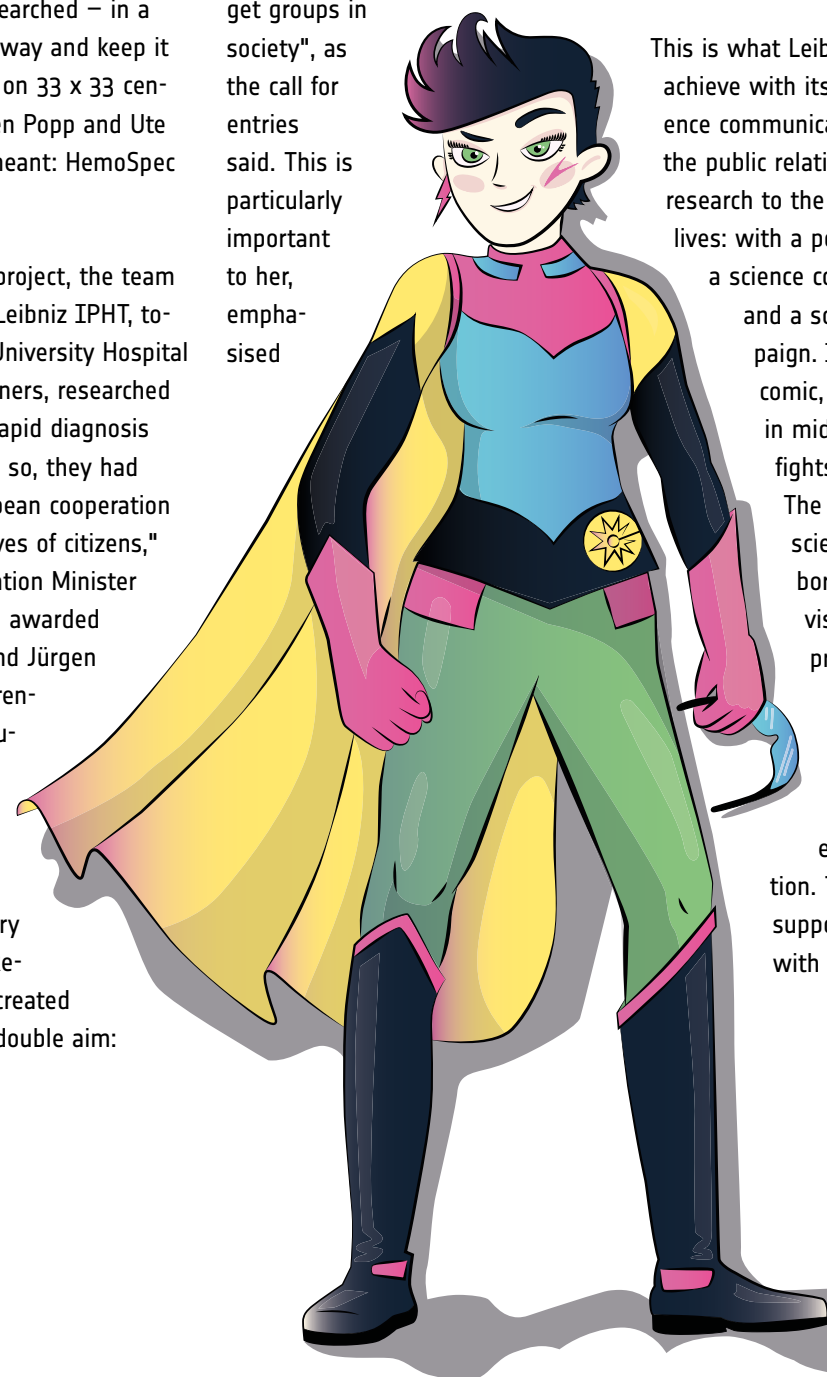
The Federal Ministry of Education and Research has newly created the award with a double aim:

to honor outstanding achievements of researchers in European projects and to promote science communication. The award is therefore also a double one: it also goes to the communication concept that the public relations team has drawn up to make the research results "known to new, non-science-oriented target groups in society", as the call for entries said. This is particularly important to her, emphasised

Anja Karliczek at the award ceremony. After all, communicating science in an understandable way is the basis for "giving citizens a say" – and thus the best way to combat the spreading scepticism about science.

Lasergirl chases the Killer Germ

This is what Leibniz IPHT wants to achieve with its concept of science communication. To this end, the public relations team brings research to the people's everyday lives: with a pop up science shop, a science comic, short films, and a social media campaign. In the superheroine comic, which will appear in mid-2020, Lasergirl fights a killer germ. The temporary pop up science shop LichtLabor (LightLab) offers visitors of all ages a program on the subject of "Research with light". LichtLabor wants to inform, inspire and encourage participation. The Federal Ministry supports the realization with up to 50.000 Euro.



Lasergirl Chases the Killer Germ

© Sandruschka

Science on a Napkin

The Bomb

There is an urgent medical need: severe infections that can lead to sepsis are often detected and treated too late. But every hour of waiting for the right therapy drastically reduces the chances of survival.

The Drop of Blood, the Light Bulb and the Robot

The European research network HemoSpec has found a solution. The research team uses laser light irradiation of the leukocytes from a blood sample to obtain the information that doctors need for targeted treatment within a very short time. Using biophotonic technologies – laser light, symbolized by the light bulb – molecular-spectroscopic fingerprints of the leukocytes are generated and interpreted with the aid of artificial intelligence.

The European Flag

Funding from the European Union and the fruitful cooperation with the team Jena University Hospital and international experts from

Greece, Italy, Portugal, France, and Denmark have made research in this field possible.

The Rocket

The researchers have found a technological solution for medical needs. In order to take off and be used in the hospital bed, the researchers must overcome ...

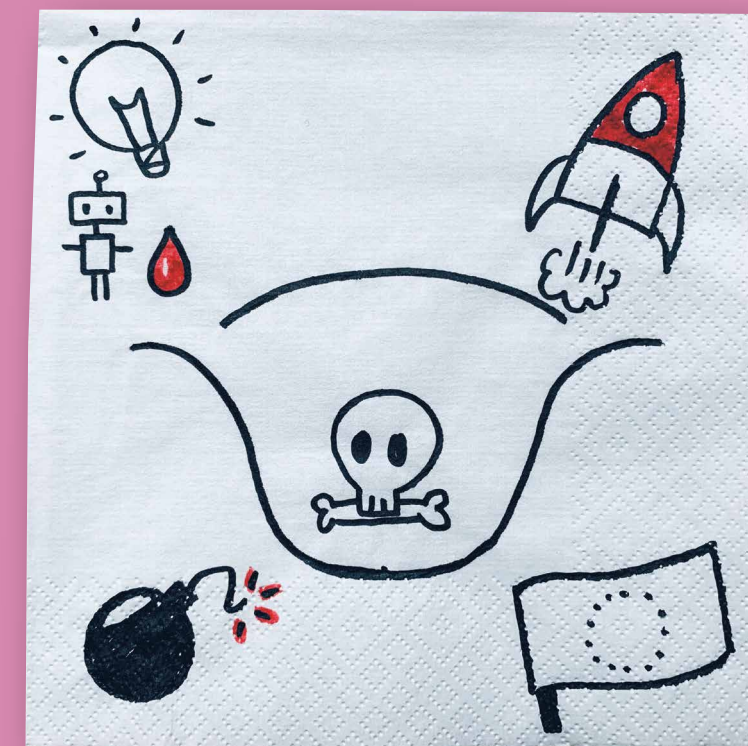
... the Valley of Death.

However, Jürgen Popp said at the award ceremony that there is a lack of suitable translation structures. "We must create new types of structured translation instruments so that researchers together with industry can bring their results to the market faster." Four months later, the Federal Ministry of

Education and Research included the new Leibniz Center for Photonics in Infection Research (LPI) on the national roadmap for future-oriented research infrastructures. The federal government is funding the establishment of the user-open center in Jena – so that good ideas from research reach patients more quickly in future (p. 24).



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"Good Ideas From Research Must Reach Patients Faster"

Future-oriented research infrastructure: The new Leibniz Center for Photonics in Infection Research (LPI) is being established in Jena



LEIBNIZ CENTER *for*
PHOTONICS *in*
INFECTION RESEARCH

In future, good ideas from research should reach patients more quickly. To this end, the federal government is investing in the new Leibniz Center for Photonics in Infection Research (LPI) in Jena. Natural scientists, technology developers, physicians, and medical technology manufacturers will develop light-based technologies for better diagnosis and therapy of infectious diseases there in future. The LPI has prevailed in the national roadmap process for future-oriented research infrastructures of the German Federal Ministry of Education and Research (BMBF) and is to be funded with approximately 150 million euros in the coming years.

The corona crisis makes us aware of the devastating effects of infectious diseases. Laboratories and clinics are not designed to cope with such an enormous burden and testing capacities are not sufficiently available. Inequalities in health care are becoming more acute. Tests, treatments, and vaccines are not equally available to all people.

A further threat is the spread of multidrug-resistant germs. Every day, 2000 people die from the consequences of bacteria, against which no antibiotics are effective. Infectious diseases are among the most common causes of death worldwide. New approaches for diagnosis and treatment are urgently needed.

Photonic technologies – i. e. methods and processes that use light as a tool – can help to solve these problems in the long term. Light-based methods measure quickly,

sensitively, without contact and contribute to better understand how pathogens make us ill, how our body defends itself, and how these processes can be influenced.

However, it takes a long time for the progress of this research to reach patients. "On average, it takes 14 years to turn an idea into a marketable product," explains Jürgen Popp, scientific director of Leibniz IPHT. With the new research center this should change. In Jena, scientists from various disciplines are working together to better respond to the growing threat of infectious diseases. The translation infrastructure is open to users from research and industry – and thus provides a foundation for research into innovative methods that is unique in Europe.

"We need good ideas, unconventional approaches, and solutions taking research from bench to bedside," said Jürgen Popp. To this end, the new Research Center combines Jena's expertise in optics, photonics, and infection research. At the LPI, scientists from Leibniz IPHT and the Friedrich Schiller University Jena, Jena University Hospital and the Hans Knöll Institute (Leibniz HKI) will in future work in a team with top international researchers and users from industry – with short distances and clear transfer points in a structured process.

The idea for the innovative translation infrastructure stems from an urgent medical need. It offers an enormous opportunity: to be faster in the fight against infectious diseases.



Closing the Gap: the new Leibniz Center for Photonics in Infection Research aims to facilitate the translation of knowledge from science to clinical application.

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What Opportunities Does the Leibniz Center for Photonics in Infection Research Open up?



"In the Corona crisis we are experiencing how fast a pandemic can spread in our globalized world. So fast that there is hardly any time to act appropriately. This shows us how urgently we need better options for diagnosing and treating infectious diseases – all over the world. LPI opens up ways for us to rapidly develop such methods and technologies and bring them to market".

Prof. Dr. Jürgen Popp | Scientific Director
of the Leibniz Institute of Photonic Technology



"LPI is an important element in the development strategy for Jena. It will become a point of attraction for international scientists, because this is where future topics in medicine are researched, such as biological therapeutics. We want to be pioneers for approaches that we believe will determine the medical agenda of the next 10 to 20 years".

Prof. Dr. Axel A. Brakhage | Director
of the Leibniz Institute for Natural Product Research and Infection Biology – Hans-Knöll-Institut



"According to the German Council of Science and Humanities, LPI could revolutionize the diagnostics of pathogens. It is no coincidence that this is happening in Jena. The combination of photonic technologies, basic research, and clinical application shows the strengths of the location. University, non-university research institutes, and industry are well networked here and make the location attractive for highly qualified scientists from all over the world".

Prof. Dr. Walter Rosenthal | Director
of the Friedrich Schiller University Jena



"LPI meets an urgent medical need. Doctors need faster and more accurate diagnostic methods. Information for the targeted use of antibiotics, for example, help to tackle antibiotic resistance. LPI offers the opportunity to link diagnostics and therapy. From a medical perspective, this opens up a great vision: to break new ground in therapeutic approaches".

Prof. Dr. Michael Bauer | Director
of the Clinic for Anaesthesiology and Intensive Care Medicine at Jena University Hospital



Observing Viruses on a Live Stream

Christian Eggeling places a ring of light around the focus of the samples he examines under the microscope – an optical trick to bypass the optical resolution limit described by Ernst Abbe. This enables Eggeling and his international team of researchers to observe processes deep inside living cells

Researchers visualize how the AIDS pathogen multiplies in the body. This helps to identify targets for new therapies

AIDS is caused by human immunodeficiency viruses (HIV) that put immune cells – so-called T helper cells – out of action. Instead of controlling other immune system cells in the defence against pathogens, infected T helper cells produce new HI viruses in large quantities. An international research team around Christian Eggeling has now managed to observe the spread of human immunodeficiency viruses amongst living T helper cells in real time with the help of ultra-high-resolution imaging.

Using super-resolution STED fluorescence microscopy, the researchers provide direct proof for the first time that the AIDS pathogen creates a certain lipid environment for replication. "This gives us a few starting points when it comes to investigating how to potentially prevent this reproduction," says Christian Eggeling, who conducts research and teaches at Leibniz IPHT, Friedrich Schiller University Jena, and the University of Oxford.

Together with a team led by Delphine Muriaux and Cyril Favard from the Université Montpellier and his colleague Jakub Chojnacki, Christian Eggeling has been examining the plasma membrane of infected T helper cells. They focused on the "gate" through which the HI virus buds from the cell after multiplying inside. The "Gag" protein, which coordinates the processes involved in the assembly of the newly produced virus particles, served as a marker. "Where this protein accumulates, the decisive processes take place that lead to the virus releasing itself

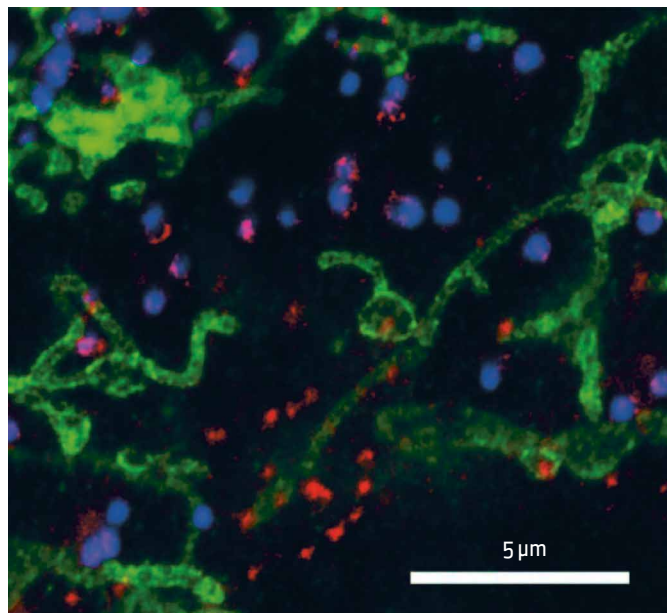
and infecting other cells," explains Christian Eggeling. In order to decipher these processes, the researchers examined the diffusion of the lipid molecules to and at the place where the "Gag" proteins gather i.e. where the virus particle buds. During the budding process, the virus particles exit the cell through the plasma membrane and receive their lipid coating. Eggeling and his colleagues have now discovered that, only certain lipids from the cell membrane interact with the HI virus. Although these lipids were already known, the research team has managed to directly prove this interaction in living cells for the first time.

Point of attack to prevent the reproduction of the virus

"This provides us with a potential target for antiviral drugs," says Christian Eggeling.

"Knowing which molecules the HI virus needs to exit the cell and multiply is a crucial

prerequisite for investigating how this can be prevented. Our technology enables us to follow the developments directly in real time". Eggeling is now working with his team on the development of antibodies to attack precisely these molecules – and thus suppress the spread of the virus.



STED microscopy image of fibroblast cells

© Leibniz IPHT

STED Microscopy

STED stands for "Stimulated Emission Depletion" and is a method used in fluorescence microscopy that allows the optical resolution limit described by Ernst Abbe to be bypassed. Light is used to excite, fluorescent dyes, which then spontaneously emit light in a lower-energy wavelength range. This spontaneous emission can be suppressed with the addition of high-intensity light at the wavelength range of emission. The de-excitation light is placed in a ring around the focus of the sample to be examined, restricting the emission of fluorescent light to the center of the sample. This optical trick makes the effective focal point significantly smaller, and its dimensions are below the Abbe diffraction limit.

"We not only want to examine these antibodies from a medical perspective, but also to find out how their biophysical interaction can be exploited to make them more effective," states Eggeling. He is trying to understand how diseases develop on a molecular level by combining super-resolution fluorescence mi-

croscopy with technology that tracks the movement of labeled molecules in real time. Eggeling helped develop the STED microscopy method during his time in the laboratory of Stefan Hell in Göttingen, who went on to win the Nobel Prize in chemistry in 2014. This enables the spatial and temporal examination of individual molecules in living cells. "We can now reveal cellular mechanisms on a molecular level. These mechanisms were much too fast and occurred over far too small spatial scales for previous method of investigation."

Publications: C. Favard et al.: HIV-1 Gag specifically restricts PI(4,5)P2 and cholesterol mobility in living cells creating a nanodomain platform for virus assembly. *Science Advances* (2019), DOI: 10.1126/sciadv.aaw8651

Solutions with Light

Technology

For New Possibilities in Diagnostics and Telecommunications

Within the European project NCLas (Nanocrystals in Fiber Lasers), researchers of the work group "Active Fiber Modules" are working on the development of fiber lasers with new wavelengths. The fiber lasers are to extend the spectral range achieved so far and enable new applications in medicine and telecommunications.

The researchers incorporate nanocrystallites into a fiber. Thus, they want to open up areas that are relevant for biomedical applications but for which there are no practical solutions yet. One planned fiber laser i.e. aims at a spectral range in which tissue is very transparent, so that even deep layers become visible. Another fiber laser is of great interest for telecommunications, where optical fibers transmit information. The EU supports the project being coordinated by Matthias Jäger which involves research partners from Spain, Poland and Great Britain.

www.nclas-fetopen.eu

Training

Career Network for International Postdocs



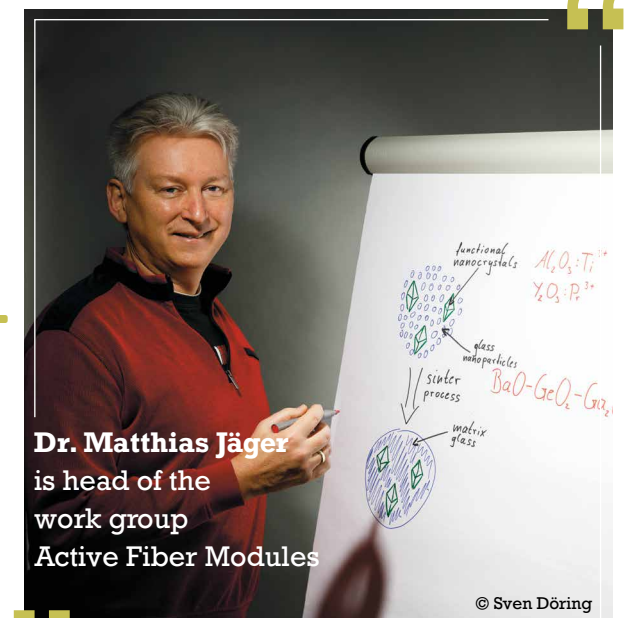
Xue Qi, Oguzhan Kara and Aikaterini Pistiki (from the left) © Leibniz IPHT

Three new postdocs from Turkey, Greece, and China have come to

Leibniz IPHT as fellows of the network MULTIPLY (*International Mobility and Training Programme in Photonics for Experienced Researchers*). Oguzhan Kara works on the development of ultrashort fiber lasers for new technologies in the mid infrared range. Aikaterini Pistiki (p. 20) uses Raman spectroscopy to distinguish between methicillin-resistant and methicillin-sensitive *Staphylococcus aureus* strains. Xue Qi works on coherent supercontinuum generation in

fibers with tailored dispersion via geometrically induced resonances. Leibniz IPHT, together with 50 other internationally leading academic and industrial partners from Europe, China, Australia, Russia, and Mexico, is part of MULTIPLY's consortium, supporting outstanding researchers with a career training. The EU funds the Marie-Skłodowska-Curie-COFUND- project in the Horizon 2020 program.

multiply.astonphotonics.uk



Dr. Matthias Jäger is head of the work group Active Fiber Modules

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We Are Working on the Development of Lasers for Future Visions

I am working on the development of innovative fiber light sources. Fiber lasers are currently the most successful laser concept because they enable compact, robust, and energy-efficient light sources. I am convinced that with our research we are paving the way for applications of optical fibers that are still a vision of the future today.



Thomas Bocklitz heads the research department Photonic Data Science

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"Artificial Intelligence Will Make Medicine Better in the Long Run"

Leibniz IPHT is increasingly focusing on artificial intelligence and learning systems. Thomas Bocklitz is heading the new research department "Photonic Data Science". We asked him how AI could help shape the future of diagnostics

What new possibilities does Photonic Data Science open up for diagnostics?

Photonic Data Science is a potpourri combining mathematical and statistical methods with algorithms and domain knowledge to translate measurement data into useful information. We usually translate photonic data into biomedical – for example diagnostic – information. By translating with the computer, robust diagnostic information can be extracted. Tiny details in complex data can be made useful for diagnostics. This opens up new possibilities for diagnostics.

Artificial intelligence (AI) then helps to evaluate this data. Which technologies researched at the institute are based on AI?

In the laser-based rapid test of infectious pathogens, machine learning methods and algorithms for data pre-treatment are used to translate Raman spectra of bacteria into a resistance prediction – i.e. to predict pathogens and antibiotic resistances on the basis of the spectroscopically recorded data. For the compact microscope Medicars ("Removing Tumors With Light", p. 28) we use deep and machine learning techniques to translate multimodal image data into a tissue prediction for the detection of tumor

margins. In smartphone microscopy, which is being researched by Rainer Heintzmann's team (p. 42), image enhancement is achieved by means of deep learning procedures.

Where do the data sets come from that are currently mainly used? Can they be applied equally to all patients?

The data sets are generated within clinical studies, which we supervise from the beginning. The studies are still too small to exclude a gender bias, but we are working on the experimental design so that there is no gender bias in the training data set and we hope that the models will not generate any bias.

Does the automated analysis of medical control data also carry a risk? A loss of control?

Of course, every technology has risks, although these are manageable here. Artificial intelligence or machine learning processes only work well if the new test data is similar to the training data. We try to tackle this problem by creating the necessary similarity through standardization and model transfer in order to improve the predictions. There is a loss of control when the models are applied fully automatically. But in the medium term the models will only

represent a second opinion, so there will be no loss of control.

Can physicians improve the learning systems? Is the procedure – of AI applications comprehensible for them?

Physicians can increase the database or reduce the uncertainty of the metadata – i.e. labels – by pooling or voting, which leads to better models. The traceability of AI models is a major topic in current machine learning research – Keyword "Explainable AI". The aim is to decipher these models in order to make it clearly understandable how mass-based learning methods and deep learning systems achieve their results.

Can AI be perfected to the point where it can eventually make better diagnoses than a human?

I think so, if the data is highly standardized. Another challenge is to demonstrate that improvement. This requires quite long clinical trials and is ethically problematic.

Could AI ever replace doctors instead of just to supporting them? For example, could operations be performed by AI-controlled robots at some point?



With the foundation of the research department "Photonic Data Science" around Thomas Bocklitz, scientific director Jürgen Popp (right) consciously embeds the research of artificial intelligence and learning systems in the strategy of the Leibniz IPHT.

© Sven Döring

I don't think so, because there are many uncertainties in an operation that must be reacted to flexibly. This is not a prominent feature of current AI procedures. It's more likely that the surgical robots will do very spe-

cific things directly on the operator's instructions.

Will AI make medicine better?

In the long run, I think so. But first, it will make diagnostics more comparable and it will also allow data to be used not only sequentially, but in combination.

	Melanocytic Nevus	Melanocytic Nevus	Melanocytic Nevus	Dysplastic Nevus	Dysplastic Nevus	Melanoma In situ	Melanoma In situ	Melanoma Level II	Melanoma Level II	Melanoma Level III	Melanoma Level III	Melanoma Level IV	Melanoma Level IV
HE													
Pathology Diagnosis													
TPEF/SHG													
Histogram													
GLCM													
Both													

Machine learning procedures are created using various feature extractors (gray level co-occurrence matrix GLCM, histogram features). They translate the multimodal image data (SHG / TPEF) into semantic segmentations representing the distribution of tissue classes (tumor, normal).

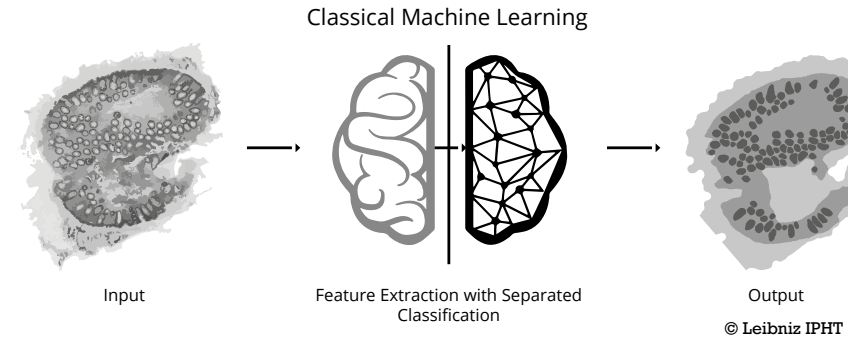
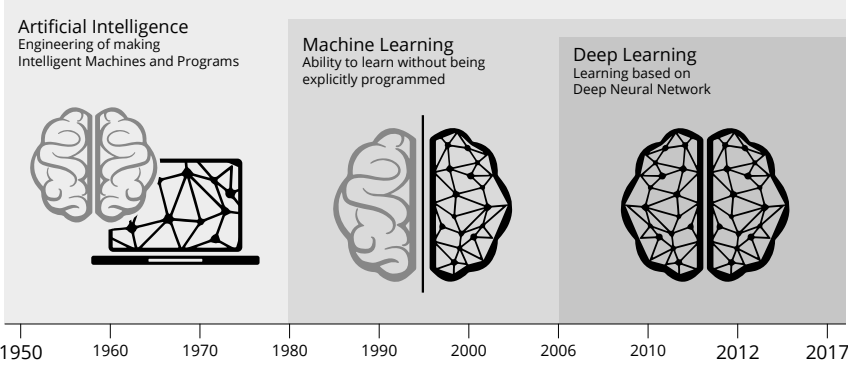
© Leibniz IPHT

**Artificial Intelligence,
Machine Learning,
Deep Learning**

Decision making, problem solving, learning – these are actions that we commonly associate with human thinking. We call their automation artificial intelligence (AI). An important part of AI is machine learning (ML). Scientists are researching algorithms and statistical or mathematical methods with which computer systems can solve specific tasks.

For this purpose, machine learning methods construct a statisti-

cal-mathematical model from an example data set, the training data. On this basis, ML methods can



make predictions or make decisions without having been explicitly programmed for it. ML techniques are used, for example, for spam detection in e-mail accounts, in image

processing, and for the analysis of spectroscopic data. Deep learning is a method of machine learning that is similar to the way the human brain processes visual and other stimuli. Artificial neurons receive input, process it and pass it on to other neurons. Starting from a first, visible layer, the characteristics in the subsequent, hidden intermediate layers become increasingly abstract. The result is output in the last, again visible layer.

**Making Tumor Tissue
Visible with AI**

Did the surgeon remove the entire tumor during surgery? In order to find out, researchers are combining optical methods with artificial intelligence (AI) and data pre-processing methods. AI is behind the compact Medicars microscope, for example, which enables rapid cancer diagnosis during surgery. Here, patterns and molecular details of a tissue sample irradiated with laser light are automatically evaluated and translated

into classical images of standard diagnostics. Thus, tumor margins become visible.

"For this purpose, we train AI algorithms together with pathologists," explains Thomas Bocklitz. "We take multimodal images of a tissue sample with our laser-based multimodal microscope. In pathology, the tissue section is then embedded, stained, and an image of the HE-stained tissue section is taken (HE = haematoxylin-eosin). This enables the pathologist to recognize tumor

tissue. Then we put the multimodal and the HE image side by side."

Based on the pathologist's analysis of the tissue structure and morphology, the research team teaches the algorithm which tissue is healthy and which is sick. "In this supervised approach, the algorithm learns to distinguish successive, healthy and diseased areas." With success: The accuracy of the predictions is more than 90 percent according to tests on a small group of patients.



Rainer Heintzmann holds a splash guard in front of the blinds. The result: a moiré effect.

© Sven Döring

Super Resolution

When trying to visualize finest details in cells, standard light microscopes reach their limits. As a doctoral student, Rainer Heintzmann discovered a method that can break this barrier. Today, he has improved the technique of super-resolution microscopy to such an extent that it is useful for applications in biology and medicine

In order to observe living cells at work, researchers have to overcome a physical law. One of the fastest techniques to overcome the resolution limit of classical light microscopy is high-resolution structured illumination microscopy.

It makes details in cells visible that are about one hundred nanometers in size, one hundred millionth of a millimeter. However, translating the recorded data back into images used to take a lot of time. Rainer Heintzmann, together with a team of researchers from Bielefeld University, has developed a technique that allows the image data to be reconstructed directly. This allows researchers to watch biological processes in the cell virtually live. "It enables completely new imaging workflows that no other high-resolution microscopy method currently allows in this way," says Rainer Heintzmann.

The graphics helps computer gamers to have a great gaming experience. Researchers use it to observe the smallest cell components in action - in real time and at a very high frame rate. "The image data can be reconstructed about twenty times faster

than it would take on a PC," explains Rainer Heintzmann, who already laid the foundations for the structured illumination method in high-resolution microscopy as a doctoral student in 1998. In cooperation with the Biele-

Structured Illumination Microscopy

Moiré means "marbled" in French and refers to an effect in which the superimposition of patterns creates new patterns: like the wavy lines that become visible when Rainer Heintzmann holds a splash guard in front of the blinds for the adjoining photo. The researcher transfers this moiré effect to microscopy in order to make things visible that are below the optical diffraction limit. In structured illumination, dyes in a sample are excited with differently shifted and differently oriented stripe patterns, resulting in moiré stripes. These are recorded and contain information about tiny structures in the sample. This information can be recovered by image processing. By processing several moiré patterns, researchers create ultra-high-resolution images that can reach a resolving power of up to 100 nanometers.

feld research team led by Thomas Huser, he further developed the technique of Super-Resolved Structured Illumination Microscopy (SR-SIM).

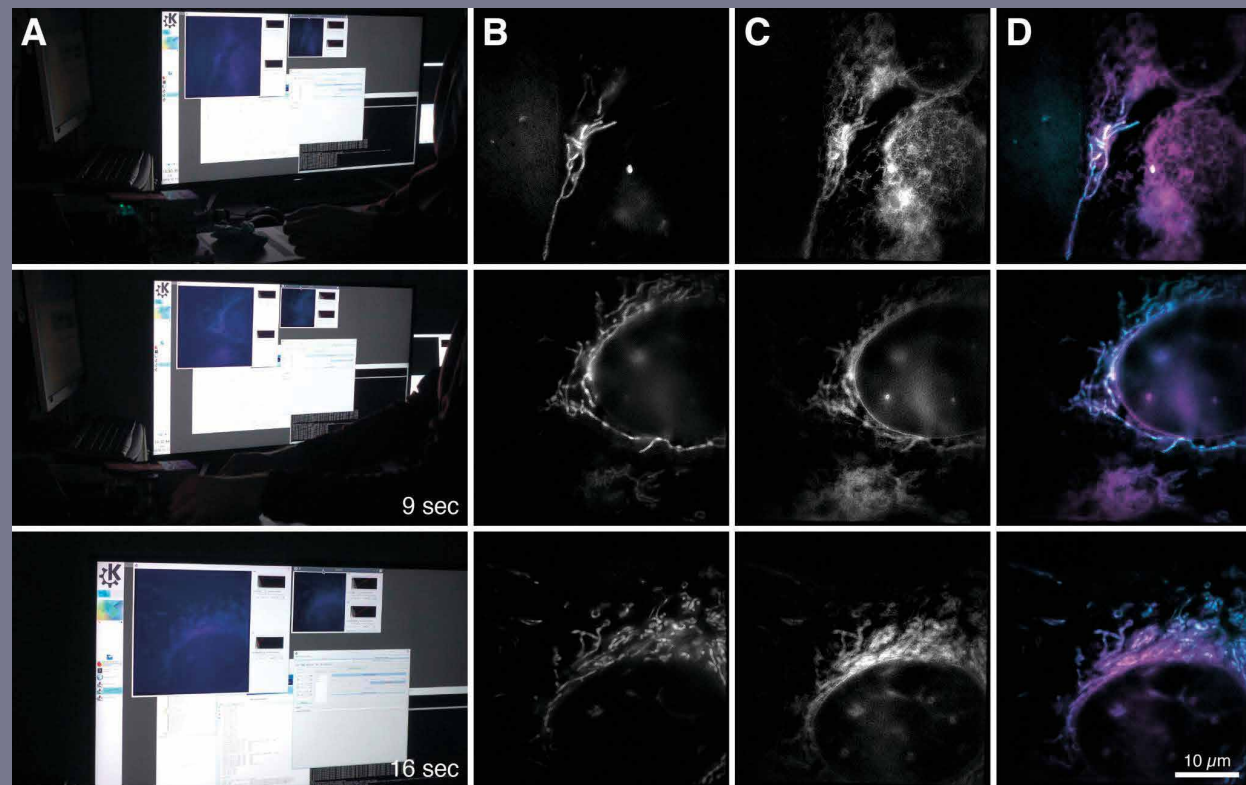
In the fluorescence microscopic SR-SIM method, objects are irradiated with laser light using a special pattern. It excites special fluorescent molecules in the sample so that they emit light at a different wavelength. The microscopic image then shows

this emitted light. It is first recorded in several individual images and then reconstructed as a high-resolution image on a computer. "The second step in particular has taken a lot of time so far," says Andreas Markwirth from Bielefeld University, first author of the study, which the research team published in the renowned journal "Nature Communications".

For the new microscope, the research team used parallel computer processes on modern graphics and was thus able to significantly accelerate image reconstruction. A minimum delay of 250 milliseconds is hardly noticeable to the human eye. The raw data can also be generated faster with the newly researched microscope.

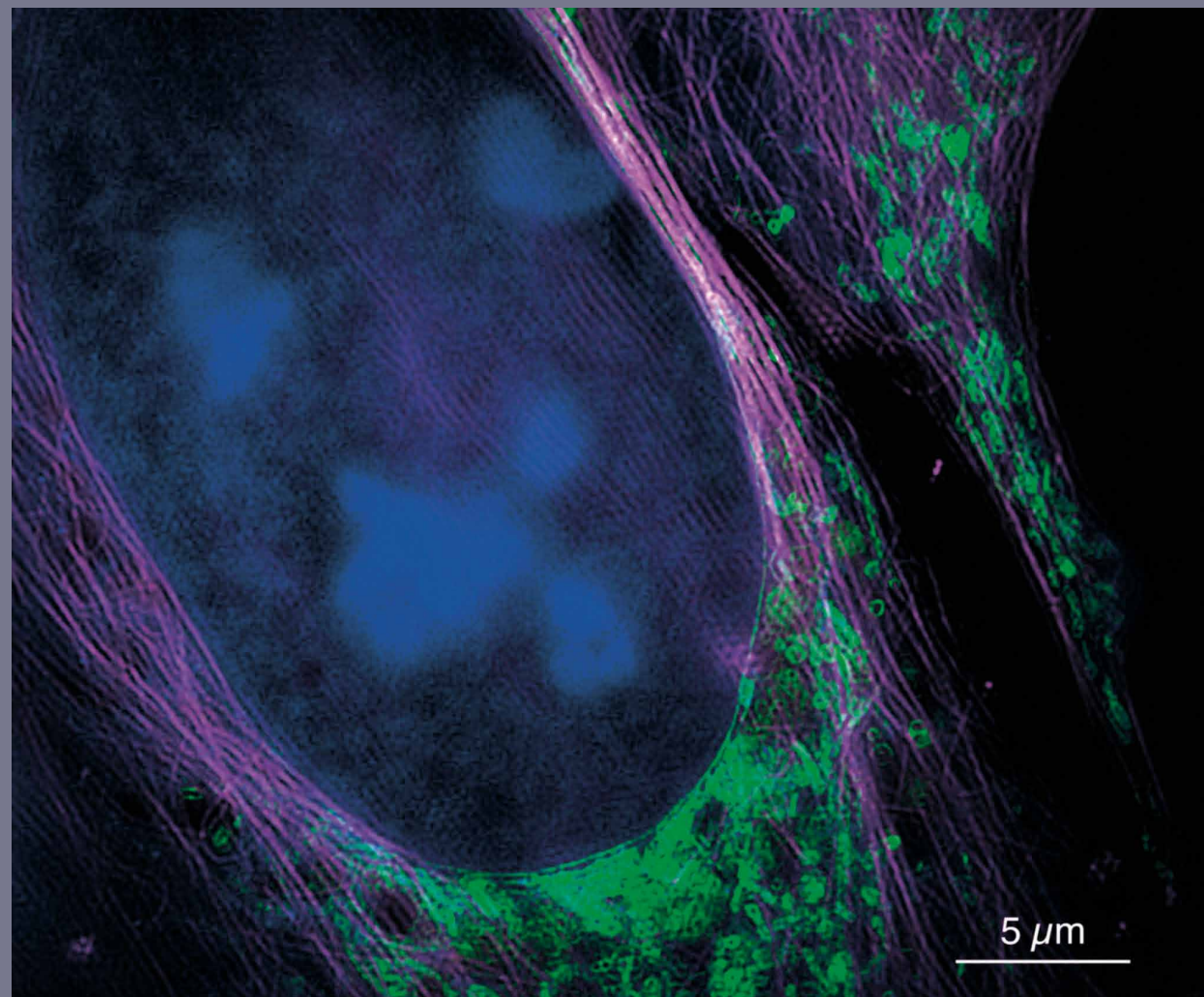
Structures that are invisible to conventional microscopes

"This makes it possible to measure samples quickly and to immediately adjust test conditions during an experiment instead of having to evaluate them afterwards," says Rainer Heintzmann, describing the practical benefits of the new technology. It is only through the rapid reconstruction of images that "this type of



Images taken with the microscope: On the left the computer image, on the right the microscope images. The picture shows a bone cancer cell with mitochondria (blue) and endoplasmic reticulum (pink) at different times.

© Bielefeld University / W. Hübner



This image of the new microscope shows a living bone cancer cell with nucleus (blue), mitochondria (green) and cytoskeleton (magenta).

© Bielefeld University / W. Hübner

microscopy becomes really useful for applications in biology or medicine," says Thomas Huser. "Because the problem so far is: microscopes that offer sufficiently high resolution cannot display information at the appropriate speed".

For their study, the scientists tested the method on biological cells and recorded the movements of mitochondria, the energy centers of the cells that are about one micrometre in size. "We were able to generate about 60 frames per second – that's a higher frame rate than in motion pictures. There are less than 250 milliseconds between measurement and image, so the technology allows real-time recordings," says Andreas Markwirth.

Until now, super-resolution methods have often been combined with conventional methods: A conventional fast microscope is used to find structures first. These structures can then be examined in detail with a super-resolution microscope. "However, some structures are so small that they cannot even be found with conventional microscopes, for example special pores in liver cells. Our method provides both high resolution and speed – this enables biologists to investigate such structures," said Thomas Huser. Another application for the new microscope is the investigation of virus particles on their way through the cell. "This enables us to understand exactly what happens during infection processes."

Publication: Andreas Markwirth, Rainer Heintzmann et al., Video-rate multi-color structured illumination microscopy with simultaneous real-time reconstruction, *Nature Communications* 10 (2019), <https://doi.org/10.1038/s41467-019-12165-x>



Alejandra Zegarrra-Valverde is doing her doctorate in the research department Microscopy

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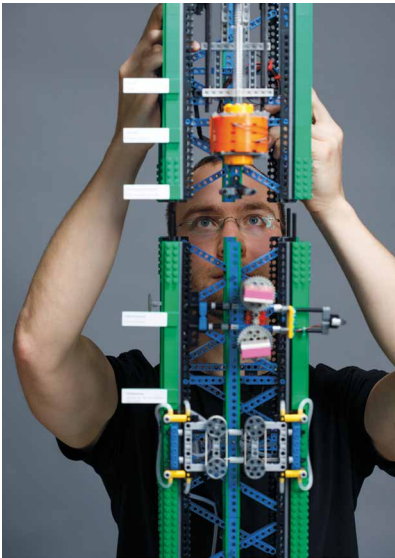
We Are Developing a Rapid Raman Microscopy Technique

A prism fans the light according to wavelength. This is the core of the new Raman micro-spectroscopy technique I'm exploring. I'm combining light sheet microscopy and integral field spectroscopy. A prism or grating breaks down the different Raman frequencies that make each molecule identifiable. This new tool is much faster and more efficient than conventional systems. I use it to visualize bacterially infected cells in order to identify them. This summer, I made a dream come true: I taught teenagers and students the basics of optics in my Peruvian homeland. They experimented with the UC2 optical toolbox developed by our team at Leibniz IPHT. In the end they were able to build their own digital holographic microscope with which they studied plants from the Andes.

Communicating

High Technology Made of Lego Bricks

The fiber drawing tower at Leibniz IPHT is 14 metres high and is one of the most modern research drawing plants for glass fibers in Europe. Adrian Lorenz has built it from Lego bricks. More than 3,600 bricks in over 40 hours, then the 1.40-metre high miniature fiber-drawing tower was ready. The physicist from the Fiber Research and Technology Department designed it himself, including specially designed and custom-made individual parts. "The many visitors to our fiber drawing tower are always fascinated by the way a highly complex, high-precision fiber is created from a rigid preform," says Adrian Lorenz. "How this process works can be illustrated in a Lego model that you can touch and try out in a playful way. During the Long Night of Science, when we presented the tower for the first time, we experienced that people were enthusiastic about this idea.



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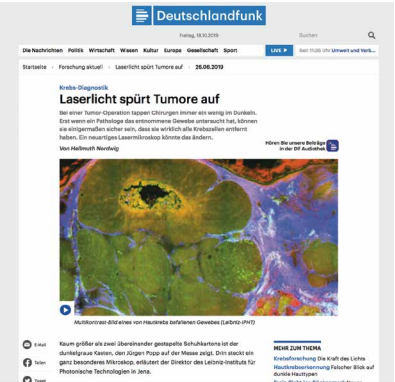
Us in the Media



With the chip for the diagnosis of infectious agents and their resistance to antibiotics in the Bild-Zeitung ...



... and in Lesch's Kosmos on ZDF



With the compact Medicars microscope for cancer diagnostics during surgery on Deutschlandfunk



With the support of our researchers for the "Fridays for Future" protests for better climate protection in the regional press



With the laser-based method for rapid sepsis diagnosis on 3sat



And with the approval of the federal government for the new Leibniz Center for Photonics in Infection Research in Jena in regional and national print and online media

Inspiring Research

Introduction to Science Communication

How to communicate research in a vivid way or replace a laboratory with a microfluidic chip: This is what pupils learned at the "Forsche Schüler" day on 28 March 2019 at Leibniz IPHT. Some translated the complex manufacturing process from quartz powder to glass fiber for a poster into their own pictures. Others practised pipetting in the laboratory next door, learned what lab-on-a-chip technologies can be used for, and had a look over the shoulder of the micro- and nanotechnology team in the clean room.



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Crash Course in the Optical Valley

Biophotonics. More than 40 students learned about the scope of this term at the summer school of Friedrich Schiller University Jena and Leibniz IPHT in June. They gained insight into how optical technologies can be used to diagnose diseases or expose counterfeit drugs and learned about the Optical Valley in Jena from the inside: at Carl Zeiss AG and Jenoptik, at the university and in several research institutes. What that was like you could see on their Insta-Takeover of the institute's Instagram account.



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Experiments for Young and Old

Revealing hidden weapons with the terahertz camera, calculating with molecules, or finding out how much sugar a drink contains with the help of nanosensors: During the Long Night of Science in November, scientists from the institute offered the numerous young and old visitors discoveries and experiments on the subject of research with light.

Well Frequented Trade Fair Booth

A portable Raman spectrometer and a microscope for rapid cancer diagnostics (p. 18) were among the attractions at the booth for photonics in the life sciences at the world's leading trade fair "Laser World of Photonics". Together with other projects funded by the Federal Ministry of Education and Research, scientists from Leibniz IPHT presented their research to media and trade fair visitors.

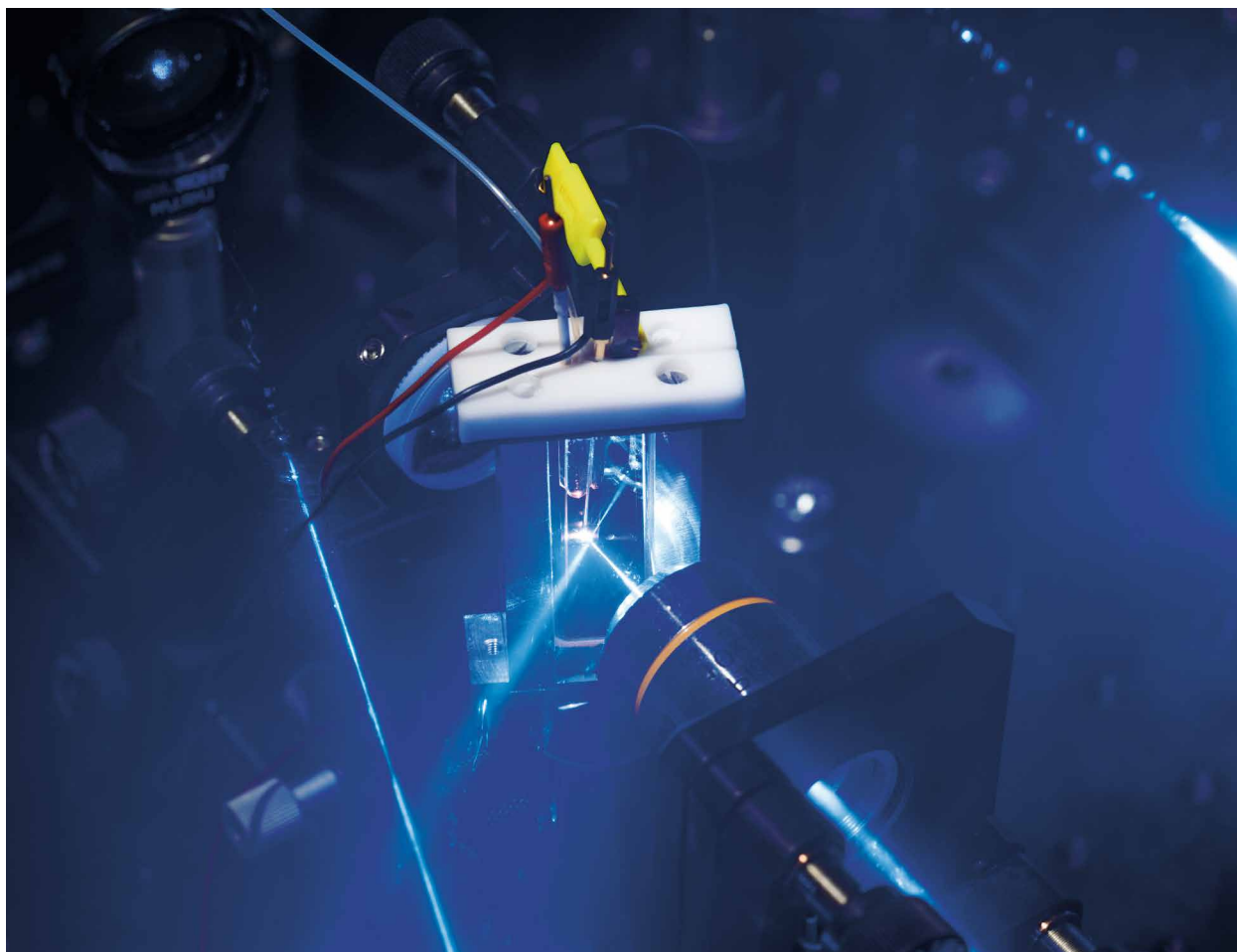


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Nature as Model

Linda Zedler, Maria Wächtler and Benjamin Dietzek are investigating the basics of artificial photosynthesis



Multi-stage multi-electron transfer cascades are essential reaction steps in the photocatalytic production of hydrogen. The researchers use a spectroelectrochemical cell to produce intermediates of this electron transfer process and then characterize them using spectroscopic techniques.

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How Light Keeps Chemical Reactions Moving

Researchers visualize ultrashort chemical reactions in a time-resolved manner and thus provide fundamental findings for the sustainable production of hydrogen from sunlight and water

In order to supply people worldwide with climate-friendly energy, hydrogen is considered the fuel of the future. Attempts to produce it in an environmentally friendly way from sunlight and water have so far been unproductive. Linda Zedler and her team from the research department

"Functional Interfaces" have now developed a method to decipher basic processes in order to investigate new materials for the use of solar energy following nature's example. Using a combination of spectroscopic and electrochemical techniques, the scientists can for the first time

show the mechanisms by which complex, multi-step light-driven processes operate.

"Up to now, we have perceived light-driven processes as a hundred meter run, where you hear the starter's gun and then only see

the finish photo again," explains Benjamin Dietzek, who heads the research department. Following the model of photosynthesis in nature, chemical reactions are triggered by light in such multi-step photocatalytic processes. Due to the extremely short lifespan of these intermediates, it has not yet been possible to investigate how these reactions take place and which factors influence the reactivity of intermediates. The research team is now showing new approaches to analyze this reactivity.

Processes that researchers previously overlooked

"It is a fundamental advance that we have managed to look at the dynamics of the processes triggered by light in an intermediate product," reports Maria Wächtler, who was involved in researching the process. "The first hurdle we cleared was to be able to produce these very reactive intermediates in sufficient concentration at all." Only then did the researchers gain access to the process after the start of photoinduction, which they had previously been blind to.

In order to make such ultrashort chemical reactions visible on a time-resolved basis the researchers combine spectroelectrochemical methods with quantum chemical simulations. "We have thus developed a method that can in principle be applied to all multi-step photocatalytic processes," says Benjamin Dietzek. It enables scientists to gain a better understanding of the entire catalytic activity by providing insights into the sequence of multi-step multi-electron transfer cascades, which has previously not

been understood until now. These take place in the respiratory chain as well as in natural and artificial photosynthesis or in solar cells. The method thus opens up new possibilities for researching highly active and stable photocatalysts for the production of hydrogen and a climate-friendly energy supply of the future.

The work was carried out within the Collaborative Research Center Sonderforschungsbereich, SFB "CataLight" ("Light-driven Molecular Catalysts in Hierarchically Structured Materials – Synthesis and Mechanistic Studies"), in which teams of scientists from Leibniz IPHT and the universities of Jena and Ulm are developing molecular catalyst systems for the light-controlled production of hydrogen and oxygen from water based on the model of natural photosynthesis.

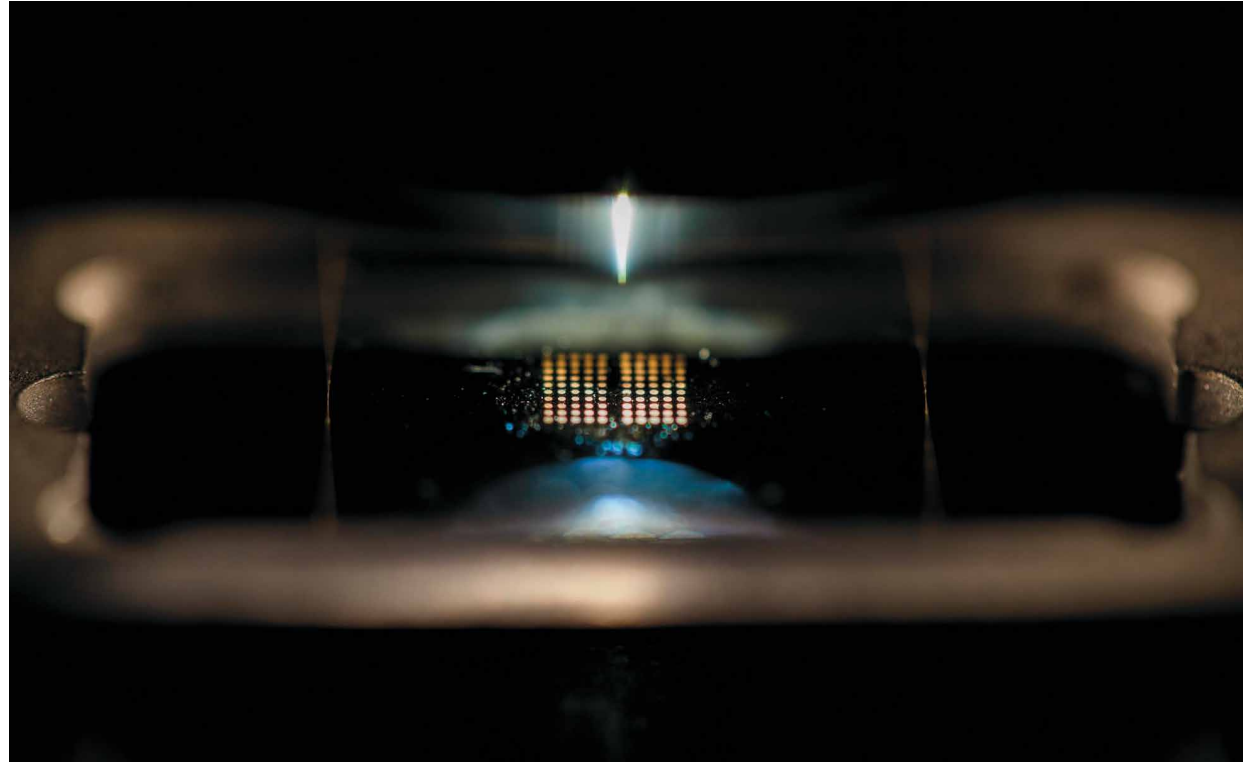
The vision: artificial chloroplasts

The research of "CataLight" focuses on the constructive interaction between molecular photocatalysts and their polymer-based environment, which allow a high degree of control over reactivity but are relatively unstable compared to photocatalytically active metal oxides. "We want to find a new way to stabilise such molecular photocatalysts and make repair methods accessible," said CataLight spokesperson Sven Rau from the University of Ulm. "We look at how nature does it," adds Benjamin Dietzek, "and integrate the molecular components into soft matter in order to establish new concepts for photocatalytic water splitting." The goal? "Using the en-

ergy of sunlight to split water with molecular machines", says Sven Rau. "We want to provide a mechanistic understanding of the interactions of light-driven molecular catalysts with structured soft materials." However, intensive research is required before basic research on the chemical process can lead to the long-term goal of producing artificial chloroplasts. "We want to recreate processes that nature has developed over millions of years," stresses Maria Wächtler. "Photosynthesis is highly complex, with several systems interacting. To efficiently imitate this with simplified systems is a great challenge. But we are convinced that the photocatalytic approach to produce hydrogen can be a technological solution."

Publication: Linda Zedler et al., Unraveling the Light-Activated Reaction Mechanism in a Catalytically Competent Key Intermediate of a Multifunctional Molecular Catalyst for Artificial Photosynthesis, *Angewandte Chemie*, 58 (37), 2019, <https://doi.org/10.1002/anie.201907247>

Environment



A microarray with spots of plasmonic gold nanoparticles. The spots are read out optically in parallel. Each spot is used to detect a water germ.

© Sven Döring

Detecting Germs in Water

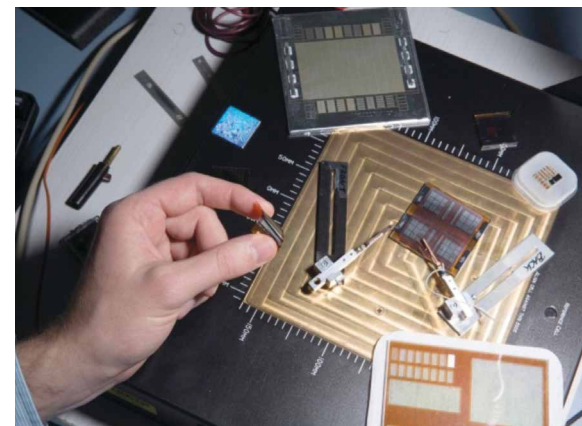
In many regions of the world, fresh water is contaminated with microbial infectious agents that can pose a health risk to people. In order to improve the monitoring of water quality and to detect dangerous pathogens, a team of the Nanobiophotonics group at Leibniz IPHT in cooperation with colleagues from the Israeli Technology Institute Technion in Haifa is researching a novel rapid detection system. The scientists determine the number of bacteria in a body of water using indicators for faecal contamination, which they visualize using optical methods.

"Up to now, water bodies have generally been examined for contamination. This provides indications of faecal contamination that can be used to assess water quality and the potential danger posed by pathogenic bacteria and viruses," explains Andrea Csäki, who heads the Nanobiophotonics research group at the Leibniz IPHT. "Tests for specific pathogens, however, are not normally carried out in routine screening because the available culture methods are lengthy – they can take up to a week – and expensive. In addition, water-borne pathogens such as Pseudomonas, Aeromonas and part of the Vibrionaceae can also occur independently from faecal contamination."

The goal of the German-Israeli research team is to develop a diagnostic technology for use in the field that can quickly and specifically identify several pathogens in water simultaneously. In the "Nanowater" project, the Jena researchers are combining their technology of plasmonic microarray chips with the microbiology and bioinformatics know-how of Israeli biotechnology experts. An Israeli team of engineers contributes an innovative approach to the concentration of target molecules.

Making Better Use of Sunlight

Making high-performance solar technology more cost-effective: The research team of the Photonic Thin Film Systems Group at Leibniz IPHT is working on this together with partners from industry and research. "We want to develop new materials and systems for energy conversion using photonic processes," explains Jonathan Plentz, who heads the EU-funded FUN project. Inexpensively produced silicon wafers in combination with novel laser-crystallized emitter layers form the basis for inexpensive and efficient solar cells that could expand conventional silicon photovoltaics in the future.



Characterization of solar cells

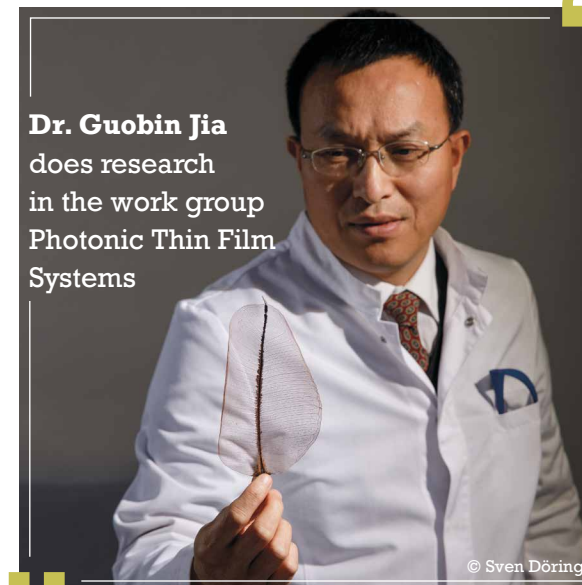
© Sven Döring

Dr. Jonathan Plentz
heads the work group
Photonic Thin Film Systems

Smartphones to Run on Solar Energy

We develop solar textiles. These are thin-film solar cells applied to textiles. My vision is that these solar fabrics will make the energy supply of small electronic devices like smartphones flexible and self-sufficient, in an environmentally and user-friendly way. And that they make a contribution for energy system transformation. This equipment accounts for a considerable part of our energy requirement.

Dr. Guobin Jia
does research
in the work group
Photonic Thin Film
Systems

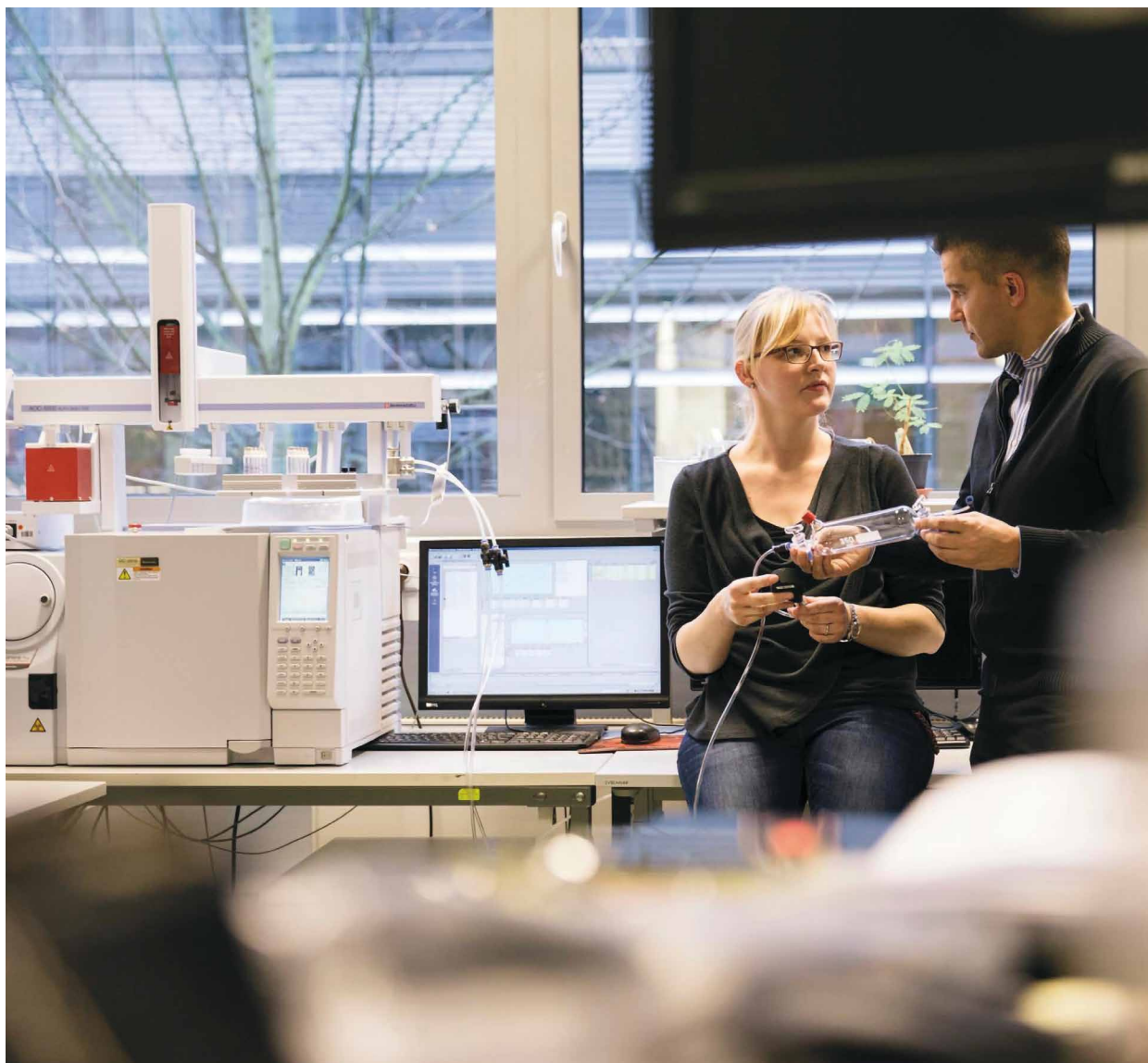


We Build Electrodes from Leaves

I have coated the fine, net-like veins of leaves with copper. The metallized leaf structures achieve excellent optical and electronic properties. Electrically conductive and optically transparent electrodes – which are also made of sustainable materials – could open up completely new possibilities in the field of flexible optoelectronics, for example for solar cells, LEDs or displays. I would like to develop this further.

Underground Fingerprints

How do climate change and land use affect the soil and our groundwater? Torsten Frosch and Andreas Knehl are developing powerful gas sensors to investigate this issue



Anne Sieburg and Torsten Frosch have developed innovative optical gas sensors to analyse biogenic gases underground.

© Sven Döring

Into the Depth

Gas sensors with innovative hollow-core optical fibers provide a key to understanding metabolic and exchange processes underground

Between the treetops and the bottom of the groundwater – at the interface of atmosphere and geosphere – lies the critical zone: a living, breathing, constantly evolving environment in which rock, soil, water, air, and living organisms interact with each other. Their complex network of relationships

regulates our natural habitat. The critical zone determines our supply of natural resources and the quality of our drinking water. And it is increasingly influenced and strained by our way of life.

How do intensive land use, environmental pollution, and the climate

change affect groundwater and the habitat under the earth? How safe are the vital underground water reservoirs? What do metabolic processes and gas exchange processes reveal about the state of the ecosystem?

In order to better understand the interrelationships between subsur-

face and surface, between environmental factors and the processes in vegetation, soils, and groundwater, the University of Jena, Leibniz IPHT, and two other partners, have set up an open-air laboratory in Thuringia's Hainich National Park that is unique in the world. In one of the last original beech forests in Germany, scientists from the Collaborative Research Center (Sonderforschungsbereich, SFB) "AquaDiva" are investigating how the above and below ground habitats of plants and microorganisms interact with each other under different land use conditions.

Investigating drought stress of trees

The Hainich Critical Zone Exploratory (CZE) research platform is equipped with new types of measuring equipment and sampling facilities to obtain and analyse samples of gases, water, and substances from the subsoil, soil, and groundwater. From this, the researchers want to deduce how we can preserve these vital ecosystems for future generations in such a way that they too can use them as a basis for life. Torsten Frosch and Andreas Knebl from the Leibniz IPHT work group "Fiber Spectroscopic Sensors" are also involved. In their team, the scientists are researching innovative optical gas sensors to analyse biogenic gases in underground habitats. These provide clues to decipher the interactions between living organisms and environmental factors – such as climate or nutrient concentration – in this ecosystem.

"Plants, animals, and microorganisms produce and consume various gases, especially oxygen and carbon dioxide," explains Torsten Frosch,

who heads the work group. "With innovative Raman multi-gas sensors, we can continuously track depth profiles of these gases on site and find out how microbial life underground is connected to the environment. "We measure gases and isotopically labelled compounds," reports Andreas Knebl. In order to use stable isotopes to trace and decompose the gas exchange of plants, the fiber-spectroscopic sensor technology research team developed a novel Raman spectroscopic gas sensor whose core component is a hollow-core optical fiber. This sensor fiber makes it possible to investigate the oxygen and carbon dioxide exchange of plants with high sensitivity and selectivity in one experiment. "Thus, we can also use this method to determine the respiration coefficient and investigate the effects of drought stress on trees," explains Torsten Frosch.

The rapid optical analysis technique allows gases to be clearly identified on the basis of their molecular fingerprint. "We can monitor all relevant gases simultaneously with one device, including the normally not easily measurable gases oxygen, nitrogen, and hydrogen," says Torsten Frosch. "This makes it particularly suitable for measuring the gas exchange of bacteria and plants in field trials," adds Andreas Knebl.

With new concepts for highly sensitive Raman gas spectroscopy, the team wants to further break down the exchange of gases between atmosphere, soil, and groundwater. To this end, the researchers are working with the fiber technologists of Leibniz IPHT on the development of specific filigree hollow-core fibers produced in-house. The gas sensors are intended to

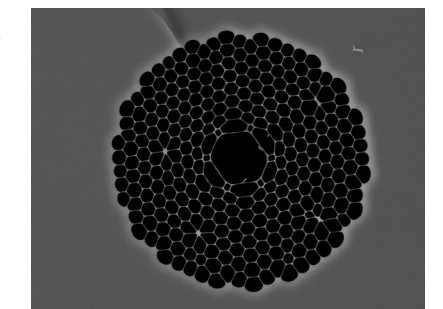
provide a better insight into natural processes. "By measuring gases and isotopes at different points in time, we want to further contribute to the mission of 'AquaDiva'", Torsten Frosch states. "We want to gain a better understanding of how the subsurface and the surface interact, and what influence humans have on this critical ecosystem."

Publication: Andreas Knebl et al., Fiber-Enhanced Raman Gas Spectroscopy for ^{18}O - ^{13}C -Labeling Experiments, *Analytical Chemistry* 2019, 91, 7562-7569, <https://doi.org/10.1021/acs.analchem.8b05684>

Collaborative Research Center AquaDiva

Friedrich Schiller University Jena | Leibniz IPHT | Max Planck Institute for Biogeochemistry | Helmholtz Center for Environmental Research | Funded by the German Research Foundation (DFG)

www.aquadiva.uni-jena.de



Microscopic image of a microstructured photonic crystal fiber

© Leibniz IPHT



Christoph Krafft can watch fish with the naked eye. Microplastic particles in water, however, ...

© Sven Döring

I Spy with my Little Eye ...

Tiny plastic particles are found in the soil, in water and in the air we breathe. How many there are, where they come from, and how they affect our health and the environment is still mostly unknown – because there is a lack of instruments to detect and count micro- and nanoplastics. Together with European partners, Christoph Krafft trains young researchers to become microplastics experts. He explained to us why they are urgently needed



... only become visible under the microscope, here at two magnifications with a digital microscope.

© Leibniz IPHT

Mr. Krafft, in the future, the EU wants to monitor how much micro- and nanoplastics is in our drinking water. However, a measuring method has yet to be established for this. Why is this so difficult?

There are various methods and protocols for detecting microplastics, but none have yet been standardized. It's still a bit like the Wild West, as our research partners at Aalborg University in Denmark, who

are among the leading experts in the field of microplastics, recently put it. There are no uniform rules for analysis.

What kind of rules are these, for example?

The preparation of the samples, the extraction of the micro- and nanoparticles, is very complex. Water can be filtered, but in the case of marine sediments, for example, the purification process alone takes three months. And in order to ensure

that the sample is not contaminated during preparation – for example by microplastic particles from synthetic clothing or polystyrene from a Petri dish – a blind sample should always be taken. But this is not yet done. There is a lack of comprehensive studies involving several institutes and laboratories that are reproducible and comparable – for example for water from plastic bottles, which is more heavily contaminated than the relatively pure tap water. In general, there is still not enough research on the occurrence of micro-



Doctoral student Barbora Marsikova (right) from Leibniz IPHT supports Robin, Emilia, and Elias in building a fluorescence microscope to proof microplastics in cosmetics.

© Sven Döring

plastics in the environment and the possible health effects.

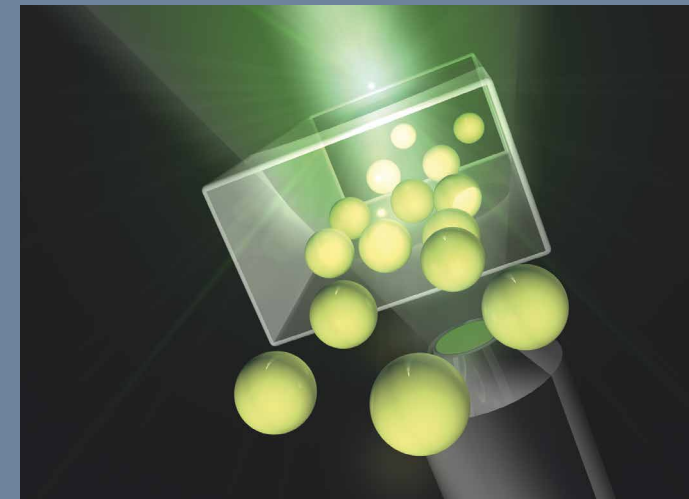
Which technologies can be used to measure the concentration of micro- and nanoplastics?

How much microplastics is contained in a sample can be determined using gas chromatography and mass spectrometry. However, we don't get to know the kind of particles, their size, shape and distribution. We have developed and patented a method to identify up to 4,000 particles per hour using infrared and Raman spectroscopy. And our team of researchers from the field of microfluidics has designed a chip-based system that provides 3D images of the particles. This allows you to determine not only the type of particles, but also their size and shape.

Can the water companies, who will have to have their water certified, already use these approaches?

At present, this would require expensive scientific laboratory equipment, for which highly qualified personnel would be needed. Many companies could not afford that. They need robust, easy-to-use and cost-effective equipment whose

measurements directly comply with the EU directive. We set the course for the development of these technologies in our project. Eight research partners from seven countries are networking with technology manufacturers and users, such as water treatment companies.



A chip-based system developed by the microfluidics research team provides 3D images that can be used to determine microplastic particles.

© Leibniz IPHT

Tracking Down Microplastics

Elias Höfling, Robin Schröder and Emilia Walther (photo left) from the 11th grade of the Jena Montessori School want to examine cosmetics with regard to microplastics and therefore build their own fluorescence microscope. In order to develop a cheap and comparably simple method for the detection of plastic particles, the three of them are using the UC2 optical construction kit designed by PhD students Benedict Diederich and René Lachmann from Leibniz IPHT.

To what end?

Our most important aim is to train the experts of tomorrow. In order to research the urgently needed new technologies and methods, we need teams of scientists and en-

gineers who work together across disciplinary boundaries. Such an environment is currently lacking in the EU and worldwide.

The global production of plastics, that take hundreds of years in order to be biologically degraded, is expected to triple in the next 30 years. What impact will this have on our health and the environment?

Little is yet known about the potential risks that micro- and nanoplastics pose to us, animals, and the environment. We want to advance this knowledge and help to supplement the limited data available. And we want to do so as extensive as possible: While our researchers are working with technologies to detect plastics, our partners are investigating the effects of plastic particles on hormones, for example. To ensure that our data and results reach as many people as possible and are as effective as possible, we make them freely available via an Open-Science platform.

www.monplas.eu

Patent: C. Krafft, J. Popp, I. Schie: Method for examining distributed objects by segmenting an overview image, WO20171851554 20170317

How was ...

... the new German-Chinese Conference Series "Science for Future" in Beijing, Maria Chernysheva?



Marie Richard-Lacroix, Yang Du, Gregor Oelsner and Maria Chernysheva (from the left) © Leibniz IPHT

"Science for Future was not the kind of conference we usually attend, but a scientific forum. Young and established scientists from very different fields of research – including Nobel Prize winners from Germany and China – came together to discuss policies and strategies for open international scientific cooperation.

The presentation of our results at the conference was quite exciting. We were supposed to practice an elevator pitch and had just two minutes to spark the participants' interest in our research area and to highlight it as a priority for international innovation.

And, of course, the hospitality of the Chinese colleagues is particularly noteworthy. We were spoiled with daily tours of universities and laboratories, receptions and excursions to the sights of Beijing."

The "Science for Future" series was launched by the National Academy of Sciences Leopoldina and the Chinese Academy of Sciences (CAS). Maria Chernysheva, Marie Richard-Lacroix, Yang Du and Gregor Oelsner were awarded a travel grant from the Leibniz Association and the Leopoldina for their participation.

... JeDis Summer School at UC Davis, Barbora Marsikova?



top: Trip to San Francisco, bottom: Prize winners Barbora Marsikova (left) and Alejandra Zegarra-Valverde with Jürgen Popp © Leibniz IPHT

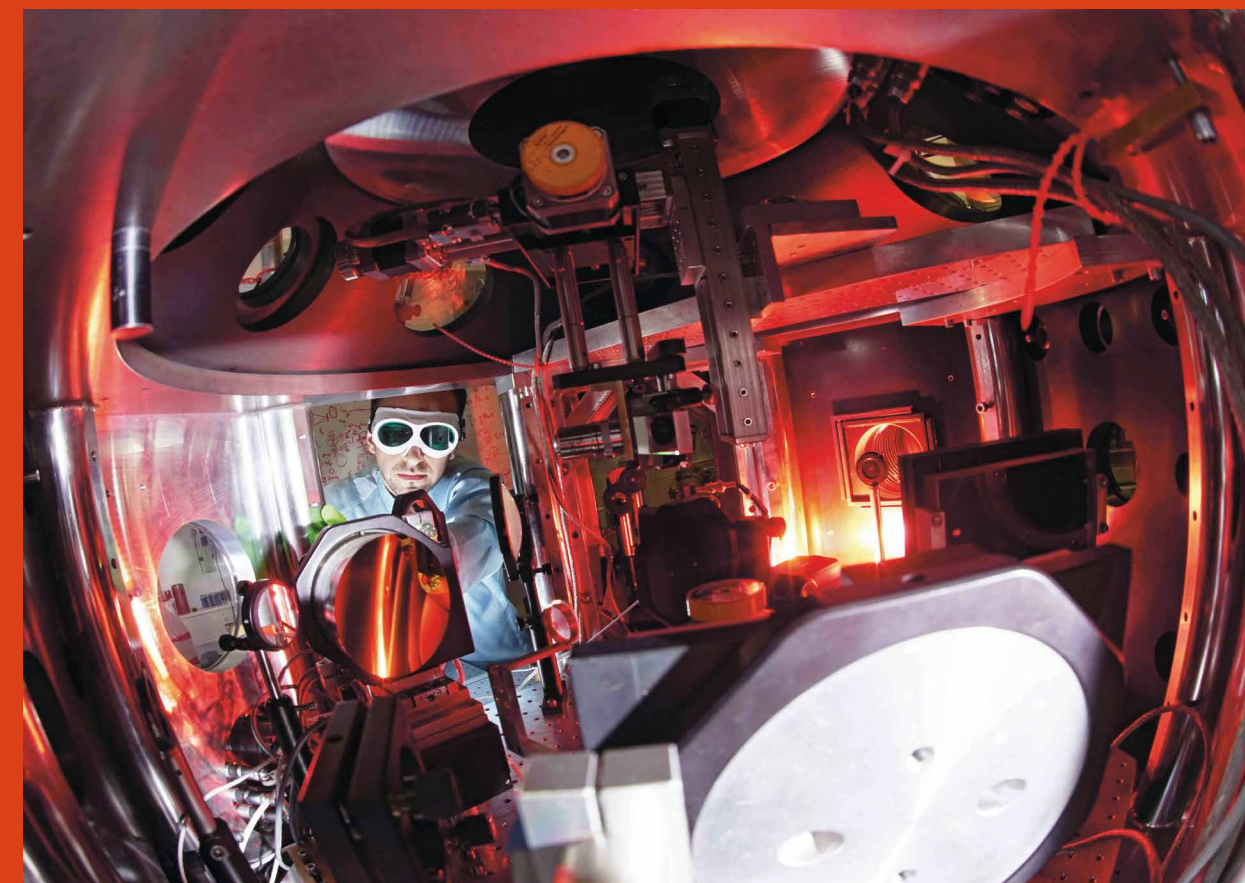
"In August we had the opportunity to visit the University of California Davis and to participate in the second summer school on biophotonics of the "Jena Davis Alliance for Excellence in Biophotonics (JeDis)". During this week we learned a lot about different optical and spectroscopic techniques and their application in clinical research and medicine. I was very impressed by the visits to the laboratories of UC Davis and the tour of the university campus. We enjoyed the hot days in California and the numerous social activities – but also presented our research projects in pitch lectures and a poster session. During

the last two days we had time for excursions to San Francisco. There we visited the Exploratorium – an interactive science and technology museum – and Lake Tahoe."

Ten young scientists from Leibniz IPHT took part in the JeDis Summer School. The doctoral students Barbora Marsikova and Alejandra Zegarra-Valverde from the Microscopy Group were awarded the 1st prize for their poster and pitch talk. JeDis is funded by the Transatlantic Programme of the Federal Republic of Germany; the aim is to establish a graduate school between Jena and Davis.

When Light Meets Matter

New Collaborative Research Center investigates nonlinear optics in smallest dimensions



View into a target chamber in the laboratory of the laser system JETI-40 at the Institute for Optics and Quantum Electronics at the University of Jena.

© Jan-Peter Kasper / FSU

The new collaborative research center (Sonderforschungsbereich, SFB) "Nonlinear Optics down to Atomic Scales" (NOA) at Friedrich Schiller University Jena investigates phenomena of nonlinear optics. Researchers of Leibniz IPHT are involved as partners, as well as the Fraunhofer Institute for Applied Optics and Precision Engineering, the Helmholtz Institute Jena and Ludwig Maximilians University Munich. Phenomena of nonlinear optics occur when light hits matter, but they only become visible and are truly relevant

at higher intensities. In addition to the original light beam, radiation of other and sometimes much shorter wavelengths is then also produced, for example. This effect becomes increasingly important with increasing power and is therefore referred to as nonlinear.

"We want to study the interaction processes between light and matter with atomic resolution, model them on the computer, and finally even learn to control them," explains physicist Ulf Peschel, spokesman of

the German Research Foundation DFG funded Collaborative Research Center. If successful, it could open up many attractive applications: from tiny nanolasers to compact X-ray sources and the optical detection of a few atoms. In the end, it might even be possible to observe chemical reactions between individual molecules in real time – a dimension into which linear optical systems have not been able to advance so far.

www.noa.uni-jena.de

Think Tank for the Research of New Technologies

biophotonics ⁴
FUTURE

With the new event series **Biophotonics4Future**, Leibniz IPHT wants to bring international experts closer together



ESULAB 2019

© Leibniz IPHT

Developing creative and innovative solutions for the future – that works best in a mutual exchange of ideas. In order to promote this, Leibniz IPHT is launching the *Biophotonics4Future* event series. "We want to bring together photonics experts from all over the world and create a space to stimulate discussion on current biophotonics issues," says scientific director Jürgen Popp.

The series is to become a think tank for the further development of light-based applications in medicine and the life sciences. With different formats such as conferences, workshops, and smaller events, the organizers hope to stimulate a lively scientific debate. "In contrast to conventional conferences, where one lecture is followed by another, we rely on two to four keynotes by international experts in order to then work in smaller interdisciplinary groups on specific issues," explains Marc Skupch from the public

relations team who organizes the *Biophotonics4Future* series.

The focus is on research into optical technologies in order to better understand, diagnose, and treat the causes of diseases. In order to ensure that as many researchers as possible can benefit from the jointly gained insights, these will subsequently be recorded in a White Paper. The documents are intended to provide reliable information with a high utility value for the scientific biophotonics community. "In this way we want to advance the transfer of results into applications as quickly as possible. Promoting this process of translation is particularly important to us in everything we research," emphasizes Jürgen Popp.

Under the umbrella of *Biophotonics4Future*, the *EurAsian Conference of Nanophotonics (EACON)* will start in 2020. The conference aims to promote cooperation between leading European and Asian scientists from

different disciplines in the field of nanophotonics. The partner countries of *EACON 2020* are Germany and Taiwan. Experts from the fields of chemistry and photonics will exchange information on the latest advances in research on nanomaterials and nanotechnologies and establish international collaborations. The aim of "*Women in Photonics*" is also to initiate sustainable cooperation. The workshop is aimed at excellent women scientists at the beginning of their career. They are given the opportunity to present their research and to establish targeted contacts with female photonics experts in leading positions at research institutions and companies. In exchange with these experienced women scientists, they can develop their own strategies for a successful career. After this concept proved successful at the first "*Women in Photonics*" workshop of Leibniz IPHT in 2018, the next edition will follow 2020 virtual and 2021 as face-to-face event. This time, the focus will be on biophotonic methods such as vibrational and fluorescence spectroscopy and photonic data science. Also in the portfolio of the *Biophotonics4Future* is the second edition of the "*European Symposium on Ultrafast Laser driven Biophotonics*" (see article on the right), which was successfully launched in 2019 and which Leibniz IPHT is organizing together with the American laser manufacturer Coherent. It is scheduled to take place in 2021.

biophotonics4future.com

Ultrafast Lasers and Functional Materials for the Future

Leibniz IPHT held two major conferences in Jena in 2019



Organizing team and award winners of the Bunsen Conference © Leibniz IPHT

Bunsen Conference 2019

Science with Streetfood was on display at the 118th Annual Conference of the German Bunsen Society for Physical Chemistry in May 2019, where more than 600 researchers from physics, chemistry, materials science, and engineering exchanged views on the topic of functional materials. These include solar cells and

batteries as well as biosensors and implants. "It was an excellent platform for bringing together ideas to overcome scientific and social challenges," reports Benjamin Dietzek, who hosted the conference. Instead of appetizers on white tablecloths, burgers, chips and ice cream were served. Leibniz IPHT and the university had organized a small streetfood festival in the Goethe-Galerie and

turned the shopping center into a congress center.

ESULAB 2019

On invitation of Leibniz IPHT and the laser manufacturer Coherent, top international researchers discussed the potential of ultrafast laser technology for medicine and the life sciences and the direction of developments in the field of spectroscopy and imaging from September 3 to 6, 2019 in Jena. At the "European Symposium on Ultrafast Laser driven Biophotonics" – ESULaB 2019 – Nobel Laureates Stefan Hell, Mihaela Zigmán and Ferenc Krausz from the Max Planck Institute for Quantum Optics in Garching, Elisabet Romero from the Institute of Chemical Research of Catalonia (ICIQ) and Wei Min from Columbia University New York, among others, presented their latest findings.



PD Dr. habil Jer-Shing Huang heads the research department Nanooptics

© Sven Döring

We Are Researching the Wireless Communication of the Future

The cluster of magnetic spheres in my hand mimicks a self-assembled gold nano-octahedron that I work with. What we are investigating is so small that it cannot be seen with the naked eye. We use nanostructures to control light at the nanoscale and thereby enhance light-matter interactions. My vision is to develop optical nano-devices for next generation wireless communication and optical sensors. It is my concern to promote scientific exchange between my home country Taiwan and Germany. That is why I am involved in the Dragon Gate programme, which enables young researchers to spend time abroad, and why I initiated the European-Asian conference EACON at Leibniz IPHT. It aims to network experts in chemistry and photonics.

Future Laboratory Technicians

Leibniz IPHT has new trainees: In August, Victoria Bohn and Tina Keilholtz started their training as physics laboratory assistants. They will learn spectroscopic and microscopic techniques.



© Leibniz IPHT

Exchange with Texas

Between quantum chemistry and nano spectroscopy: Volker Deckert teaches and conducts research at Texas A&M University for three months a year starting September 2019. Among other things, he is building a platform for the detection of bioagents at the optical limit.



© Sven Döring

On the Board Again

The InfectoGnostics Research

Campus Jena has appointed Jürgen Popp to the board of directors again in January. Here, partners from science, medicine, and industry develop diagnostic procedures for infections.



© Sven Döring

From the Laboratory to the Lecture Hall

Iwan Schie develops optical devices for biomedical diagnostics and clinical analysis. Since the winter semester he is also Professor for Biomedical Engineering at the Ernst Abbe University of Applied Sciences Jena.



© Sven Döring

Traditional Association

Benjamin Dietzek has been appointed a fellow of the Royal Society of Chemistry. Thus, the British Society, founded in 1841, honors researchers for outstanding contributions to chemistry.



© Sven Döring

Research Advises Politics

In October Jürgen Popp was elected to the National Academy of Science and Engineering acadtech, which is funded by the Federal Government and the Länder, advises politics and society on technology-related issues.



© Sven Döring

Equal Opportunities for All



Sarah Meinhardt received the award
© Kai Neunert / Total-E-Quality Deutschland

For the second time, Leibniz IPHT has been awarded the Total-E-Quality label in 2019. The association of the same name certifies that the institute is successfully committed to treating men and women equally, promoting diversity, and creating the conditions for employees to be able to combine work and private life.

"We have 401 employees from 36 countries. We want them to feel comfortable," says Equal Opportunities Commissioner Sarah Meinhardt. To this end,

the Institute provides a parent-child workroom and places at the Beutenberg day-care center, for example, or grants travel subsidies if employees need childcare on business trips. Those who look after relatives in need of care receive support, as do those who return to work after a long illness.

From China to Jena: Charity Auction of Guest Gifts for Association "Grenzenlos"



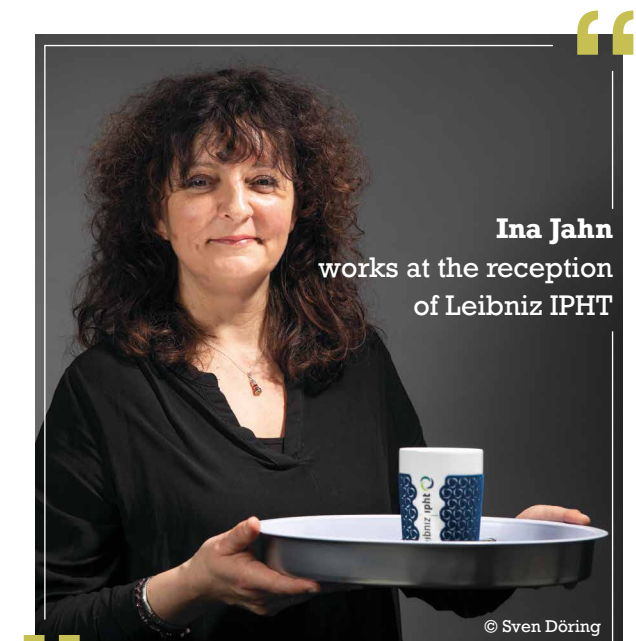
Jürgen Popp with the managing directors of the Grenzenlos ("Boundless") association
© Leibniz IPHT

A small archway with a bronze bell, an embroidered picture scroll or a golden elephant for a bunch of keys: when Jürgen Popp returns from trips to international research partners, he often has unusual guest gifts in his luggage. The scientific director

of Leibniz IPHT has made the gifts from all over the world available for a charity auction.

At the institute's summer party, employees bought the gifts at an auction to support Jena's association

"Grenzenlos" (boundless), which supports disabled people. 500 euros were collected. "We are very happy that you, who have both feet firmly on the ground, also think of those who do not have it so easy", expressed Managing Director Ursula Müller in her thanks.



Ina Jahn works at the reception of Leibniz IPHT
© Sven Döring

No More Paper Cups for the Coffee Machine

I used to throw away bag after bag of disposable waste from our coffee machine in the foyer. Nowadays, only those who bring their own cup get coffee here. For me, it is very important not to waste resources in my everyday work.

Award-Winning Research



© Steffen Walther / TMWWDG



Thuringian Research Prize

awarded to the research team of Leibniz IPHT, Friedrich Schiller University Jena and Jena University Hospital for the RAMANBIOASSAY™ for the rapid detection of infectious agents and their antibiotic resistances



Gold Medal at the International Trade Fair "Ideas Inventions New Products" iENA 2019

awarded to Thomas Bocklitz, Olga Chernavskaja, Tobias Meyer, and Jürgen Popp for two diagnostic procedures for the rapid detection of cancerous tissue and skin examination for psoriasis



© Steffen Höpfer



Friedrich-Hund-Dissertation Prize of the University of Jena

awarded to Mario Chemnitz for his scientific contributions to the dynamics of solitons and his involvement in research and teaching



© Jan Bernert Photography

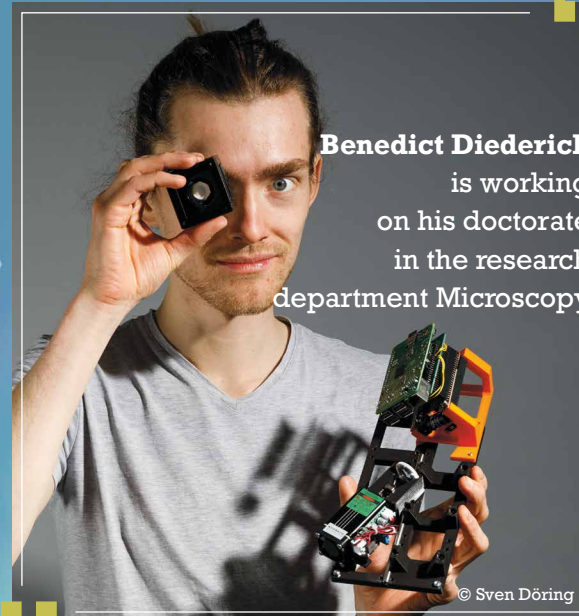


2nd Prize at the eHealth Hackathon of the Jena eHealth Center for Cancer Therapies

awarded to Christoph Krafft and his team for a method of detecting bladder cancer with infrared and Raman spectroscopy



© JeCaThon



Benedict Diederich is working on his doctorate in the research department Microscopy

We Are Building a Creative Microscopy Community

We want to open up the world of microscopy to a broad public with our modular optical toolbox UC2. To achieve this, we rely on open source, 3D printing, and the smartphone as a camera to reduce the exclusivity of cutting-edge science. We use our system to detect microplastics, observe living cells, or in physics lessons. With our next step towards mass production, we are focusing even more on the creativity of the users.

Together with researchers from Stockholm, we want to connect microscopes to the Internet and thus reduce the barrier to this technology and further develop the lab-in-the-cloud concept. With UC2, we recently convinced the audience at the "Elevator Pitch" at the Photonics Days and are very pleased to receive the €20,000 prize money to drive the implementation of our ideas even further.

useetoo.org



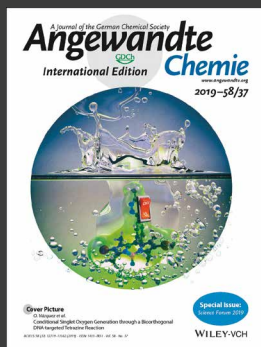
© Sven Döring



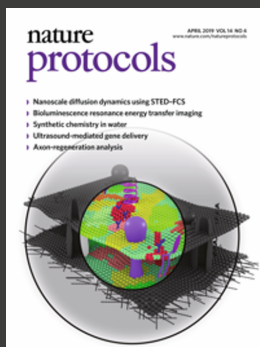
1st Place in the Elevator Pitch of the Photonics Days 2019

awarded to René Lachmann & Benedict Diederich for their modular optical toolbox UC2 for research and MINT training

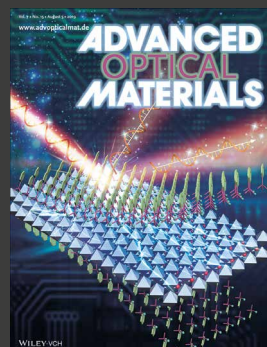
Selected Publication Highlights



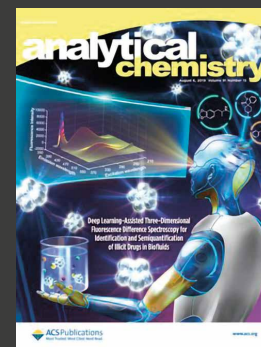
Unraveling the Light-Activated Reaction Mechanism in a Catalytically Competent Key Intermediate of a Multifunctional Molecular Catalyst for Artificial Photosynthesis
—
Angewandte Chemie (International ed. in English) 58 (37), S. 13140–13148. DOI: 10.1002/anie.201907247.
—
Linda Zedler | Alexander Klaus Mengele | Karl Michael Ziems | Ying Zhang | Maria Wächter | Stefanie Gräfe et al. (2019)



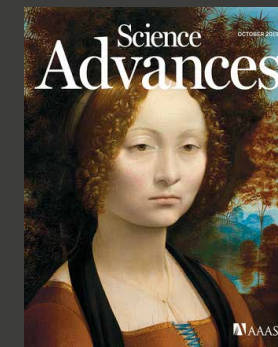
Measuring nanoscale diffusion dynamics in cellular membranes with super-resolution STED-FCS
—
Nature protocols 14 (4), S. 1054–1083. DOI: 10.1038/s41596-019-0127-9. — 11,334
—
Erdinc Sezgin | Falk Schneider | Silvia Galiani | Iztok Urbančič | Dominic Waithe | B. Christoffer Lagerholm | Christian Eggeling (2019)



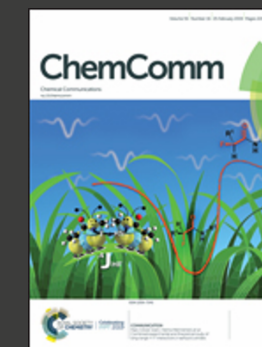
Stress-Induced 3D Chiral Fractal Metasurface for Enhanced and Stabilized Broadband Near-Field Optical Chirality
—
Adv. Optical Mater. 7 (15), S. 1900617. DOI: 10.1002/adom.201900617.
—
Ming Lun Tseng | Zhan Hong Lin | Hsin Yu Kuo | Tzu Ting Huang | Yi Teng Huang | Tsung Lin Chung et al. (2019)



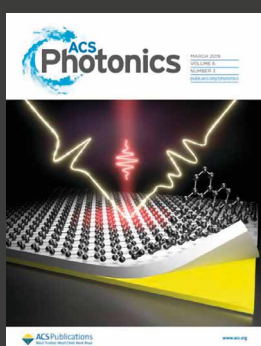
Designable Spectrometer-Free Index Sensing Using Plasmonic Doppler Gratings
—
Analytical chemistry 91 (15), S. 9382–9387. DOI: 10.1021/acs.analchem.9b02662.
—
Fan-Cheng Lin | Kel-Meng See | Lei Ouyang | You-Xin Huang | Yi-Ju Chen | Jürgen Popp | Jer-Shing Huang (2019)



HIV-1 Gag specifically restricts PI(4,5)P2 and cholesterol mobility in living cells creating a nanodomain platform for virus assembly
—
Science advances 5 (10), eaaw8651. DOI: 10.1126/sciadv.aaw8651.
—
C. Favard | J. Chojnacki | P. Merida | N. Yandrapalli | J. Mak | C. Eggeling | D. Muriaux (2019)



Remote control of electronic coupling – modification of excited-state electron-transfer rates in Ru(tpy)2-based donor-acceptor systems by remote ligand design
—
Chemical communications (Cambridge, England) 55 (16), S. 2273–2276. DOI: 10.1039/c8cc10075f.
—
Yusen Luo | Jens H. Tran | Maria Wächter | Martin Schulz | Kevin Barthelmes | Andreas Winter et al. (2019)



Boosting Light Collection Efficiency of Optical Fibers Using Metallic Nanostructures
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ACS Photonics 6 (3), S. 691–698. DOI: 10.1021/acsp Photonics.8b01560.
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Ning Wang | Matthias Zeisberger | Uwe Hübner | Markus A. Schmidt (2019)



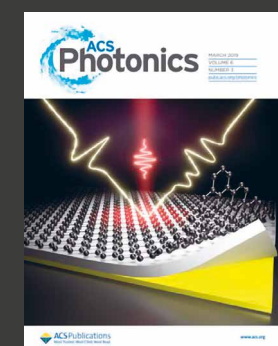
Video-rate multi-color structured illumination microscopy with simultaneous real-time reconstruction
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Nature communications 10 (1), S. 4315. DOI: 10.1038/s41467-019-12165-x.
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Andreas Markwirth | Mario Lachetta | Viola Mönkemöller | Rainer Heintzmann | Wolfgang Hübner | Thomas Huser | Marcel Müller (2019)



Light-sheet microscopy of cleared tissues with isotropic, subcellular resolution
—
Nature methods 16 (11), S. 1109–1113. DOI: 10.1038/s41592-019-0615-4.
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Tonmoy Chakraborty | Meghan K. Driscoll | Elise Jeffery | Malea M. Murphy | Philippe Roudot | Bo-Jui Chang et al. (2019)



Molecular recognition of the native HIV-1 MPER revealed by STED microscopy of single virions
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Nature communications 10 (1), S. 78. DOI: 10.1038/s41467-018-07962-9.
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Pablo Carravilla | Jakub Chojnacki | Edurne Ruja | Sara Insausti | Eneko Largo | Dominic Waithe et al. (2019)



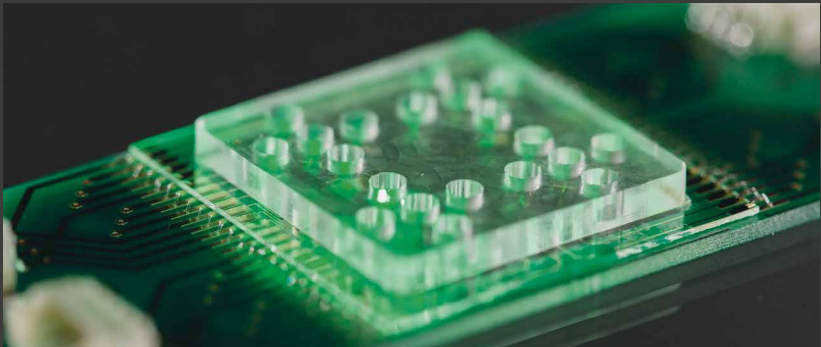
Hollow Core Light Cage: Trapping Light Behind Bars
—
ACS Photonics 6 (3), S. 649–658. DOI: 10.1021/acsp Photonics.8b01428.
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Chhavi Jain | Avi Braun | Julian Gargiulo | Bumjoon Jang | Guangrui Li | Hartmut Lehmann et al. (2019)



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Journal of Statistical Software 90 (3). DOI: 10.18637/jss.v090.i03
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Robert Geitner | Robby Fritsch | Jürgen Popp | Thomas W. Bocklitz (2019)

Research Highlights 2019

on www.leibniz-ipht.de



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Biophotonics

Loop-Mediated Isothermal DNA Amplification for the On-Site – Detection of Human Pathogenic Legionella from Water Samples

Cornelia Reuter | Thomas Henkel | Andrea Csáki | Wolfgang Fritzsche
–

Observation and Modulation of the Spread of a Virus Using Super-Resolution Microscopy

Pablo Carravilla | Christian Eggeling
–

MRSA Super Germ from the Indian Subcontinent: “Bengal Bay” Strain Combines Characteristics of Hospital-Acquired and Community-Acquired Pathogens

Stefan Monecke | Elke Müller | Sascha Braun | Annett Reissig | Cindy Burgold-Voigt | Ralf Ehricht
–

Rat Plague in Vienna: Infection Researchers Detect Multi-Resistant Pathogens in Urban Rats

Stefan Monecke | Elke Müller | Sascha Braun | Annett Reissig | Cindy Burgold-Voigt | Ralf Ehricht
–

Single-Molecule Studies at High Endogenous Concentration

Francesco Reina | Christian Eggeling
–

Phenotypical Characterization of Immune Cell Activation following Defined Bacterial Toxin Stimulation Using Raman Spectroscopy

Anuradha Ramoji | Astrid Tannert | Oleg Ryabchykov | Ignacio Rubio | Michael Bauer | Thomas W. Bocklitz | Jürgen Popp
–

Untersuchung der Wirkung biomimetischer Mineralisierung in menschlichen Zähnen mittels Raman-Mikroskopie

Christoph Krafft | Jürgen Popp
–

Investigating the Effect of Biomimetic Mineralization in Human Teeth via Raman Microscopy

Tobias Meyer | Hyeonsoo Bae | Sybille Hasse | Jörn Winter | Thomas von Woedtke | Michael Schmitt | Klaus-Dieter Weltmann | Jürgen Popp
–

Long-Term Stability of Form-Anisotropic Plasmonic Nanoparticles

Andrea Csáki | Steffen Trautmann | Robert Müller | Ondrej Stranik | Wolfgang Fritzsche
–

Metabolite Detection Using SERS

Olga Žukovskaja | Izabella J. Jahn | Anna Mühlig | Karina Weber | Dana Cialla-May | Jürgen Popp
–

Label-Free Identification and Molecular Characterization of Pollen

Andreas Kleiber
–

Molecular SERS Sensor for the Detection of Cu(II) Ions

Vera Dugandžić | Thomas Henkel | Karina Weber | Dana Cialla-May | Jürgen Popp
–

Raman Spectroscopy as a Screening Method

Olga Žukovskaja | Thomas W. Bocklitz | Karina Weber | Jürgen Popp
–

Open Source Implementation of Two-Dimensional Correlation Analysis – the corr2D Package in R

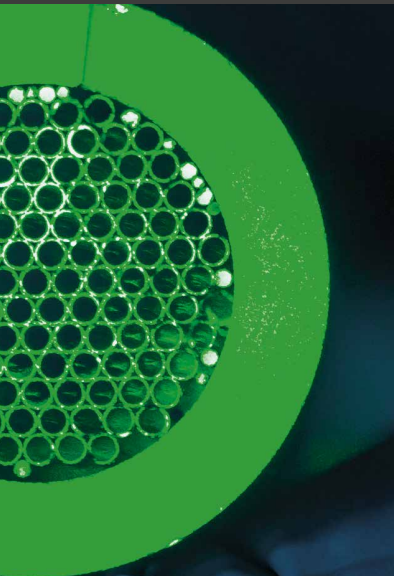
Thomas W. Bocklitz
–

Feature Extraction in Raman Spectral Data Analysis

Shuxia Guo | Petra Rösch | Jürgen Popp | Thomas W. Bocklitz
–

Machine Learning and Deep Learning for the Analysis of Multimodal Imaging Data

Pranita Pradhan | Elsie Quansah | Hyeonsoo Bae | Tobias Meyer | Michael Schmitt | Jürgen Popp | Thomas W. Bocklitz
–



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Fiber Optics

Real-Time Characterization of Ultrashort Pulse Dynamics and Application in Gyroscopy and Navigation

Maria Chernysheva | Srikanth Sugavanam | Sergei Turitsyn
–

Uncovering Photosensitivity in Cer-Doped Fibers

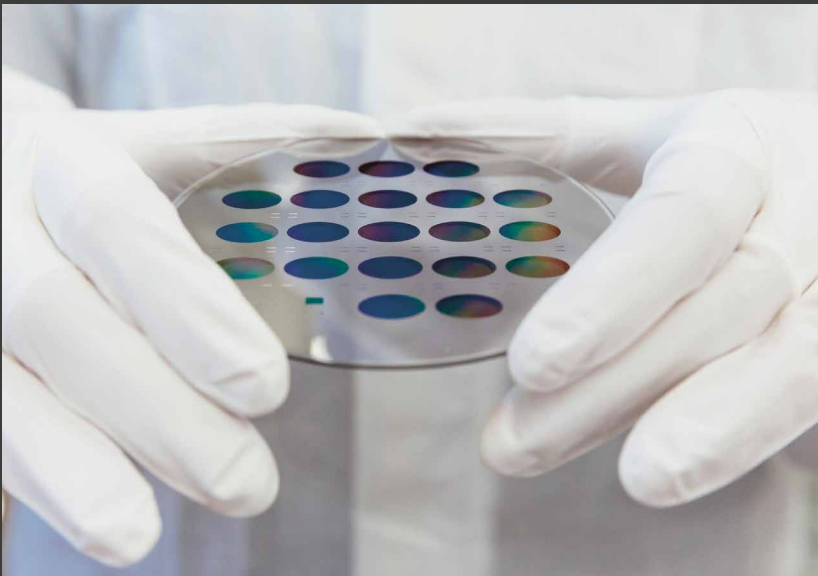
Tino Elsmann | Martin Becker | Olugbenga Olusoji, | Sonja Unger | Katrin Wondraczek | Claudia Aichele | Florian Lindner | Anka Schwuchow | Johannes Nold | Manfred Rothhardt
–

All-normal Dispersion Suspended-Core Fibers for Nonlinear Applications: Design and Fabrication

Alexander Hartung | Adrian Lorenz | Jörg Bierlich | Jens Kobelke | Matthias Jäger
–

Photodarkening in Yb Fibers: Experimental Investigations and Model Considerations

Martin Leich | Sylvia Jetschke | Anka Schwuchow | Sonja Unger | Ulrich Röpke | Matthias Jäger
–



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Photonic Detection

An Optically Isotropic Metamaterial via the Combination of Top-down and Bottom-up Approaches

Kay Dietrich | Matthias Zilk | Martin Steglich | Thomas Siefke | Uwe Hübner | Thomas Pertsch | Carsten Rockstuhl | Andreas Tünnermann | Ernst-Bernhard Kley
–

Highly Transparent and Resistant MgF2 Films for the Combination of Super-Resolution Microscopy and Multi-Electrode Array Technology

Gabriele Schmidl, Jonathan Plentz, Annett Gawlik | Jan Dellith | Uwe Hübner | Volker Tympel | Frank Schmidl | Lars Schmidl | Holger Haselmann | Christian Geis
–

Nanowire Single-Photon Detectors Made of Atomic Layer-Deposited Niobium Nitride

Emanuel Knehr | Artem Kuzmin | Denis Vodolazov | Mario Ziegler | Steffen Doerner | Konstantin Ilin | Michael Siegel | Ronny Stolz | Heidemarie Schmidt
–

Thermoelectric Properties of Atomic Force Microscopy Probes Electrochemically Layered with Porous Platinum

Sarmiza Elena Stanca | Frank Hänschke | Andrea Dellith | Gabriel Zieger | Jan Dellith | Heidemarie Schmidt
–

Key Figures of 2019

18 EU-co-financed projects
3 thereof coordinated by Leibniz IPHT

13 Patent applications,
8 thereof with cause for
the right to priority

10 Trademark registrations
5 with patent grants

172 Talks | Posters
63 thereof
invited talks |
Keynotes |
Plenary Talks

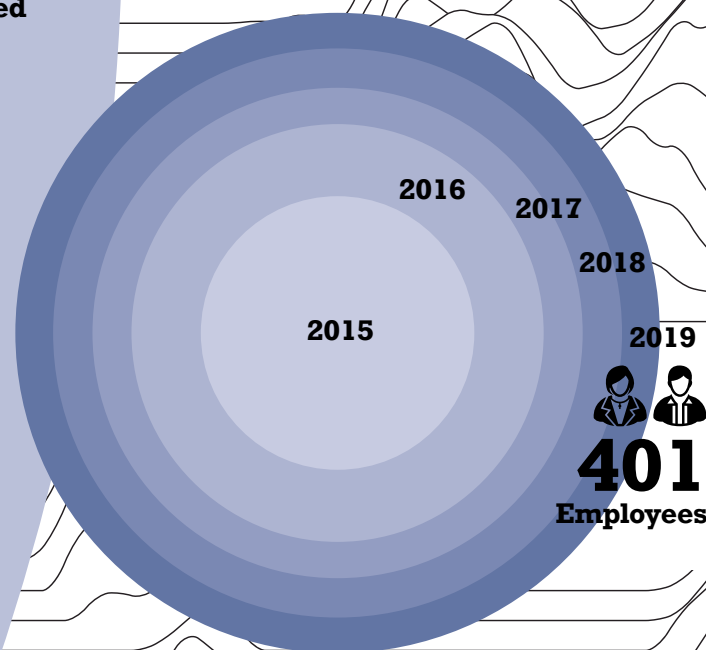
18 Doctorates,
5 thereof earned by women

10 EU-co-financed projects (ERA-Net, Eurostars, JPI etc.)
3 thereof coordinated by Leibniz IPHT

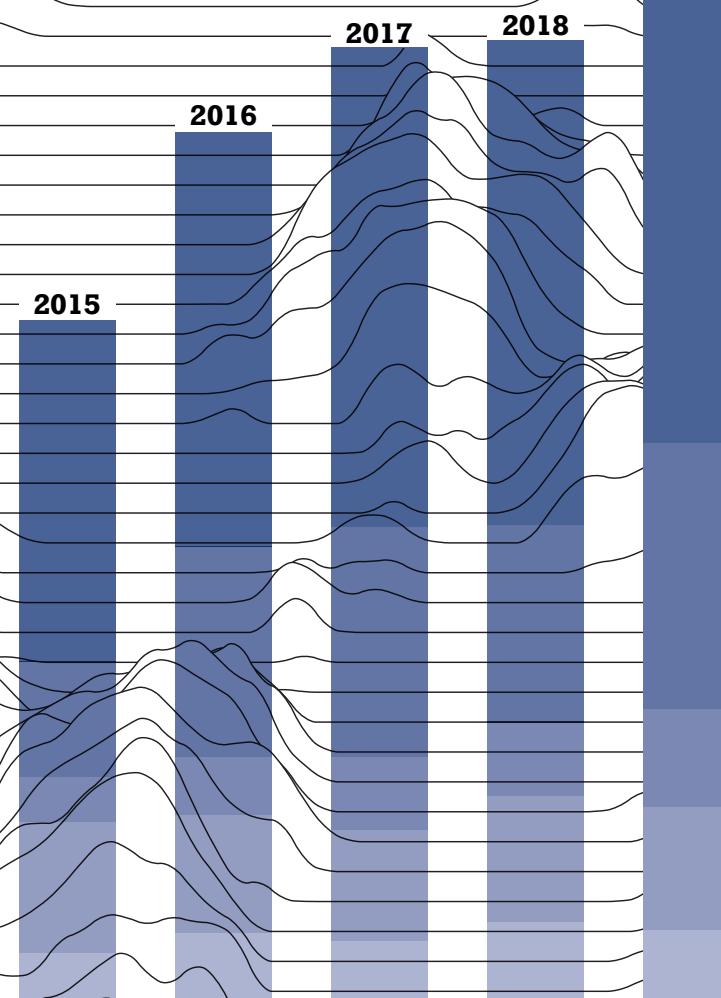
Employees from **36** countries

30 %
Proportion of
international scientists
and doctoral students

212
Published
articles in
peer-reviewed
journals



401
Employees



31,185,555 €
Total budget
= 46,98 % Third-party funding

16,535,581 €
Institutional funding

6,967,100 €
National projects

2,507,932 €
DFG funding

3,302,301 €
Industrial projects

1,872,640 €
EU third-party funding, thereof from
ERA-Net / ERA-NetPlus, JPI etc.

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Frank Sondermann // Administrative Director	Prof. Dr. Benjamin Dietzek // Deputy Scientific Director	
Consultants to the Executive Committee	Staff Units	Employee Representation
Susanne Hellwage // Personal Consultant to the Scientific Director	Dr. Ivonne Bieber // Project Management and Patents	Claudia Aichele // Employee Representative
Dr. Karina Weber // Consultant to the Executive Committee	Gabriele Hamm // Internationalization	Sarah Meinhardt // Councillor for Equality
	Daniel Siegesmund // Public Relations and Research Marketing	Mario Ziegler // Head of PhD Council (until end of 2019)
		Tino Fremberg // Head of PhD Council (as of 2020)

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Research Departments

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Nanobiophotonics		Fiber Photonics
apl. Prof. Dr. Wolfgang Fritzsche	Nanooptics	Prof. Dr. Markus Schmidt
Nanoscopy	PD Dr. habil. Jer-Shing Huang	Quantum Detection
Prof. Dr. Volker Deckert	Optical Molecular Diagnostics and System Technology	Prof. Dr. Heidemarie Schmidt
Microscopy	Prof. Dr. Ralf Ehricht	Functional Interfaces
Prof. Dr. Rainer Heintzmann	Photonic Data Science	Prof. Dr. Benjamin Dietzek
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Prof. Dr. Christian Eggeling		Dr. Ronny Stolz

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Dr. Maria Chernysheva

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Frank Sondermann // Leibniz Institute of Photonic Technology e.V., Jena
Prof. Dr. Herbert Stafast // Jena

Budget of the Institute 2019

	in T Euro
Institutional Funding (Free State of Thuringia, Federal)	16,535.6
Third-Party Funding	14,650.0
total	31,185.6

Institutional Funding: Use

Staff	8,778.8
Materials	3,808.0
Investments	3,948.8
total	16,535.6

Third-Party Funding

Federal Ministries of which for projects funded by Leibniz Accociation 680.1 T€	3,879.7
DFG Additionally IPHT-scientists at the Universtiy Jena used DFG-funds of 855.8 T€	2,507.9
Free State of Thuringia of which for restructuring in the frame of EFRE 1,757.4 T€	2,889.0
EU of which for EU-Initiatives such as ERA-Net / ERA-NetPlus, Joint Programming Initiatives and more: 589.7 T€	1,872.6
Assignments from Public Institutions	175.2
Other Contributions	198.5
Subcontracting in Joint Projects	225.1
R&D Contracts incl. Scientific-Technical Activities	2,902.0
total	14,650.0

Institute Personnel 2019

	Full-time Equivalents			Total	Persons
	Institutional Funding	Third-Party Funding	Professors		
Scientists	46.13	51.78	8.00	105.91	116
External Funded Scientists*	-	-	-	-	21
Visiting Scientists**	-	-	-	-	24
Doctoral Students	10.10	26.63	-	36.73	65
External Funded Doctoral Students*	-	-	-	-	48
Technical Staff	40.92	34.96	-	75.88	82
External Funded Employees*	-	-	-	-	1
Administration	13.07	10.23	-	23.30	25
Scientific Coordination	4.75	2.88	-	7.63	8
PR and Research Marketing	3.38	3.00	-	6.38	7
Trainees	2.00	-	-	2.00	2
Executive Committee	1.00	-	0.50	1.50	2
Total Personnel	121.35	129.48	8.50	259.33	401

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

**Scientists, who worked in the legal year 2019 longer than one month and who are financed by another institution. Key date regulation 31.12.2019 does not apply.

We Thank our Sponsors



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Authorized Representatives: Jürgen Popp, Scientific Director (Chairman), Frank Sondermann, Administrative Director

Artwork: Katrin Uhlig

Cover: Charlotte Siegesmund

Photographs: Sven Döring

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