Leibniz ipht
LEIBNIZ INSTITUTE of PHOTONIC TECHNOLOGY

# reflexion

## Annual Report 2020

**Solutions with Light**

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# Research in Crisis Mode

Leibniz Association

jenaphotonics®

PHOTONICS FOR LIFE
*from Ideas to Instruments*

# Dear Readers,

Prof. Dr. Jürgen Popp © Sven Döring

Frank Sondermann © Sven Döring

Annual reports are contemporary documents: they tell – in the case of the Leibniz Institute of Photonic Technology already for the 29th time – of successes as well as of the respective framework conditions under which these have been achieved. The present report is no exception in this respect. What is new is that one of the central circumstances that has significantly shaped the work at the institute over the past year does not specifically affect the Leibniz IPHT alone or science in general. Rather, we are confronted with global challenges that equally affect all parts of society, the economy and science: we are talking about the Corona pandemic.

In the face of the crisis, society is confronted with unanswered questions and unknown risks. Science is challenged to confront the fears and provide answers. In times of lockdown and working from home, research must be conducted on concrete solutions to get a grip on the pandemic. This expectation has helped raise the profile of science in the public eye.

Leibniz IPHT is one of the leading international research institutions in the field of optical health technologies. We want to contribute with light-based solutions to make life safer and healthier. For several years, we have been working on innovative methods and procedures for infection diagnostics. Last year, the detection of the novel corona virus came into focus. We are pursuing different approaches, which we would like to present to you in the current issue of "reflexion" with the main topic "Research in Crisis Mode".

Photonic technologies can make an important contribution to the fight against the pandemic, and not only in diagnostics. Infrared sensors, manufactured in the clean room of Leibniz IPHT, are used in ventilators to monitor the oxygen content in the breathing air of patients in intensive care units.

We are proud of our colleagues, of the fact that, spurred on by the current circumstances, they are working with undiminished passion and enormous commitment to fulfill our mission and vision. This is evidenced not least by the key figures of the past year, above all the numerous publications in top-class journals. Our scientists have clearly not been discouraged by the crisis. We hope you feel the same way – stay healthy and confident.

We hope you enjoy reading this issue.

**Jürgen Popp**
Scientific Director

**Frank Sondermann**
Administrative Director

# Contents

# Top Marks from the Leibniz Association

**Research for the future: Leibniz IPHT was impressing in its 2019 evaluation**

In the summer, we received the good news from Berlin that the evaluation had been successfully completed. In December 2019, a panel of high-ranking international experts from science and politics had formed a picture of the institute – of science and research, services and other areas of responsibility, from equality and internationalization to networking and transfer to planning for the future. Every seven years, the Leibniz Association takes a close look at its institutes to review how they have developed in terms of content and structure and in which direction future plans are aimed.

Leibniz IPHT was impressive. With its excellent achievements in research into light-based processes for medicine, the environment and security, and its strong regional and international networking, the institute is of great importance for the science location of Jena, the Leibniz Association judged. As a result, Leibniz IPHT will continue to receive funding from the federal government and the Free State of Thuringia over the next seven years due to its supra-regional relevance and a national interest in science policy.

According to the evaluation panel, Leibniz IPHT has played a significant role in Jena's development into a location of international visibility in the forward-looking field of biophotonics and research into optical health technologies. The scientists achieved very good to excellent research results. In an excellent infrastructure: With the ultra-modern fiber drawing facility, a clean room and optical laboratories, this is unique in Germany. In addition, the institute is working successfully to transfer research results into applications – especially into clinical practice.

> “We are very pleased about the positive evaluation, which motivates us to further develop our technologies for better diagnostics and therapy. We sincerely thank all members of the evaluation panel for the fair process and the constructive assessment of our work. We find their recommendations extremely helpful for our future plans.”
>
> Jürgen Popp, Scientific Director Leibniz IPHT

## Jena made internationally visible as a biophotonics location

Leibniz IPHT has excellent regional and international networks. On the one hand, it has succeeded in attracting internationally renowned researchers to the institute and, on the other, in further developing the fruitful collaborations in Jena. In addition to participation in several DFG-funded collaborative research centers at the University of Jena and the only cluster of excellence in Thuringia, these are particularly evident in the planned Leibniz Center for Photonics in Infection Research (p. 50).

In order to further advance the research of optical health technologies and to open up new disease patterns, Leibniz IPHT intends to strengthen its activities in the field of infrared biospectroscopy in the future. The institute is also pursuing plans for an extension building on the Beutenberg campus.

> “In recent years, Leibniz IPHT has excellently developed its regional networking. Particularly noteworthy is the cooperation with the Friedrich Schiller University Jena and the University Hospital Jena. (...) Leibniz IPHT has also strategically expanded its international network since the last evaluation.
>
> The research field of biophotonics, which is significantly advanced by Leibniz IPHT, has a great potential for development. The work of the institute is not only scientifically but also socially highly relevant, as is currently demonstrated by its participation in the development of an antibody test for Sars-CoV-2. Leibniz IPHT meets the requirements of an institution of supraregional importance and national scientific policy interest.
>
> With regard to the transfer of research and development results into practice, Leibniz IPHT pursues a coherent and very successful strategy. (...) It is welcomed that the institute attaches particular importance to translation into clinical practice, which often takes place in cooperation with partner institutions, especially the University Hospital of Jena.”

From the statement of the Senate of the Leibniz Association. The complete statement of July 15, 2020 can be read on the website of the Leibniz Association. **www.leibniz-gemeinschaft.de**

Walter Hauswald heads the technology group "Sensor Systems and Systems Technology". At the evaluation in December 2019, he presented the compact spectrometer Raman2Go developed at the institute. © Leibniz IPHT

# In Focus: Research in Crisis Mode

**All over the world, researchers are working under high pressure to find solutions to the Corona pandemic – also at Leibniz IPHT in Jena**

© Sven Döring

Researchers at the institute are developing technologies to get to the bottom of the virus. They are working on diagnostic testing for SARS-CoV-2, studying human immune responses, and helping to forecast how the pandemic will develop in the country. The technology experts are making sensors for ventilators, developing special chips to optically characterize SARS-CoV-2, and custom-made optical fibers in which the virus can be confined and measured.

In doing so, they are building on a foundation of knowledge, technologies and strong alliances that Leibniz IPHT has developed over decades. In addition to its technological infrastructure with clean room and fiber center, it is above all the networks in research, industry and application that are unleashing their power in the joint efforts against the pandemic.

This thematic focus sheds light on how researchers at Leibniz IPHT are searching for solutions to get a grip on the corona virus and its effects – and to use light as an innovative tool in the fight against infectious diseases.

# Crisis Helper

**Sensors from Leibniz IPHT fly to planets and celestial bodies. In the Corona crisis, they are needed on Earth: as life-saving technology in ventilators**

In the institute's clean room, experts manufacture the IR sensors that form the heart of ventilators. © Sven Döring

It was March 2020 when the effects of the global pandemic arrived in the clean room of Leibniz IPHT. "We have to ramp up production, at least by double," was the motto among the IR sensor manufacturing team. The more the novel coronavirus spread around the world, the more urgently the sensors were needed, which the employees of the Competence Center for Micro- and Nanotechnologies manufacture.

The IR sensors are a basic component in ventilators sold by the U.S. corporation General Electric to intensive care units and hospitals around the world. Demand was growing as infection rates skyrocketed. At this point, the USA alone had already requested a hundred thousand additional devices. To this, they need the support from Jena and Hermsdorf, where the technology company Micro-Hybrid Electronic GmbH builds the sensors from Leibniz IPHT into a module.



## Measure how much air the patient gets

"Our scientists have further developed and optimized the infrared sensors over many years, so that today they are among the best in the world," explains Jürgen Popp, scientific director of Leibniz IPHT. The

Sensor production (above) and press event in April 2020 at the institute © Sven Döring

Jena sensors are regularly on board of space missions, most recently to Mars and Mercury. Their readings from there provide information about the weather on Mars and contribute to gaining insights into the formation of the planet.

The technical principle is the same, whether in space or in intensive care. The sensors measure the incoming infrared radiation. Converted, this reveals both what the temperature of a body is – a planet, for example – and how a patient is doing.

"The ventilators have an infrared light source," explains Kay Dietrich, who heads the research group that makes the IR sensors. "Their light shines into a chamber where the patient's breathing gas circulates. At the other end of the chamber, the sensor measures the amount of incoming infrared light. The higher the $CO_2$ concentration in the breathing air, the more infrared light is absorbed. From the change in the amount of light that makes it to the sensor, the amount of $CO_2$ in the breathing air is calculated." This lets doctors know how high the respiratory rate is and how well the oxygen supply through the lungs into the blood is working.

## Double shifts at Easter

In the middle of the first lockdown, the two dozen or so employees in sensor production are working at full speed: double shifts into the evening hours and on weekends. Even at Easter, operations continue. They are battling against corona-related supply bottlenecks for substrates and mastering the challenge of balancing family and career in view of closed schools and kindergartens. They are converting their system and producing more than twice as many sensors as before. "A great achievement," Jürgen Popp emphasizes. "I would like to thank our employees very much for this. We can be proud that we can continue to support our partners so well even in this state of emergency."

# Research Team Co-develops Coronavirus Antibody Test

A good two months after the first infection with the coronavirus was reported in Germany, Leibniz IPHT and the Weimar diagnostics company Senova were already able to present an antibody test for the novel virus at the beginning of April: ready-to-use and available on the market. The test uses a blood sample to indicate within ten minutes whether a person is in the acute phase of infection with the SARS-CoV-2 virus (IgM antibodies) or has already recovered from the infection (IgG antibodies).

The strip test is a lateral flow assay. A drop of blood from the fingertip is sufficient and after about ten minutes, lines on the test strip indicate whether one of two types of antibodies has been found. The IgM antibodies are found in the blood just a few days after infection, while the IgG antibodies are formed later in the course of infection. They usually remain detectable for many months and indicate an existing immunity. According to the Robert Koch Institute, there is currently no clear answer to the question of whether a person is permanently immune after contracting Covid-19 (as of January 2021).

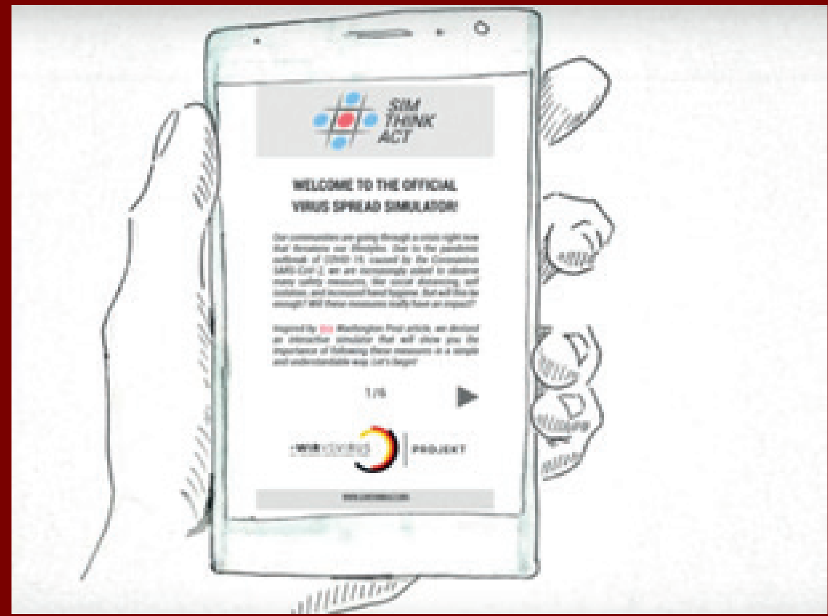

The Federal Ministry of Education and Research announced the development of the test on the short message service Twitter.

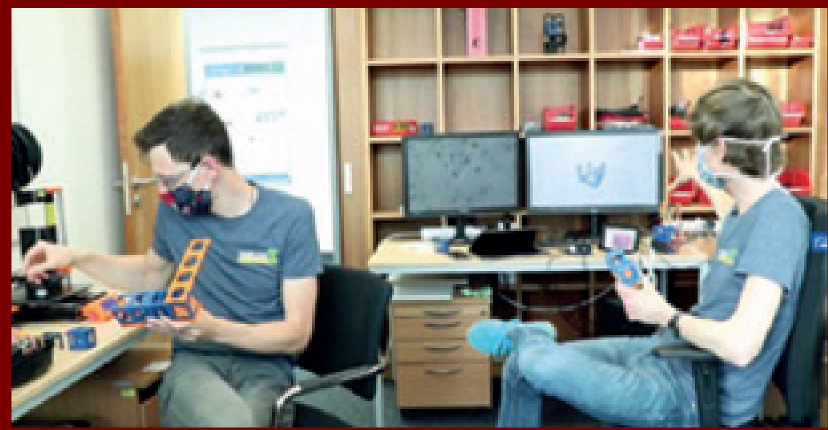
Already after the first reports of the coronavirus outbreak in China, Senova and the team from Leibniz IPHT had started to develop the test with a Chinese company and the medical device distributor Servoprax.

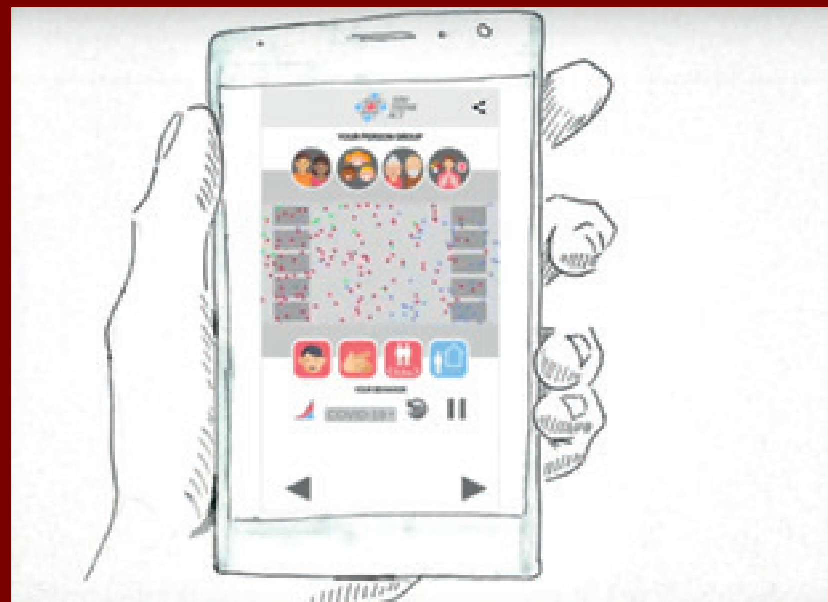
"Getting to an available product so quickly is only possible when partners from industry, science and medicine work hand in hand, as we do at the Infectognostics Research Campus Jena," emphasizes Ralf Ehricht from Leibniz IPHT. His team from the research department "Optical-Molecular Diagnostics and Systems Technology" has been working on the development, evaluation and quality control of the rapid test.



# Combatting the Virus with Creativity





How does my behavior contribute to spreading the virus? That's what the #SimThinkAct web app simulates. © #SimThinkAct

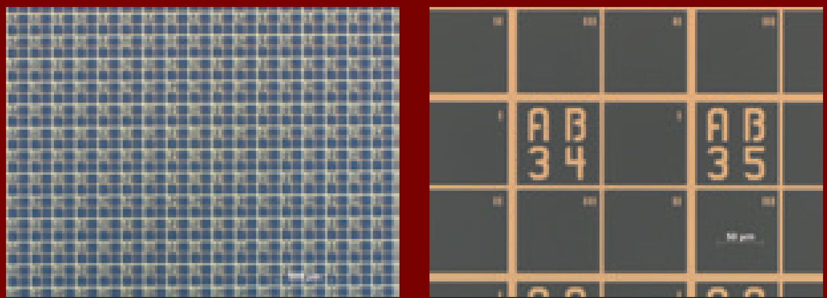
"We vs. Virus": This was the motto of the German government's call for a hackathon in March 2020 to initiate digital projects to tackle the Corona crisis. In this digital participation process, more than 28,000 people developed over 1,500 creative solutions to deal with the challenges of the pandemic. Francesco Reina, Alex Seltmann and John Wigg from Christian Eggeling's research department were among them. Within 48 hours, they and their team set up the interactive web app #SimThinkAct. It simulates the extent to which one's own behavior contributes to spreading the virus.

In the local "Jena vs. Virus" issue, René Lachmann and Benedict Diederich from Rainer Heintzmann's research department also came up with a resourceful idea. They developed a program with which students in "Stay Home" times can also control their experiments under the microscope from their home computers. To do this, they used their UC2 optical toolbox (A Microscope for Everyone, p. 58).

# On the Trail of the Virus

**SARS-CoV-2 or influenza? Researchers are developing an optical method to quickly identify viruses. To do this, they combine topographic and spectroscopic methods**

The structures on the ultra-thin special substrates on which the viruses are examined, are produced by the team in the institute's clean room. © Sven Döring




Chip for the investigation of nanoparticles © Leibniz IPHT

AA 33, AA 34, AA 35 horizontally; AB 33, AC33, AD 33 vertically... The 50 micrometer tiny golden numbers on the fine microscope cover sheet are not visible to the naked eye. The coordinate system on the chip is reminiscent of the game "sink ships" – except that the researchers are using it to detect and localize virus particles rather than boats. In order to characterize SARS-CoV-2 quickly and in a structure-specific manner, an interdepartmental team at Leibniz IPHT is combining topographic and spectroscopic methods. In this way, the researchers want to develop a method to quickly and reliably identify individual virus particles in clinical sample material using Raman spectroscopy. Whether a person is infected with influenza or with SARS-CoV-2 could thus be distinguished within minutes.

The basis for the research is the chip with the box pattern. It goes back to an idea from the group of nano-optics expert Jer-Shing Huang. Huang and his team use it to localize nanoparticles and to measure or process them in a targeted manner. The ultra-thin chips are manufactured using mask-based photolithography in the institute's clean room. Using vacuum processes, the employees vaporize the fine structures with gold. After a final "lift-off," only the box pattern and the lettering remain as gold structures on the chip.

Working with the filigree materials requires a delicate touch. "For optical and metrological reasons, we use very thin glass substrates; these are microscope cover sheets that are just 170μm thick," explains Uwe Hübner, head of the Competence Center for Micro and Nanotechnologies. "They tend to break during the processing steps – so for one chip you have exactly one attempt."

The chips are then first used under the scanning probe microscope. The team of nanoscopy expert Volker Deckert uses them to examine samples of SARS-CoV-2 virions; these are individual virus particles outside a cell. The research partners from the working group of virologist Stefanie Deinhardt-Emmer from the Institute of Medical Microbiology at Jena University Hospital have previously labeled the viral RNA with the dye SYBR gold, which does not change the size of the virions.

## Three methods, one statement

Deckert and his team now first examine the samples topographically, i. e. make a quick preselection of potential virus candidates for further examination according to morphological criteria based on size. Without the specially manufactured substrates, says Volker Deckert, the virus particles, which are between 50 and 100 nanometers in size, would not even be detected in the subsequent experiments. Using the grid, however, the particles in question can be precisely assigned by their location – and the sample goes to the next round: to Christian Eggeling in his "Biophysical Imaging" research department.

Eggeling and his team examine the sample at the same location with the fluorescence microscope. Using the fluorescence of the SYBR gold dye, they find the labeled RNA of the virions. The substrate is returned to Volker Deckert for inspection: he uses atomic force microscopy to check again whether there are any losses or changes in the sample. In the vast majority of cases, however, these are negligible, says Deckert. Taken together, the fluorescence images and the topographies now provide a reliable identification of the virus particles. To do this, the images are correlated with each other, i. e. superimposed.

To find out whether the virus is active or whether RNA has been lost, another method now comes into play: Using super-resolution fluorescence microscopy, Rainer Heintzmann and his team from the "Microscopy" research department focus on the spike protein of the virus. This protein is used by SARS-CoV-2 to dock onto cells. Via the spike-like structures, the virus binds to specific receptors on the surface of human cells in order to infect them.

Because the RNA dye is not suitable for super-resolution, Heintzmann and his team label the sample with antibodies. These can recognize the virus on the basis of the spike protein. Using super-resolution fluorescence microscopy, the researchers achieve a resolution of about 50 nanometers. This allows them to identify the spike protein of the samples. However, the labeled samples can no longer be used for further investigations afterwards.

Three methods, one statement: via the precise local comparison, the researchers succeed in reliably narrowing down the size distribution of SARS-CoV-2 virions in the sample. "It is an essential step to unambiguously identify SARS-CoV-2 particles and to quickly pre-select potential candidates for further investigations without labeling," explains Volker Deckert: "based solely on morphological properties and under clinically relevant environmental conditions."

This pre-selection finally allows Deckert and his team to investigate the structure of the identified viral particles at the nanoscale using tip-enhanced Raman spectroscopy (TERS). "With TERS, we can look specifically at individual virus particles and measure them precisely with nanometer resolution and chemical specificity," Deckert said. "Using the TERS spectra obtained, we can capture the sample surface of the particles very quickly; in less than a second per spectrum."

## The goal: label-free rapid diagnostics

Fast, accurate and label-free, studying SARS-CoV-2 by tip-enhanced Raman spectroscopy could, in perspective, allow us to learn more about the mechanisms by which the virus interacts with the cell surface. "Studying this is only possible if dyes are not used," Deckert says.

For rapid diagnostics, the combined method could open up entirely new possibilities. Topographic measurement could be used to determine very quickly whether or not virus particles are present in a sample. The researchers are now working on optimizing the method so that they can detect whether a sample contains SARS-CoV-2 or influenza viruses within a very short time. According to Voker Deckert, this would even be possible before antibodies are present.

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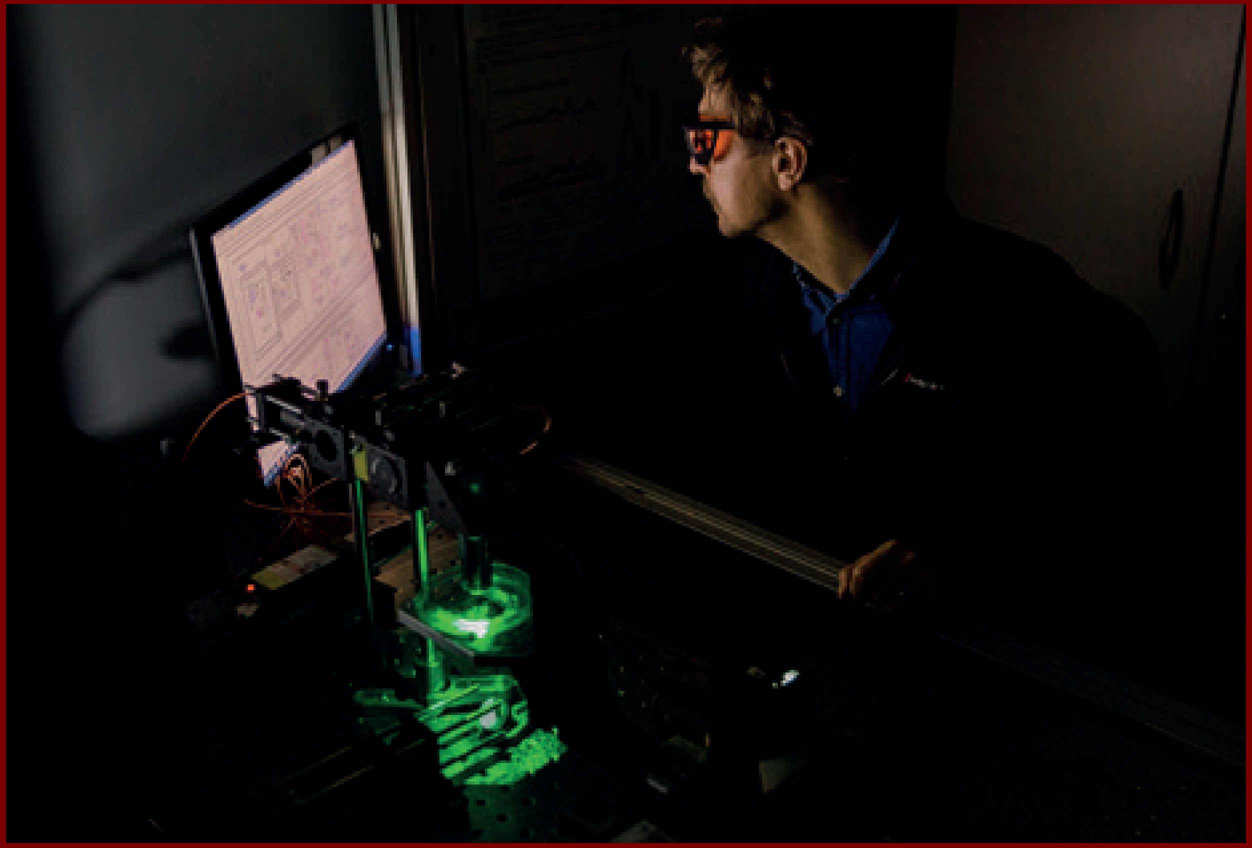
**Publications:** V. Deckert et al., Laser spectroscopic technique for direct identification of a single virus I: FASTER CARS, Proc. Natl. Acad. Sci. (2020), DOI: /10.1073/pnas.2013169117. // T. Peng et al., Enhancing sensitivity of lateral flow assay with application to SARS-CoV-2, Appl Phys Lett. 117, 120601 (2020), DOI:10.1063/5.0021842.



A method developed in the research group of Iwan Schie, allows the Raman spectroscopic analysis of about 2,000 cells in one hour. © Sven Döring



Research partner: Intensive care physician Michael Bauer and his team at Jena University Hospital © Sven Döring

# Detect Severe Cases Early

**A research team from Leibniz IPHT and Jena University Hospital is focusing on the immune defense. It could reveal whether people are infected with the coronavirus and help predict how they react to the disease**

The Corona pandemic is placing a particular strain on the healthcare system. People with severe courses are dependent on intensive medical treatment – but the number of beds and ventilators is limited. A team from Leibniz IPHT and Jena University Hospital (UKJ) is researching a prognostic model to predict severe Covid-19 disease progression early. In the future, it could help medical staff to plan occupancy in advance and transfer particularly at-risk patients to clinics with free capacity in good time.

To do this, the researchers are targeting the body's immune defenses. "We are profiling white blood cells using Raman spectroscopy. This allows us to see how the patient is doing," explains Jürgen Popp. His "Spectroscopy / Imaging" research department is developing the approach together with the "Clinical Spectroscopic Diagnostics" team of Ute Neugebauer, the "Photonic Data Science" research department of Thomas Bocklitz, and with Sina Coldewey and Michael Bauer from Jena University Hospital. As director of the Department of Anesthesiology and Intensive Care Medicine and spokesperson of the Center for Sepsis Control and Care (CSCC), Bauer is largely responsible for the sepsis and infection focus of the hospital, in which Leibniz IPHT is also involved, as is Coldewey, an intensive care specialist who heads a junior research group at the ZIK Septomics. Also on the team is Michael Kiehntopf, who heads the Institute for Clinical Chemistry and Laboratory Diagnostics at the UKJ.

For the study on disease progression in Covid-19 patients, the researchers are linking up with a light-based method for rapid sepsis diagnostics that they developed together with international partners (Infection diagnostics as a superheroine adventure, p. 52). In the process, they irradiate the leucocytes in a blood sample with laser light. Using the Raman spectra obtained in this way, they obtain a molecular fingerprint of the cells and can break down their chemical composition. An artificial intelligence-based evaluation then provides information within a very short time and with a high degree of accuracy as to whether sepsis is present and what triggers it: an infection with a virus, a bacterium or a fungus.

"Our goal is to extract the maximum amount of information from a blood sample," says photonic data science expert Thomas Bocklitz. "Is there an infection or not? Is it caused by a bacterial or a viral pathogen? If it's a virus: Is it SARS-CoV-2? And if so, is it expected to be severe or mild?" For this purpose, the researchers are examining leucocytes from blood samples of patients who have been treated with Covid-19 disease at Jena University Hospital. "We compare the host response at different time points of the disease using machine learning methods," explains Thomas Bocklitz: from the first day of admission, to the first week in the hospital, to a year later. A method researched at Leibniz IPHT allows the analysis of about 2,000 cells in one hour.

From the evaluation of the immune response, the researchers hope to develop a prognostic model that indicates what course the disease will take in Covid-19 patients during the first three to seven days of infection. The team was already able to show that leucocytes provide valuable information about how a person's immune system reacts to an infection and what course it will take as part of the HemoSpec sepsis research project. "Now we are pursuing the vision of learning more about the course of disease in corona infections on the basis of these findings, and thus helping patients to receive the right treatment for them," Ute Neugebauer looks ahead.

The Carl Zeiss Foundation is supporting the research work with funds from its Corona Measures Fund, which it uses to help scientists find solutions to the corona pandemic.

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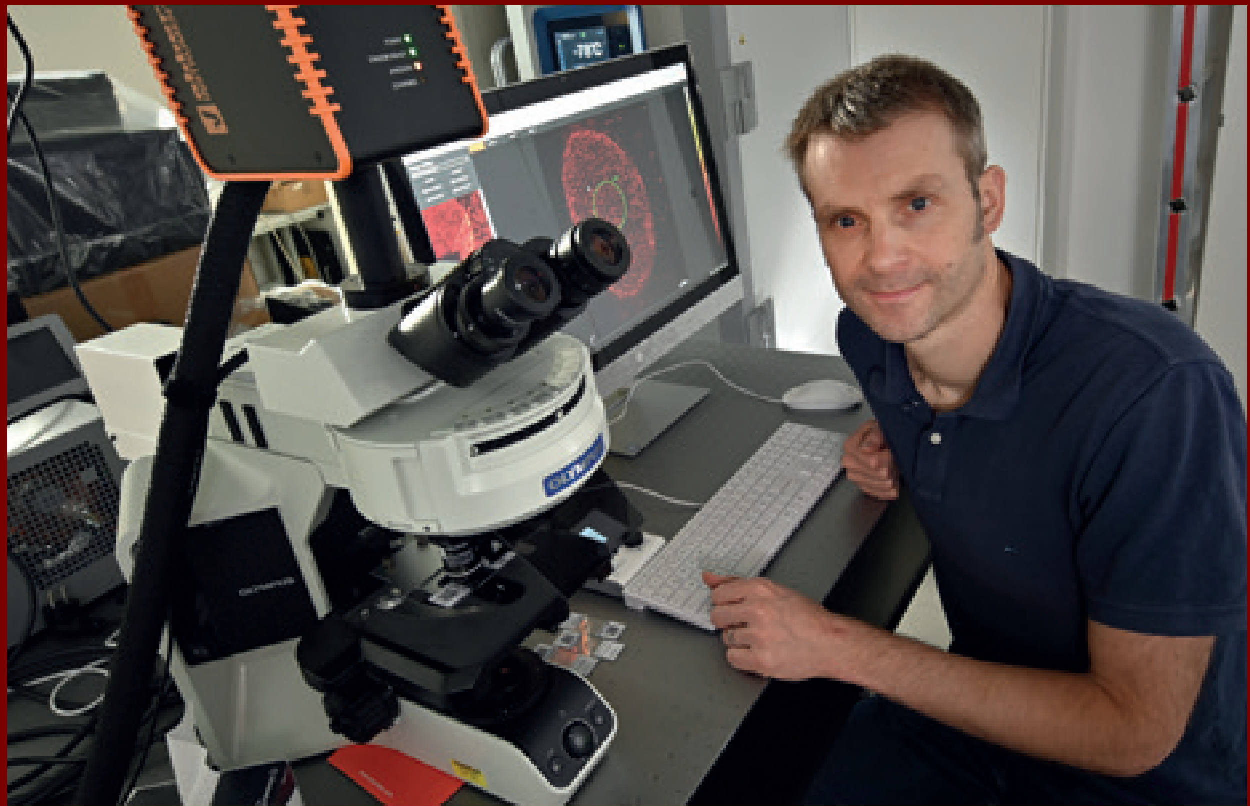
**Study:** ICROS / CoRA: Identification of Cardiovascular and Molecular Prognostic Factors for the Mid- and Long-term Outcome of Sepsis / Corona-detection with Raman spectroscopy

**Publication:** Anuradha Ramoji et al. HemoSpec study: Leukocyte activation profile assessed by Raman spectroscopy helps diagnosing infection and sepsis. Critical Care Explorations, 2021.

# Illuminate How the Virus Replicates in the Body

**A team around Christian Eggeling and Pablo Carravilla aims to visualize how the coronavirus enters the cell and identify its points of attack**



Christian Eggeling investigates HI viruses. Now he is also focusing on SARS-CoV-2. © Jan-Peter Kasper / Jena University

Sars-CoV-2 belongs to the coronavirus family. They are so named because their many spikes resemble a crown. With these spikes, the so-called spike proteins, the virus docks onto the human cell and hijacks it. In this way, the virus introduces its operating program into the cell, thereby causing it to produce new viruses. The pathogen uses its host to replicate.

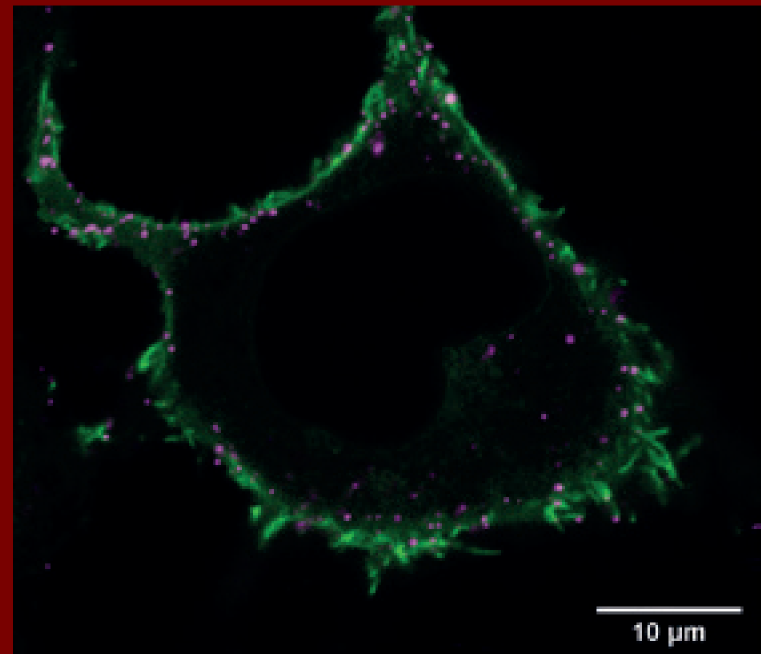
Christian Eggeling and Pablo Carravilla want to find out how to block this process. "To do this, we are investigating how viruses enter cells, in particular which processes take place at the cell membrane, the gateway to the cell," explains Christian Eggeling, who heads the "Biophysical Imaging" research department at Leibniz IPHT. To study the molecular structure and dynamics of the virus, the researchers use super-resolution fluorescence STED microscopy; this bypasses the resolution limit of optical microscopy and makes it possible to visualize dynamic processes in the tiny viruses in detail.

## Block the passage of the virus

Using super-resolution imaging, Eggeling and Carravilla have already studied how HI viruses, causing the AIDS disease, spread between living T helper cells and observed how the virus reacts to neutralizing antibodies. "In the process, we have identified potential points of attack where antiviral drugs can be targeted," reports Christian Eggeling: distinct characteristics of the cell and virus membrane to deteriorate viral docking to the cells, as well as the gateway through which the HI virus – after it has replicated inside it – exits the cell again to infect other cells.

To figure out how SARS-CoV-2 enters human cells, the researchers make so-called pseudoviruses – a trick they also use in their study of the AIDS pathogen. "They have a surface like the real virus and the same ability to penetrate cells, but they are not capable of reproducing and are therefore not pathogenic," explains Pablo Carravilla. This means that experiments can also be carried out in laboratories with low security levels.

The virus-like particles consist of a core with lentiviral genes – the HI virus also belongs to the lentivirus genus – and an envelope with the surface proteins of SARS-CoV-2. The researchers also incorporate a fluorescent protein that makes the virus-like particles visible under the microscope. The research team has also made these pseudoviruses available to other scientists for their own measurements.




SARS-CoV-2 pseudoviruses (magenta) enter a human cell expressing the entry receptor ACE2 (green). © Leibniz IPHT

In order to observe the processes in which pathogens such as viruses, bacteria or fungi infect whole organisms and not only in individual cells, but also to find out how this infection occurs in a more natural environment of cell layers, the IPHT researchers, as well as many other research teams throughout Jena, are collaborating with Alexander Mosig and his research group at the University Hospital. Mosig and his team are developing biochips that replicate complex organ functions in order to use these chips to study specific aspects of these organ functions under laboratory conditions. "For many pathogens such as SARS-CoV-2 but also other viruses such as the influenza virus, the trigger of the annual flu, these would be lung chip models – a lung on a chip," says Christian Eggeling. The researchers are currently laying the groundwork for this, for example by optimizing the advanced imaging within the chips.

Together with researchers from Jena University Hospital led by Ralf Mrowka, from Ilmenau Technical University and Jürgen Popp's "Spectroscopy / Imaging" research department at Leibniz IPHT, Eggeling's team is also developing an optical-photonic detection method to quickly and efficiently diagnose and quantify SARS-CoV-2 from patient samples. Funded by the Free State of Thuringia, the "SARS-rapid" research group at the Thuringia Innovation Center for Medical Technology Solutions (ThIMEDOP) is investigating how the novel coronavirus interacts with the host cell. Hereby, also the pseudoviruses are further optimized.

## By drug cab to the site of inflammation

A novel method for treating infections and inflammatory reactions directly at the site of inflammation with the help of tailored nanoparticles is being developed by an interdisciplinary research team from chemistry, biochemistry, physics, materials science, medicine and pharmacy at the Polytarget Collaborative Research Center at the University of Jena, in which Leibniz IPHT is also involved with several research departments.

Together with chemist and SFB spokesman Ulrich Schubert and intensive care physician Michael Bauer, Christian Eggeling and his team are investigating carriers for antiviral substances using Sars-CoV-2 as an example. "The basis are virus-like, polymeric nanoparticles. These are supposed to protect the substances and guide them to the right tissue cells," says Christian Eggeling. The nanoparticle treatment can be thought of as a cab with GPS, explains Michael Bauer, director of the Department of Anesthesiology and Intensive Care Medicine at the University Hospital and deputy spokesman for the Collaborative Research Center. "This cab transports the drugs to their destination in the body and brings them to their precise effect there."

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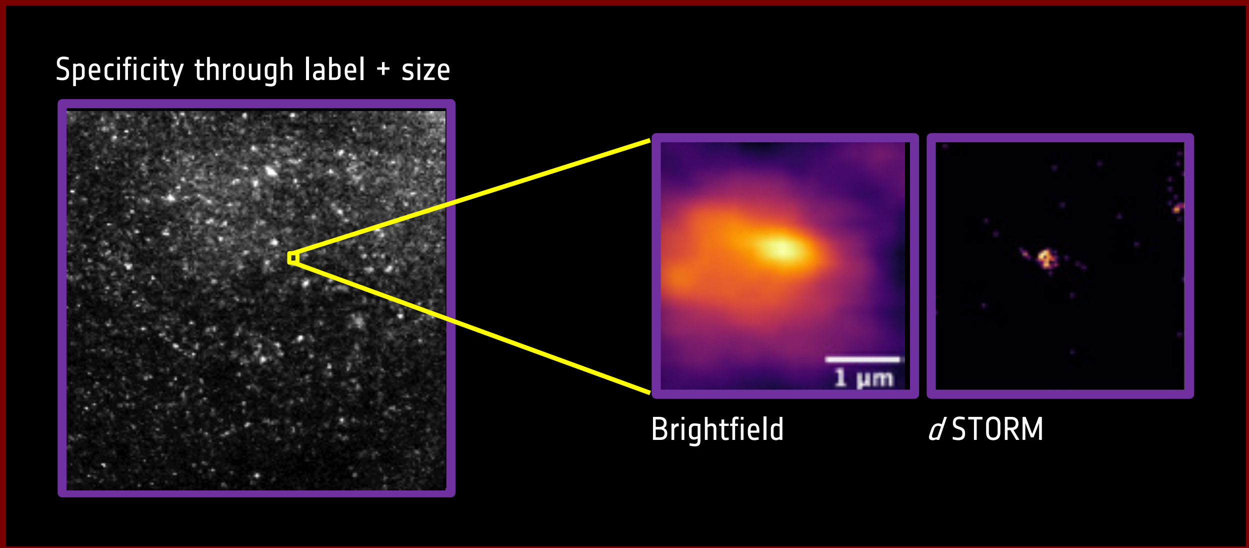
**Publication:** Hoffmann, M., et al. (2020). SARS-CoV-2 Cell Entry Depends on ACE2 and TMPRSS2 and Is Blocked by a Clinically Proven Protease Inhibitor. Cell 181, 271-280 e278. // Carravilla, P., et al. (2019). Molecular recognition of the native HIV-1 MPER revealed by STED microscopy of single virions. Nat Commun 10, 78. // Favard, C., et al. (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, eaaw8651. // Chojnacki, J., et al. (2017). Envelope glycoprotein mobility on HIV-1 particles depends on the virus maturation state. Nat Commun 8, 545.

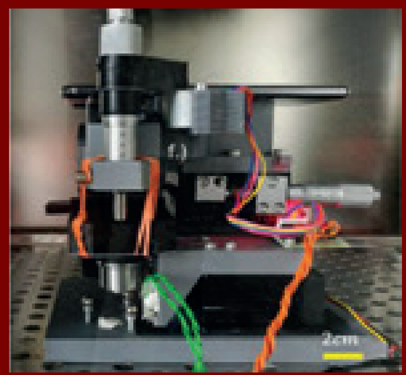
# Making Corona Viruses Visible on a Smartphone




Localization of SARS-CoV-2 with CellSTORM: Images show spike antibody-labeled active SARS-CoV-2 particles with classical wide-field fluorescence and high-resolution single molecule localization microscopy. The resolution is higher than 100 nm. © B. Diederich

It costs less than 1,000 euros and can make active SARS-CoV-2 viruses visible: Together with an international team from Jena, Tromsoe and Oslo, junior researcher Benedict Diederich has constructed a DIY microscope that uses a smartphone and special photonic waveguide chips to deliver high-resolution images beyond the optical resolution limit.

Using a lens from a standard Blu-ray player that can be positioned with nanometer precision, the researchers couple a laser beam into the single-mode waveguide. A fluorescent sample lies on the waveguide; this can be visualized using Total Internal Reflection Fluorescent Microscopy (TIRFm). "The intensity in the TIRF range and the sensitivity of the cell phone camera are large enough to detect individual molecules," explains Benedict Diederich; for example, using direct Stochastic Optical Reconstruction Microscopy (*d*STORM).




So small that it fits in an incubator: the DIY microscope. © Leibniz IPHT

The researchers use antibodies to bind the fluorescent molecules to the skeleton of a cell or to the spike proteins of the SARS-CoV-2 virus. By localizing many of these proteins, they can achieve resolution in the range of less than 80 nm.

"From a variation in the excitation pattern and the associated change in the emission signal, we can use machine learning algorithms to further increase the resolution in live cell images," Diederich says. The cell phone handles both image processing and control of the 3D printed microscope.

The complete device into a handy box and thus fits well in an incubator or in a high-security laboratory. There, it could be used to visualize living cells, for example, or to look at how viruses enter cells. "It's ideal if you don't want to bring the sample to the microscope, but the microscope to the sample," says Diederich, who successfully completed his PhD at Leibniz IPHT and the University of Jena in early 2021 (A microscope for everyone, p. 28).

"Safety labs with super-resolution microscopes, that's an exclusive combination that only exists in very few research facilities in the world," he explains. The building instructions for the DIY nanoscope, meanwhile, are open source, along with the cell phone software. This has already been used to build several devices outside Leibniz IPHT.

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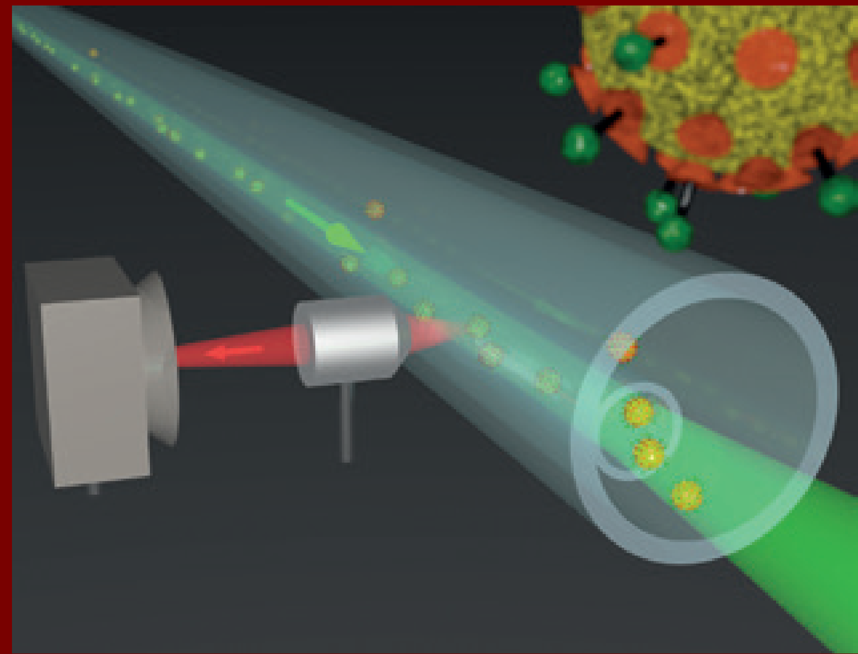
**Publication:** Benedict Diederich et al. (2020): Nanoscopy on the Chea(i)p. BioRxiv, https://doi.org/10.1101/2020.09.04.283085

# Locked Up: The Virus in the Fiber

Viruses are constantly on the move. And they are so small – the virus particles of SARS-CoV-2 measure just under 100 nanometers on average – that they cannot be seen under the microscope. To characterize the tiny nanoparticles and observe their dynamics, Markus Schmidt locks them up – in a fiber. To do this, he and his team, together with experts from the Competence Center for Special Fiber Optics at Leibniz IPHT, have developed a sophisticated microstructured fiber with special optical properties. It has a hollow core and can be used like an analysis vessel. "We fill a solution with the nano-objects to be examined – viruses, for example – into the fiber, couple light into it and look at how the viruses diffuse," Markus Schmidt explains the method.



In the hollow-core fiber, it is possible to observe how the viruses diffuse. © Markus Schmidt

The unique microstructure of the fiber, which is permeated by ultra-thin glass membranes, offers a decisive advantage: it limits the lateral diffusion of the particles. In other words, the viruses in the hollow core cannot float away. This gives researchers the ability to observe the light scattering of individual particles over long periods of time. "We can look at the viruses in up to 100,000 images," says Markus Schmidt. That's significantly more images than researchers achieve with conventional methods, which typically yield 200 to 500 images.

"This enormously improves the informative value about the size distribution of the particles in the sample," Schmidt says. He and his team analyze about 1,000 particles in a sample. They use the size distribution as a benchmark to find out whether the virus is changing – whether it is decomposing under the influence of UV radiation, for example.

"By measuring the elastic scattering, we can make statements about individual nanoparticles without having to bleach or stain beforehand – and more precisely than is possible with previous non-invasive methods," Schmidt sums up the advantage of the method. In collaboration with the research department "Optical-Molecular Diagnostics and Systems Technology," he and his team have already successfully demonstrated this in experiments with lambda phages. These are even smaller than SARS-CoV-2 viruses.

For research on the coronavirus, the fiber photonics experts are now collaborating with the virology department of the University Hospital. They have already conducted initial successful experiments with SARS-CoV-2 viruses. Now they are elaborating the method further. "Our goal is to detect SARS-CoV-2 reliably and marker-free and to gain information about the long observation time of single viruses," Markus Schmidt looks ahead.

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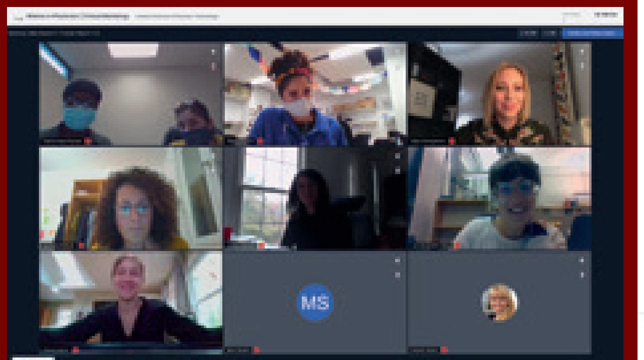
**Publications:** Förster et al.: ACS Sens. 2020, 5, 3, 879, doi.org/10.1021/acssensors.0c00339 // Jiang et al.: Nanoscale 2020, 12, 3146, doi.org/10.1039/C9NR10351A

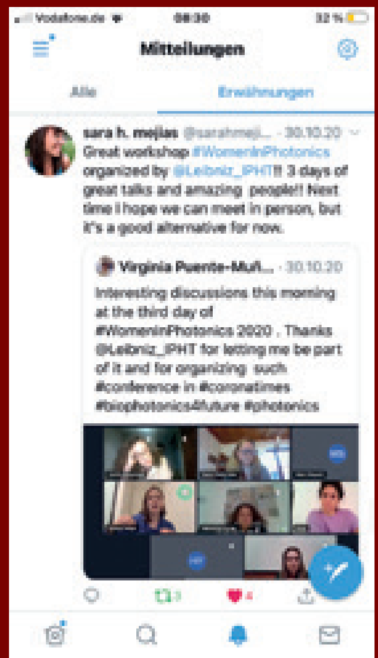
# Scientific Exchange in 3D

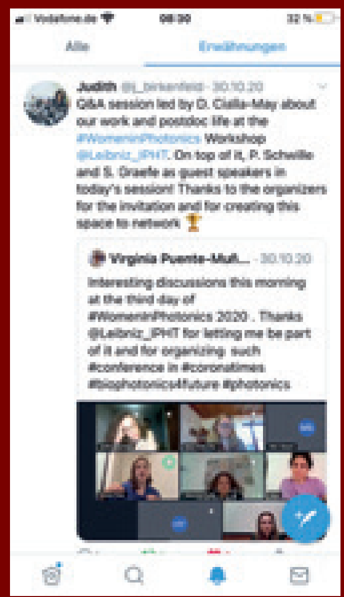
**Leibniz IPHT brought its international conferences to the screen – and the venue along with it: with a walk-in digital edition of the institute**

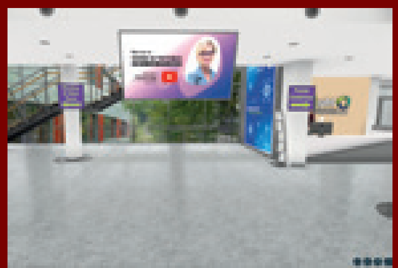
Two major international conferences were scheduled to take place at Leibniz IPHT in 2020: the "EurAsian Conference on Nanophotonics" (EACON) with scientists from this year's partner country Taiwan and the career workshop "Women in Photonics", for which young researchers from France, Spain and Switzerland, from India, Australia and the USA had registered. It was clear from the first lockdown in March at the latest that neither could take place as planned in view of the Corona pandemic. So Leibniz IPHT moved the conferences into virtual space – and the institute itself along with them.

The Weimar agency Rooom digitally reconstructed the foyer and the event rooms. This allowed participants to move around the three-dimensional Leibniz IPHT as if they were in a computer game and to take advantage of offerings just like at a real conference: with live discussions, video lectures and a poster exhibition. "Our goal was to make the event an experience online as well. This was very well received," reports Marc Skupch, who is in charge of event organization at Leibniz IPHT. "We are convinced that we have created a sustainable format for the future."




At the digital EACON, more than 80 participants from Germany and Taiwan exchanged ideas on chemistry, materials and nanotechnologies for "nanophotonics" from October 5 to 7. Jer-Shing Huang, head of the Nanooptics Research Department, initiated the conference series to bring experts from chemistry and photonics in Asia and Europe closer together. The next edition of EACON is planned for 2021.

The career workshop "Women in Photonics" brought together more than 90 international young female scientists with photonics experts from research institutions and companies. The participants came from the ICFO in Barcelona, from Harvard or from the Ècole Polytechnique Fédérale in Lausanne. In addition to the focus on biophotonics, vibrational spectroscopy and photonic data science, the main aim was to give the postdocs the opportunity to exchange ideas with experienced female scientists from research and industry and to jointly develop strategies for a successful career.

Insights into their own careers were provided, for example, by renowned medical technology expert Anita Mahadevan-Jansen from Vanderbilt University and Katarina Svanberg, an expert in laser-based cancer diagnostics and photodynamic therapy at Skåne University Hospital/Sweden and former president of the International Society for Optics and Photonics SPIE. "The workshop offered many points of contact to exchange ideas, start new collaborations and develop one's own career," says Maria Chernysheva. She was a participant at the first "Women in Photonics" workshop in 2018 at Leibniz IPHT; today, she leads the junior research group "Ultrafast Fiber Lasers." "You are part of a great community," Elisabeth Rogan, CEO of the Optical Society OSA had told the participants at the start of the workshop. "I see optimism and hope and a future where you have the opportunity to be successful. We all need a little bit of inspiration in these challenging times, and I think this is the event that will deliver that."

# Support for Parents in a State of Emergency

**During the Corona pandemic, Leibniz IPHT offers employees a working time account**


© Sven Döring

A tight homeschooling schedule, a toddler who also wants to be kept busy – and then, between the school cloud crash, apple-cutting and coloring, there's your own work. In Corona times, parents need to be one thing above all: flexible. To help employees reconcile work and family in the face of closed schools and kindergartens, Leibniz IPHT created an offer in fall 2020 that gives them this flexibility – with a working time account.

Employees can accumulate working hours on the account during quieter times – and then cash in the saved time budget when it becomes difficult to manage the full workload due to kindergarten or school closures. Conversely, they also have the option of recording time debts during stressful periods and working them off again at a later time in consultation with their superiors. A traffic light system helps employees and supervisors to keep an eye on the account balance at all times and to plan pre- and post-work times.

"We are committed to minimizing the burden on parents during these challenging times," says Jürgen Popp. "I'm pleased that we can make this offer to our employees with the support of the works council."

# Team Spirit in Times of Social Distancing

**In order to help employees to stay in touch while working remotely, Leibniz IPHT created new communication formats**

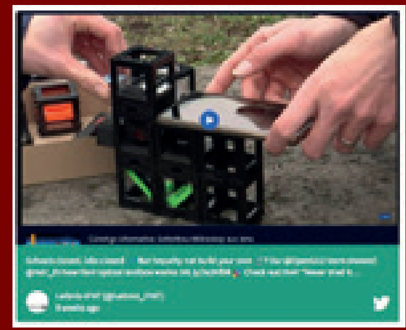

And suddenly half the staff was working from home. Like everywhere else, the first Corona lockdown in March 2020 also marked a break in the everyday working lives of the employees of Leibniz IPHT. For some more, for others less: because the institute did not have to

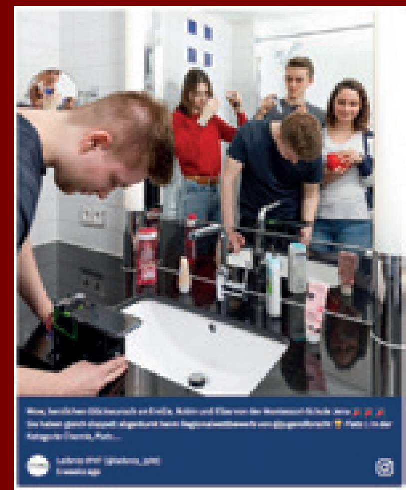

be closed at any time, all those who had to work in laboratories, for example, could continue to do so on site while complying with hygiene requirements.

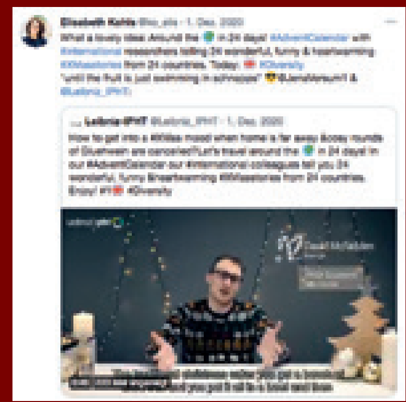
"We established strict safety and hygiene rules early on to ensure the health of our employees and to be able to maintain operations," says institute director Jürgen Popp. "So we've made it through the crisis very well so far, for example with a detailed room layout that guarantees safe working." This was and is important not least because the Leibniz IPHT is in part making a very direct contribution to coping with the pandemic; with its research work on infection diagnostics and in particular the production of sensors for ventilators (see p. 18).

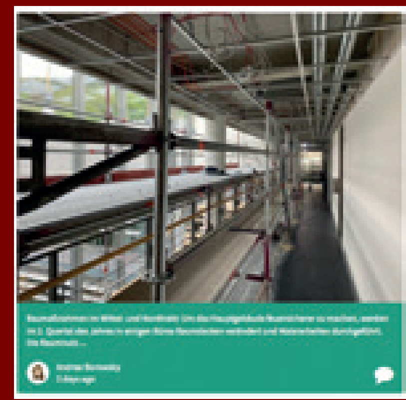

In order to also let employees at home participate in current developments at the institute and to promote the feeling of togetherness within the team despite remote work, individual shifts in the laboratory and closed coffee break corners, the public relations department has launched some new formats.

**Up to date with the virtual bulletin board**







On the digital newswall as well as in the social media channels of Leibniz IPHT, internal news are running. They can be read from anywhere via the intranet; on site, they can also be read as they pass by: on monitors in the foyer and in the corridors.

**Snapshots from the new everyday life**

Working has become different in the corona crisis – also at Leibniz IPHT: "Snapshots: Research at Leibniz IPHT" captures the new everyday life at the institute. In the short film series, employees talk about how the corona pandemic has changed their working lives and the way they work together: in the operating technology, the administration, in the clean room or in the laboratory.

**Advent calendar instead of Christmas party**

How do you get into Christmas spirit when home is far away and mulled wine rounds are cancelled? – With a journey around the world in 24 days.

In the video Advent calendar 2020, international employees of Leibniz IPHT told 24 stories from 24 countries: why the trees bend their tops in Syria, what becomes of dough with lots of schnapps in England, what belongs in a German potato salad or how a Christmas song from Ghana sounds.

Disseminated on the institute's social media channels and website, these moments of confidence and anticipation triggered an extremely positive response.

# A Microscope for Everyone

**A young research team is developing an open source optical toolbox for research and education. The system is 3D printed and delivers images with resolutions as high as commercial microscopes that cost a hundred times as much**

Excite the enjoyment of playing and experimenting is one of the aims René Lachmann (left) and Benedict Diederich are pursuing with their UC2 optical toolbox. © Sven Döring

Modern microscopes that make biological processes visible cost a lot of money, are located in specialized laboratories and require highly qualified personnel. Using them to explore new, creative approaches to urgent scientific issues – for example, in the fight against infectious diseases such as Covid-19 – is reserved primarily for scientists at well-equipped research institutions in rich countries.

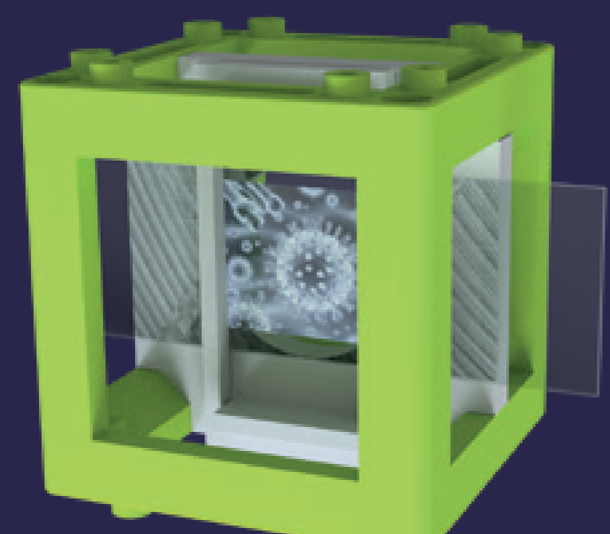
Benedict Diederich, René Lachmann and Barbora Maršíková want to change that. The up-and-coming researchers have developed an optical toolbox that can be used to build microscopes for a few hundred euros that deliver high-resolution images as commercial microscopes – but cost only a hundredth or thousandth as much. With open source blueprints, components from the 3D printer and smartphone camera, the UC2 (You. See. Too.) modular system can be combined as the research question requires – from long-term observation of living organisms in the incubator to use in optics education.

The basic building block of the UC2 system is a 3D-printable cube into which components such as lenses, LEDs or cameras can be built. Several such cubes are plugged onto a magnetic grid base plate. Skillfully arranged, this creates a powerful optical instrument.

## Observe pathogens – and then recycle the contaminated microscope

Helge Ewers is a professor of biochemistry at Freie Universität Berlin and Charité. He uses the UC2 kit to study pathogens. "The UC2 system allows us to produce a high-quality microscope at low cost, with which we can observe living cells in an incubator," he reports. As a result, UC2 opens up areas of application for biomedical research for which conventional microscopes are not suitable.

"You hardly smuggle costly microscopes into a contaminated lab," says Benedict Diederich. The postdoc at Leibniz IPHT developed the optical toolbox together with René Lachmann in Rainer Heintzmann's "Microscopy" research department – and did so precisely because of this dilemma: Their PhD colleague Swen Carlstedt, a biologist at the University Hospital, wanted to observe in the incubator how monocytes develop into macrophages in order to learn more about the growth and nutritional behavior of these scavenger cells of the immune system. The only problem was that there was no suitable microscope. "Then we'll build one ourselves," the PhD students thought, using plastic parts from the 3D printer. Like Diederich's homemade microscope made from a smartphone and Blu-ray player (p. 29), they can simply be incinerated or recycled after use in the safety lab.



A cube is the basic building block of the UC2 system. © UC2

## Building according to the Lego principle

Building according to the Lego principle – this not only awakens the inner play instinct, but also opens up new possibilities for tailoring a tool. "You can quickly put together the right device to map specific cells," says Benedict Diederich. "For example, if a red wavelength is needed as excitation, you simply build in the appropriate laser and swap the filter. If you need an inverted microscope, you stack the cubes accordingly." With the UC2 system, elements can be combined depending on the required resolution, stability, duration or microscopy method, and tested directly in a "rapid prototyping" process.

The researchers archive construction plans and software on the freely accessible online repository GitHub, so that anyone can access them, rebuild, modify and extend the setups. "With the feedback of the users, we improve the system bit by bit and keep adding new creative solutions to it," reports René Lachmann.

The goal behind this is to enable open science. Thanks to the documentation, researchers all over the world can reproduce and further develop experiments. Benedict Diederich calls this vision "Change in Paradigm: Science for a Dime": to herald a paradigm shift in which the scientific process is open and accessible and researchers share their knowledge with each other.

To get young people beyond the scientific community excited about optics, the research team has developed a kit specifically for education at schools and universities. "UC2: The Box" contains a sophisticated kit that allows users to learn about and try out optical concepts and microscopy methods. "The components can be combined to make a projector or a telescope; you can build a spectrometer or a smartphone microscope," explains Barbora Maršíková, who developed the experiments and has already tested them with the UC2 team in workshops in Jena and the U.S., in Great Britain and Norway.

## UC2 experiment box brings science to schools

In Jena, they have already used the kit at several schools, helping students, for example, to build a fluorescence microscope to detect microplastics. "We combined UC2 with our smartphone," reports Emilia Walther from the Montessori School in Jena. "This allowed us to build our own microscope inexpensively without any major prior optical knowledge and work out a simple method to detect plastic particles in cosmetics." With success: at the regional competition of "Jugend forscht," Emilia and her classmates Robin and Elias took first place in the chemistry category in early 2021, and second place in the technology category.

To awaken the spirit of research and the joy of experimentation - that is also the mission of UC2. "We want to make modern techniques accessible to a broad audience," says Benedict Diederich, "and build an open and creative microscopy community." Especially in the home-schooling times of the Corona pandemic, students can thus easily build their own teaching materials at home.

**www.useetoo.org**

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**Publication:** Benedict Diederich, René Lachmann et al.: A Versatile and Customizable Low-Cost 3D-Printed Open Standard for Microscopic Imaging. Nature Communications 11 (2020), DOI: 10.1038/s41467-020-19447-9.

© Charlotte Siegesmund



# Traces on the Retina

**Researchers use spectroscopic methods to look for signs of Alzheimer's disease on the retina of mouse models. This opens up opportunities to detect the disease at an early stage in the future**

Detecting neurodegenerative diseases in the eyes long before they break out: A European research team with the participation of Leibniz IPHT has come one step closer to this aim. Using a laser based method, the researchers have succeeded in distinguishing the retina of an Alzheimer's mouse model from a healthy one on the basis of its spectral fingerprint.

Unlike previous studies, the researchers do not rely on the controversial detection of certain biomarkers – such as protein deposits typical of Alzheimer's disease – but use spectroscopic means to decipher the biochemical composition of the retina of mouse models. This enables them to detect minimal changes even before they are reflected in the retina. This would allow them to detect signs of emerging Alzheimer's disease much earlier than it is possible with current methods.

"The literature describes that subtle biochemical modifications probably take place before they become visible on the retina," explain Clara Stiebing and Izabella Jahn, first authors of the study. While morphological changes in the retinal layers can be diagnosed in vivo using standard optical coherence tomography (OCT), deviations in biochemical composition cannot be detected in this way. "This is where Raman spectroscopic investigation, as an adjunct to optical coherence tomography and fluorescence imaging, could make a crucial contribution to improving the accuracy of ocular disease diagnosis," said Jürgen Popp, scientific director of Leibniz IPHT.

Together with the Medical University of Vienna and partners from Germany and the Netherlands, the Leibniz IPHT team is working on a novel diagnostic platform for age-related eye diseases and Alzheimer's disease. It combines Raman spectroscopy with OCT.



### Diagnostic features for drug development

Whether specific biomarkers for Alzheimer's disease can be detected noninvasively in the retina is controversial in research. Some studies have identified the protein deposits characteristic of the disease – amyloid plaques and tau fibrils – in both human retinas and mouse models. Others, however, report the absence of these clues and question the diagnostic value of the approach.

### Medical approval process to be completed shortly

By using spectroscopic methods to distinguish healthy and diseased samples for the first time, the researchers are now demonstrating a new way to detect Alzheimer's disease in the retina. "We biochemically characterized two defined mouse models," reports Clara Stiebing. In doing so, the researchers succeeded in biochemically identifying the individual layers of the retina on the basis of cross-sections via their different contents of nucleic acids, rhodopsin, lipids and proteins. Using frontal images – which are closer to the intended in vivo application - they were able to distinguish healthy and diseased mouse retinas with an accuracy of 86 percent. Distinct accumulations of amyloid plaques could not be found in either the cross-sections or the frontal images.

The Jena research team had already shown in an earlier study that spectroscopic examinations of the retina – an eye scan using laser light – are theoretically possible and can provide valuable clues to disease (see also Annual Report 2019). "The question that needed to be answered after that was: can Raman spectroscopy detect differences between healthy and diseased retinas?" explains Izabella Jahn. "We have now shown that this is possible using the retina of mouse models. This was important to test the hypothesis that there are also differences in biochemical information in the retina in neurodegenerative diseases."

The researchers performed the experiments on ex vivo samples from mice under ideal experimental conditions, i.e., without adhering to laser safety limits for ocular exposure. The question remains whether it is possible to obtain high-quality Raman spectra directly from living humans, Clara Stiebing said, "and whether these data can be used to generate robust statistical methods." Of course, one must be careful about generalizing results from measurements in mice to humans as well, says Rainer Leitgeb from the Medical University of Vienna, who is coordinating the project. "However, the new results reinforce our specific goal of also being able to detect neurodegenerative diseases such as Alzheimer's by a simple eye scan. Even without the previously assumed deposits of amyloid plaques, there are changes in the retina that could potentially be detected by Raman spectroscopy. This would provide an objective and comparable diagnostic feature, which would also be of great importance for drug development. The researchers show this in a study with mouse models. How specific these changes really are must ultimately be shown in the targeted human studies."

The project partners are now building a device at the Medical University of Vienna that combines Raman spectroscopy with optical coherence tomography (OCT). Medical approval should be completed in the first half of 2021, Rainer Leitgeb reports. Then the device can be tested on the first patients.

## Multimodal Optical Diagnostics for Age-related Diseases of the Eye and the Central Nervous System (MOON)

In the MOON project, scientists from Leibniz IPHT together with partners from Germany, Austria, France and the Netherlands are researching new technologies for the diagnosis of age-related eye diseases and neurodegenerative diseases. MOON is funded by the European Union.

**moon2020.meduniwien.ac.at**

**Publication:** Clara Stiebing, Izabella J. Jahn et al.: Biochemical Characterization of Mouse Retina of an Alzheimer's Disease Model by Raman Spectroscopy. ACS Chem. Neurosci. 2020, 11, 20, 3301–3308. doi.org/10.1021/acschemneuro.0c00420

Harnessing energy from light: Doctoral student Carolin Müller with a photoreactor © Sven Döring

# Using Solar Energy at Night

**Researchers develop a chemical system that collects light energy and stores it on a molecule for several hours**

Nature has already solved the problem: In photosynthesis, plants convert carbon dioxide into chemical compounds with the help of sunlight – and do so in such a way that the solar energy stored in chemical bonds is available even when it is dark. Researchers are trying to imitate this process using nature as a model. If it were possible to use the energy from the sun as efficiently as nature and convert it into chemical energy, global $CO_2$ emissions could be drastically reduced. However, due to a lack of suitable storage options, solar-driven photochemistry has so far only worked in bright light.

Researchers from Leibniz IPHT and the University of Jena have now presented a molecular approach to storing solar energy that, for the first time, makes it possible for photochemical reactions to take place independently of daylight. They have developed a chemical system that collects light energy and stores it on a molecule. The molecular storage system based on a copper complex thus decouples photochemical processes from the day-night cycle.

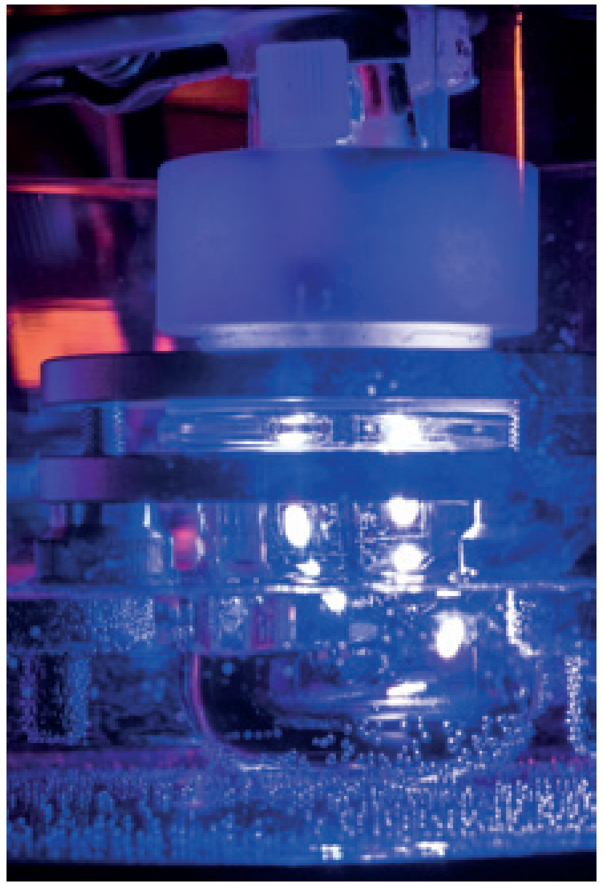
## For the first time: Light-driven photochemistry in the dark

In contrast to previous approaches based on solid-state materials, the researchers create reactive photoredox equivalents on a small molecule. This allows them not only to store light energy for a previously unattainable duration of at least 14 hours, but also to regenerate it when needed.

"The dependence on brightness and darkness has so far been a major hurdle when it comes to using solar-powered photochemistry for continuous industrial production processes," explains first author Martin Schulz, who conducts research at the University of Jena as well as in the "Functional Interfaces" research department at Leibniz IPHT. "We anticipate that our results will open up new opportunities to explore systems for solar energy conversion and storage, as well as for photo(redox) catalysis."

## High charging capacity even after several cycles

In the chemical system developed by the Jena researchers as part of the collaborative research center "CataLight", the photosensitizer and the charge storage unit are located on the same small molecule. This eliminates the need for intermolecular charge transfer between a separate sensitizer and charge storage unit. The system retains three-quarters of its charge capacity even after four cycles.



Photoreactor for the investigation light-driven reactions © Martin Schulz

The researchers use a copper complex and thus a molecule based on a readily available metal, whereas previous approaches have relied on rare and expensive noble metals such as ruthenium. The doubly reduced copper complex can be stored after photochemical charging and used as a reagent in dark reactions, such as the reduction of oxygen.

The Jena researchers developed the approach together with partners from the University of Ulm, the Leibniz Institute for Solid State and Materials Research Dresden and Dublin City University in the collaborative research center "CataLight" ("Light-driven Molecular Catalysts in Hierarchically Structured Materials – Synthesis and Mechanistic Studies"). Here, teams of scientists from the universities of Jena and Ulm are researching sustainable energy converters modeled on nature.

Within the framework of the SFB, another team from Leibniz IPHT recently provided another important piece of the puzzle. The researchers had succeeded for the first time in making reactive intermediates visible in ultrafast electron transfer steps (read about it in the 2019 annual report). "For our common aim of performing and understanding artificial photosynthesis, this provides a powerful tool to decipher and understand the individual steps of light-driven electron transfer reactions – under process conditions," Martin Schulz explains. "In turn, we effectively decouple light and dark reactions by converting and storing light energy. This opens up a completely new way for us to do photochemistry: For one thing, the long storage times allow us to virtually count the electrons when we use them in the dark reaction." For another, Schulz says, the system in principle enables "photocatalysis round-the-clock."

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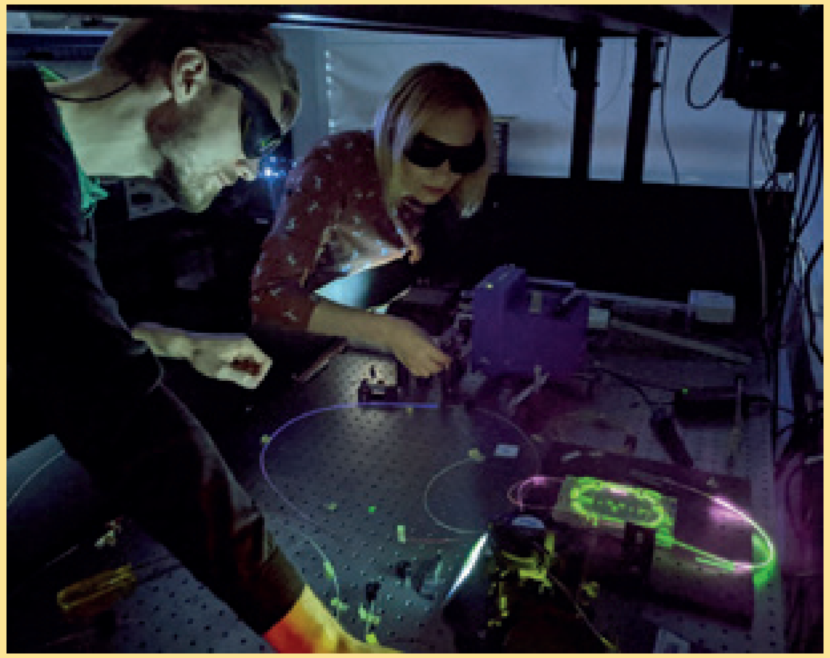
**Publication:** Martin Schulz, Nina Hagmeyer, Frerk Wehmeyer, et al. (2020), Photoinduced Charge Accumulation and Prolonged Multielectron Storage for the Separation of Light and Dark Reaction. J. Am. Chem. Soc. 2020, August 22, 2020. https://doi.org/10.1021/jacs.0c03779

# Light Instead of a Needle and Thread

**Welding with ultrashort laser pulses: researchers are working on a gentle method to rejoin tissue**



Maria Chernysheva and PhD student Dennis Kirsch during an experiment with a Tm fiber laser (purple), which is pumped by an erbium fiber laser (green) is pumped. © Leibniz IPHT

To reconnect organs and tissues as naturally as possible after a surgical procedure and to restore function quickly, lasers are increasingly proving to be a gentle and effective alternative. Established methods of resealing wounds by suturing, stapling or gluing, while well developed, are not a panacea. For example, glues, once applied, do not allow correction of wound closure, while metal staples, for example, do not form a watertight bond, which can lead to inflammation.

Maria Chernysheva, head of the junior research group "Ultra Short Pulse Fiber Lasers", together with a team from the British Aston Medical School, has now developed a multifunctional optical fiber probe that can be used to reliably connect biological tissue. Using an ultrafast fiber laser, the researchers succeeded in welding the walls of dissected chicken hearts together in such a way that a tensile bond corresponding to the native tissue was created. The researchers monitored the welding process using fluorescence spectroscopy, which detects the biochemical composition of the tissue. "We came up with this idea quite spontaneously," Maria Chernysheva reports. "During an experiment on laser ablation of cardiac tissue, we noticed that the fluorescence spectrum of the tissue during laser irradiation behaved differently than we expected for certain radiation parameters." When they examined the spectrum, the researchers concluded that the increase in characteristic peaks of elastin, collagen and methemoglobin indicated the onset of welding. Guided by fluorescence spectroscopy, they varied laser power, pulse packet duration and exposure rate and eventually found the most effective method. Compared to conventional mode-locked operation, this enables tissue to be welded more gently and at the same time more deeply.

### Faster healing, Fewer complications

"Compared to conventional suturing, laser welding is potentially less traumatic as well as easier and faster for surgeons to perform," explains Maria Chernysheva. "Healing is accelerated. The wound is immediately tightly closed, and the risk of postoperative complications decreases." Foreign body reactions are thus avoided; the risk of necrosis – a death of tissue – at the edges is minimized, as is the formation of a large scar.

In a next step, the researchers now want to extend their approach to minimally invasive surgery to other biological tissues and explore laser welding of tissue for in vivo use. A long-term study on animal models will show how laser welding affects the dynamics of wound healing.

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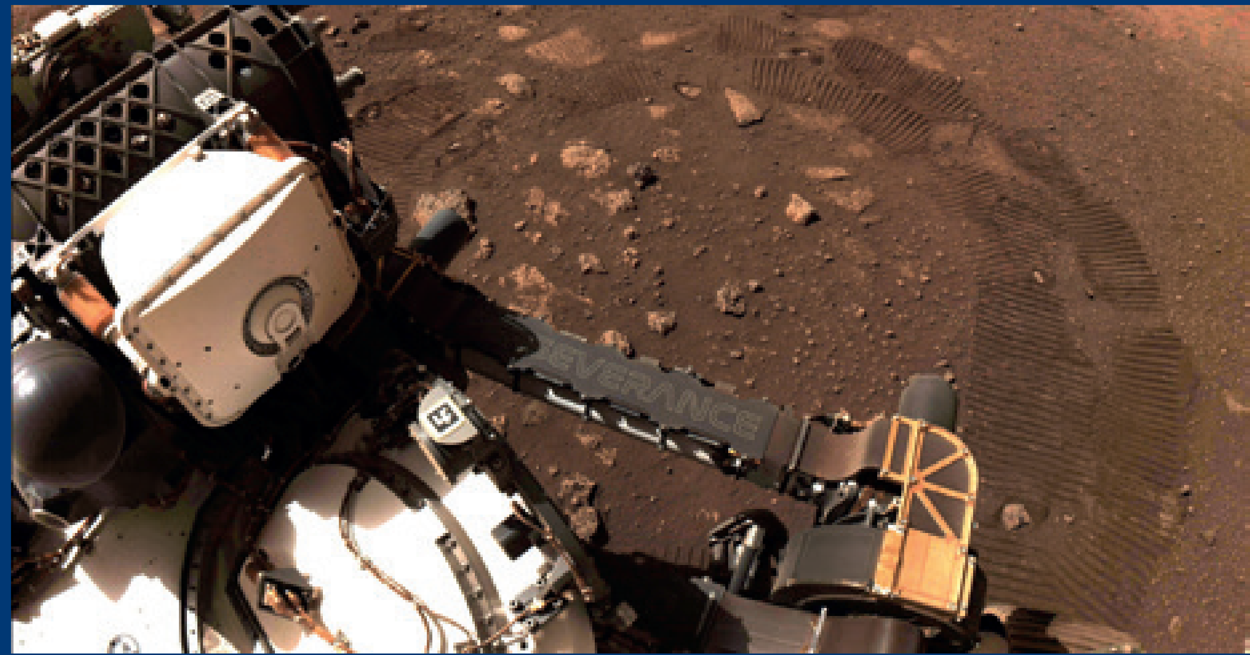
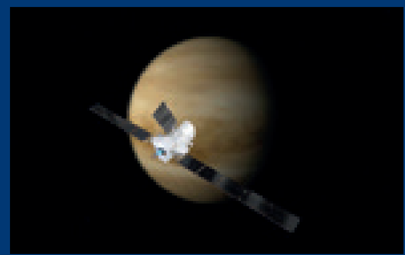
**Publication:** Karina Litvinova, Maria Chernysheva, Berthold Stegemann, Francisco Leyva: Autofluorescence guided welding of heart tissue by laser pulse bursts at 1550 nm. Biomedical Optics Express. 2020 Nov 1; 11(11): 6271–6280. DOI: 10.1364/boe.400504

# Expedition to Space

**One on a Venus flyby, the other on Mars: In 2020, thermal sensors from Leibniz IPHT went on two spectacular space missions**



Perseverance's first trip to Mars on March 4, 2021. This image was taken by the rover's navigation cameras. © NASA / JPL-Caltech



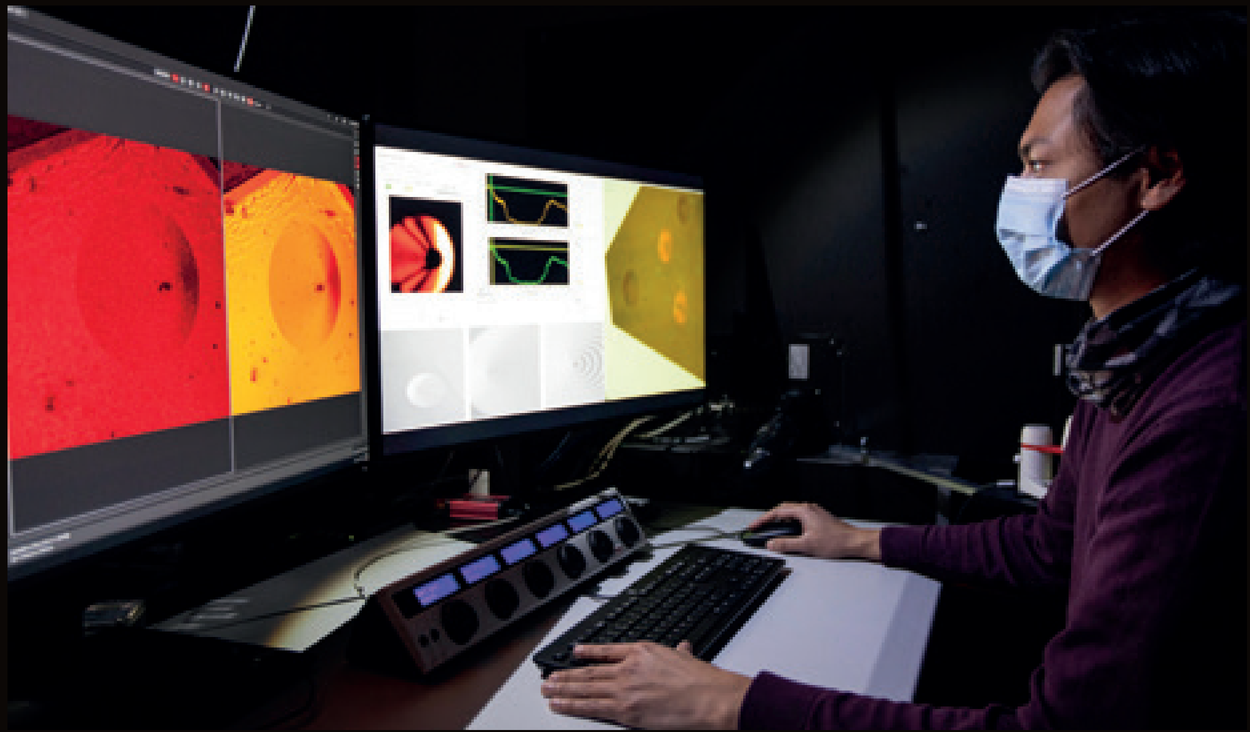
BepiColombo during a flyby of Venus © ESA / ATG Medialab

Touchdown confirmed. All over the world, people cheered in front of their screens when the Mars rover Perseverance landed on the Red Planet in February 2021, a good six months after its launch. On board: thermal sensors from Leibniz IPHT. They contribute to one of the goals of the NASA mission – to explore what the weather is like on Mars.

Part of an instrument package developed by the Spanish space agency INSA, the sensors measure, without contact, the temperatures on the surface of the Jezero crater where the rover landed. They are based on the thermoelectric conversion principle and do not require a power supply. This is the third time that the space-tested technology from Leibniz IPHT has been sent to Mars. The institute's sensors have also been installed in the rover Curiosity, which has been operating on the planet since 2012, and in the lander In-Sight, which was launched in November 2018.

Another mission with Jena sensors on board passed Venus in October 2020 – a flyby of the European-Japanese probe BepiColombo on its nearly nine billion kilometer journey to Mercury. The Jena scientists developed the sensor specifically for this mission. It also measures temperature highly accurately and without contact, but in addition performs significantly more operations at once than the Mars sensor, reports Gabriel Zieger, in whose Thermosensorics working group it was developed. The robust sensor is designed to explore the mineralogical composition of the smallest and so far least explored planet – and to do so under extreme conditions: at temperatures of up to 430 degrees Celsius during the day and minus 180 degrees Celsius at night, braced against the solar wind and high radiation.

"A space mission is a new challenge every time," says Gabriel Zieger. "That's because you only have one shot: you can't test the sensors in the mission area beforehand, and once the mission is launched, they have to work. We have no possibility to readjust anything else." But so far, he adds, it has always worked.



Parijat Barman, PhD student in SFB NOA, in front of a non-linear Raman setup for recording the SECARS spectra on plasmonic nanostructures. They serve to increase the sensitivity of Raman spectroscopy towards recording Raman spectra of single molecules. © Daniel Siegesmund



# Chemical Reactions In Close Up

**What happens between atoms and molecules when they react with each other cannot yet be observed directly. A team led by Jürgen Popp and Jer-Shing Huang has developed a strategy to amplify the weak signals of their interaction with light – a crucial step toward being able to see right into the middle of a chemical reaction in the future**

We bring knowledge "to light". When we gain an insight, "a light comes on". There are many metaphors about the insight-giving effect of light. And not without reason: "If we want to learn something about our environment, about matter and molecules that surround us and the fundamental processes that take place in them, we need light," says Jürgen Popp. "From the simplest microscopes to state-of-the-art imaging techniques based on the interaction of laser light with matter, light is the key to what we see." Popp and his teams at Leibniz IPHT and the Institute of Physical Chemistry at the University of Jena are researching spectroscopic methods that make it possible to see right into the middle of a chemical reaction.

To this end, they are optimizing Raman spectroscopy – a spectroscopic-analytical method that already has many applications, for example in the analysis of drinking water, foodstuffs or clinical diagnostics for the detection of pathogens. Using Raman spectroscopy, any material and any molecule can be clearly identified without contact. "The spectrum of a sample is like a chemical fingerprint," illustrates Michael Schmitt from Popp's team. However: the effect of inelastic light scattering underlying the Raman signal is a weak process; if the researchers want to look at individual molecules, they have to amplify the signals to be able to measure them at all.

This is precisely what Jürgen Popp and Michael Schmitt are working on together with Jer-Shing Huang, head of the research department Nanooptics at Leibniz IPHT, as part of the Collaborative Research Center "Nonlinear optics down to atomic scales" at the University of Jena. At the end of 2020, they took a first decisive step: with partners from Taiwan, the Jena researchers combined two methods to effectively amplify the Raman signal.

## Weak Raman signal is amplified plasmonically

On the one hand, they use plasmonic nanostructures for this purpose. Such optical antennas can be used to illuminate even nanometer-sized areas and thus increase the resolution of imaging methods. Here, however, the researchers use plasmonic structures to amplify the weak Raman signal itself: Electrons in the nanostructures are excited with a laser to form so-called surface plasmons. This creates a strong electric field with which molecules are absorbed and can interact at the nanostructure surfaces. This "surface-enhanced Raman scattering" (SERS) enhances the interaction between Raman excitation light and the molecules under investigation and thus also the intensity of the Raman scattering.

## Nanostructures of gold

For the experiments, the research team uses nanostructures made of gold. These are milled into mirror-smooth individual crystals, known as gold flakes, that are only hundreds of micrometers wide and about 300 nanometers thin. "We use different sizes and shapes of the nanostructures and want to find out how the design affects the plasmonic effect," explains Jer-Shing Huang. In doing so, the researchers are proceeding in a highly planned manner: Theoretical groups of the SFB led by Stefanie Gräfe and Ulf Peschel from the University of Jena first model the interaction of the structures with light on the computer in order to derive the optimal design parameters for the desired effect.

In addition to the SERS method, the researchers use another way to amplify the Raman signal: Through nonlinear interactions between light and material, the Raman-scattered light excited via intense short-pulse lasers is coherently focused. As a result, "Coherent anti-Stokes Raman Scattering" (CARS) also leads to amplified Raman signals.

The researchers conclude that this know-how can significantly improve the detection limit of Raman spectroscopy. "In addition to the existing advantages of the method – such as the fact that sample molecules can be used directly without dyes - there is now a high sensitivity," Jürgen Popp makes clear. The goal, adds Michael Schmitt, is to refine the methodology to the point where it can be used to directly observe chemical reactions on single molecules, "the dream of every chemist."

**www.noa.uni-jena.de**

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**Publication:** Lei Ouyang et al.: Spatially Resolving the Enhancement Effect in Surface-Enhanced Coherent Anti-Stokes-Raman Scattering by Plasmonic Doppler Gratings, ACS Nano 2021, DOI: 10.1021/acsnano.0c07198

## Plasmonic Nanostructures

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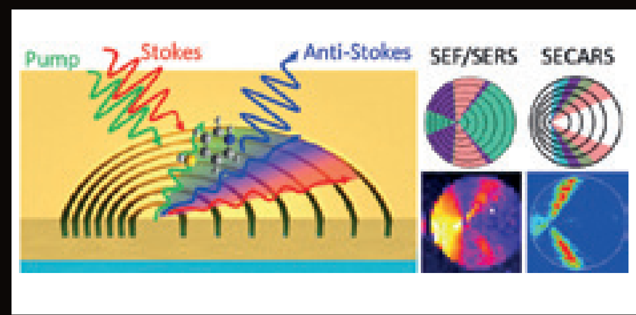
These are tiny optical antennas. As with radio or television antennas, optical antennas can be used to concentrate electromagnetic waves in one place and convert the wave into an electric current or, conversely, to radiate an electric signal in the form of a wave. The length of the antenna is adapted to the wavelength of the electromagnetic radiation. Unlike radio waves, which have a wavelength of several meters, visible light has wavelengths of only about 380 to 780 nm. Optical antennas must therefore be extremely small. Only the development of nanotechnology in the 2nd half of the 20th century made it possible to produce such small structures.

When the nanostructures are illuminated, the electromagnetic light wave and the mobile conduction electrons in the metal interact. The electrons are set into collective oscillations called surface plasmon polaritons, or plasmons. This allows much smaller structures to be illuminated and detected than with an ordinary light microscope.




The researchers use SERS and SECARS techniques to amplify the Raman signal. © ACS Nano 2021, 15, 1, 809-818

Using a Raman microspectroscope, PhD student Marcel Dahms records the specific vibrational spectra of bacteria trapped on a chip. © Sven Döring

# Step Towards Clinical Application

**European laboratories aim to create standards for Raman spectroscopy. To this end, Leibniz IPHT has initiated the largest cross-laboratory study to date**

Is the tissue healthy or pathologically altered? Does the antibiotic work against the germ or is it resistant to it? With the help of Raman spectroscopy, such questions can be answered quickly and precisely. However, one challenge for the use of the light-based analysis method in everyday clinical practice is that the results depend sensitively on the respective measurement conditions. In order to create solutions for this challenge, Leibniz IPHT has initiated the largest European cross-laboratory study to date.

Using Raman spectroscopy, biological samples in diagnostics, microbiology, forensics or pharmacology can be precisely characterized via the unique fingerprint of the molecules. "However, the results also contain other fingerprints: those of the measurement system, for example the Raman spectrometer," explains Thomas Bocklitz, head of the "Photonic Data Science" research department. For example, the same sample can lead to different Raman spectra if it is measured with different setups, under different conditions or at different times, says Bocklitz, who also works at Friedrich Schiller University in Jena.

At the initiative of Leibniz IPHT, 86 researchers from 15 institutions in seven European countries have now put the comparability of Raman spectroscopic devices with different configurations to the test. The European Union funded the project "Raman4Clinics" as a COST Action (European Cooperation in Science and Technology). With the largest laboratory comparison of Raman spectroscopy experiments to date, the study is an important step toward bringing Raman spectroscopy into clinical applications, said Jürgen Popp, spokesman for the "Raman4Clinics" consortium.

## Open source crucial for common standards

The team's conclusion is a clear recommendation to both spectrometer manufacturers and the scientific community of Raman spectroscopy. "Manufacturers and scientists should perform spectrometer calibration as standard and make the corresponding software modules open source," says Thomas Bocklitz. This, he said, is a viable and attractive first step to correct for the influence of measurement-related effects on Raman signals.

It is also crucial, he says, that both manufacturers and researchers make their data openly available. "We encourage scientists to actively contribute to building larger databases," Thomas Bocklitz appeals. "This would be an enormously valuable resource for building machine learning models and chemometric methods that are tolerant of undesirable variations."

The results of the research team, which is now looking at complex biological samples after studying simple substances such as polystyrene and paracetamol, will be incorporated into the National Research Data Infrastructure (NFDI). This networked structure, funded by the German Research Foundation (DFG), is designed to systematically develop, sustainably secure and make accessible the data holdings of science and research.

"Our data contribute to achieving uniform standards for Raman spectroscopy," explains Bocklitz, who is an official participant in the NFDI's chemistry consortium (NFDI4Chem). The goal is to get internationally binding protocols for Raman spectroscopy off the ground. "We hope that our study will encourage the scientific community of Raman spectroscopy to commit to such common standards," Thomas Bocklitz emphasizes. "Only then can we realize the full potential of this powerful non-invasive method for clinical applications."

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**Publication:** Thomas Bocklitz et al., Comparability of Raman Spectroscopic Configurations: A Large Scale Cross-Laboratory Study, Anal. Chem. 2020, 92, 24, 15745–15756. https://doi.org/10.1021/acs.analchem.0c02696

## New Standard Tool for Microbiology

Learning what happens when microorganisms interact with each other or with more highly developed organisms can be very valuable for humans. Bacteria, for example, often produce substances during such processes that could provide the basis for new drugs or antibiotics. To observe such processes, researchers use modern imaging techniques such as Raman spectroscopy.

To enable microbiologists at Friedrich Schiller University Jena to use this powerful technology to study biological samples and biomolecules, the research team in Jürgen Popp's group is now providing them with a Raman microscope and supporting them in its use. The state of Thuringia is funding this with 400,000 euros as part of the project "Investigation of microbial interactions using Raman spectroscopy" - or "MICROVERSE-Raman" for short. The new Raman technology will be an essential building block in the "Imaging Center" of the Cluster of Excellence "Balance of the Microverse", which provides various modern imaging techniques.

# Research News



## Rapid Test for Dangerous Tropical Disease

Bacterial colony of the melioidosis pathogen Burkholderia pseudomallei. The pathogen pictured was isolated by researcher Stefan Monecke from a sample taken from a German traveler returning from Asia. © Stefan Monecke; JMM Case Reports

The infectious disease melioidosis – also known as pseudorotz – is widespread in Southeast Asia and northern Australia as well as in tropical regions of Africa and South America. The pathogen is found in soil and water, such as in rice fields – a bacterium that is already naturally resistant to numerous antibiotics. Melioidosis is difficult to treat, and mortality is high. The biggest obstacle to successfully combating it so far is that the infection is often not detected in time due to its non-specific clinical course.

The team of the research department "Optical-Molecular Diagnostics and Systems Technology", together with the Weimar-based diagnostics company Senova and other national and international partners, has now developed a rapid test that provides clarity within 15 minutes. The inexpensive blood serum strip test meets the requirements for the first time in risk areas such as Thailand to enter the diagnostic routine and improve it significantly – a reliable alternative to expensive and time-consuming laboratory tests does not exist in the affected countries so far. Senova – industry partner in the InfectoGnostics network – is now further developing the test for the markets in Asia and Australia.

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**Publication:** Wagner GE et al. (2020) Melioidosis DS rapid test: A standardized serological dipstick assay with increased sensitivity and reliability due to multiplex detection. PLOS Neglected Tropical Diseases 14(7): e0008452. https://doi.org/10.1371/journal.pntd.0008452

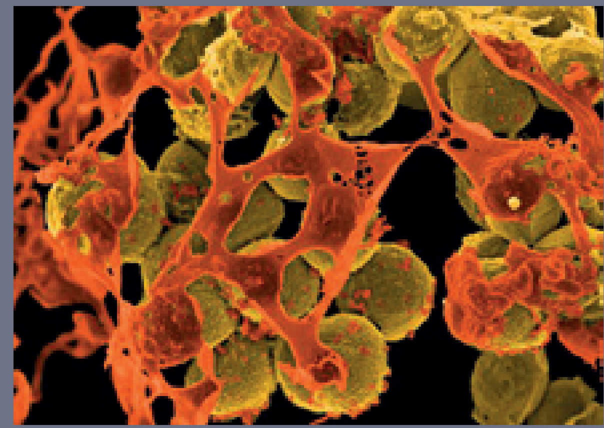
## Automated Detection of Poisoned cells

Scientists at Leibniz IPHT, Jena University Hospital and Ilmenau University of Technology are developing an evaluation platform that can be used to effectively detect cell reactions to toxic substances at an early stage. The platform is to be used in drug testing or for new diagnostic procedures. The MorphoTox research network is receiving over 600,000 euros in funding from the state of Thuringia.

The research team from Leibniz IPHT is studying the altered shape of the poisoned cells using spectroscopic imaging techniques, such as multimodal imaging. The analysis of the acquired image data is the second major part of the project. "In addition to reliable correction of measurement artifacts, the challenge is to combine the results of the various investigation methods," says Thomas Bocklitz, head of the "Photonic Data Science" research department. The appropriately processed measurement data will serve as training data for machine learning algorithms, on which the resulting evaluation platform will be based.

Possible applications of the platform include not only toxicity testing of drug candidates, where early detection of toxic cell reactions helps to save costly animal or patient studies. Conceivably, it could also be used to detect intentional toxic reactions, for example in the testing of new chemotherapeutic agents. Analyses on cell lines obtained from patient samples could also contribute to personalized therapy decisions as individualized toxicity tests.

## Tests Fail on New Multidrug-resistant Germs



Digitally stained image of an MRSA strain imaged with a scanning electron microscope. © NIAID

Two market-leading rapid tests are unable to detect a new multidrug-resistant strain of bacteria. This is what a team from the research department "Optical Molecular Diagnostics and Systems Technology" and the InfectoGnostics research campus with international partners has discovered. The researchers show that a new strain of bacteria, which is increasingly spreading in Europe, has altered its genome in such a way that some of the market-leading PCR tests no longer correctly identify it as MRSA.

The origin of the new pathogen, called "European CC1-MRSA-IV," is believed to be southeastern Europe. The MRSA strain has also been detected in Ireland, Italy, Germany and Austria. MRSA are bacteria of the species Staphylococcus aureus, which become resistant, i. e. insensitive, to the antibiotic methicillin and also to most other antibiotics.

The false-negative test results could lead to wrong decisions in antibiotic therapy and delay infection prevention measures in hospitals, the researchers warn.

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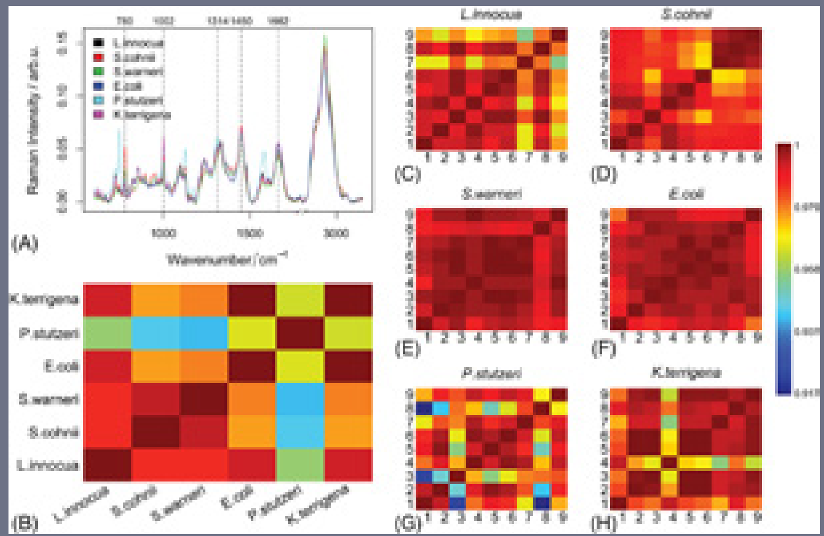
**Publication:** Stefan Monecke et al., An epidemic CC1-MRSA-IV clone yields false-negative test results in molecular MRSA identification assays: a note of caution, Austria, Germany, Ireland, 2020. Euro Surveill. 2020;25(25):pii=2000929. DOI: 10.2807/1560-7917.ES.2020.25.25.2000929

# International Training Network in the Fight Against Infectious Diseases




Mean spectra and correlation coefficients of the bacteria data set. (A) Mean spectra of each species calculated from all batches. (B) Intergroup correlation coefficients calculated from the mean spectrum of each species. (C)-(H) Inter-replicate correlation coefficients of the different species calculated from the mean spectrum of each batch from the same species.

They are among the most common causes of death worldwide, and not just since the outbreak of the Corona pandemic. Infectious diseases are caused by mostly microscopic organisms such as bacteria, viruses, fungi or parasites and are transmitted from person to person. To enable young researchers to develop innovative methods for better diagnosis and treatment of infectious diseases, the European Marie Skłodowska-Curie training network IMAGE-IN was launched in 2020.

Coordinated by Leibniz IPHT, leading institutions from research and medicine join forces with companies from Germany and Portugal to offer international young researchers excellent training in the field of imaging and data analysis in this International Training Network (ITN) funded by the European Union. The program includes stations at various partner institutions, such as Jena University Hospital and the Portuguese software company BMD in Aveiro.

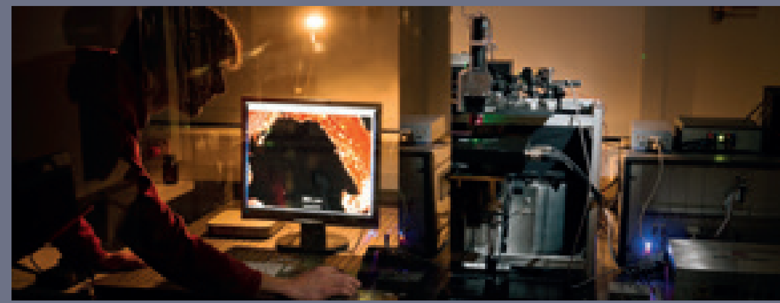
"The researchers gain insights into medical needs and learn imaging and spectroscopic techniques," explains Ute Neugebauer, whose research department "Clinical Spectroscopic Diagnostics" is involved in IMAGE-IN. This includes molecular imaging as well as multi-scale visualization of infections and host responses for accurate diagnostics and personalized treatment.

"In order to extract the crucial information from the large, multidimensional amounts of data produced by imaging techniques, we provide the ability to handle and analyze this data," adds Thomas Bocklitz, head of the research department "Photonic Data Science." To better understand the pathogenesis of difficult-to-treat infections, the researchers combine data from different imaging techniques. The research departments "Spectroscopy / Imaging" and "Microscopy" with Jürgen Popp and Rainer Heintzmann are also significantly involved in the training network.

**IMAGE-IN: Imaging Infections – integrated, multiscale visualization of infections and host response**

**www.image-in-itn.eu**

# Tracking Down the Cellular Origins of Cancer



Tobias Meyer-Zedler researches laser-based, multimodal imaging techniques to visualize biomolecules in cells, tissues and organs.

© Sven Döring

Researchers from Jena, together with European partners from research, medicine and industry, want to develop a novel microscopy technology and bring it to market. It should help to track down the cellular origins of cancer diseases and decisively advance precision medicine. With this goal in mind, the team from Leibniz IPHT, Jena University Hospital (UKJ) and laser system manufacturer Active Fiber Systems launched the transnational transdisciplinary research project CRIMSON (Coherent Raman Imaging for the Molecular Study of the Origin of Diseases) in December 2020. The coordinator is the Politecnico di Milano.

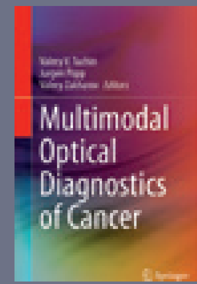
Together with other leading research institutions and companies from Italy, the UK and France, they are developing a biophotonic imaging device based on next-generation coherent Raman microscopy for biomedical research. It combines advanced laser techniques with data analysis through artificial intelligence. The European Commission is funding the project with more than 5 million euros over 42 months.

**Innovative microscopy technology for imaging inside the body**

"Our goal is to bring an innovative, label-free microscopy technology to the market and to the clinic that makes it possible to detect changes in cells on the basis of a molecular fingerprint," explains Jürgen Popp. In perspective, the microscopic method will also be used for endoscopic imaging inside the body and enable rapid, highly precise tissue diagnostics. "This innovative technology will enable us to better understand the interaction between cancer cells in the head and neck region and the cells of the immune system," adds Orlando Guntinas-Lichius, director of the Department of Otolaryngology at UKJ. For the planned device, the Jena-based company Active Fiber Systems (AFS) is developing a new type of compact fiber laser that will enable the researched microscopic method to be used directly in the clinic in the future.

**www.crimson-project.eu**

# Laser Light Detects Tumors: How Optical Technologies Improve Cancer Diagnostics




A scientific overview of the latest optical methods for the non-invasive detection and treatment of cancer is provided by international biophotonics experts Jürgen Popp, Valery V. Tuchin and Valery Zakharov in the anthology "Multimodal Optical Diagnostics of Cancer". It serves as a guide to optical approaches for cancer diagnostics and screening, for long-term monitoring to image-guided intervention.

"Light-based methods are a forward-looking tool to facilitate early detection and diagnosis of cancer," explains Jürgen Popp. "The multimodal approach provides a wealth of information: for example, on the structure and morphology of the tissue and its molecular composition. This helps physicians make an accurate diagnosis and choose the appropriate treatment." Rapid advances in photonic technologies are spurring research into new diagnostic techniques, the authors said. For example, novel fiber-optic instruments could open a path to minimally invasive medicine.

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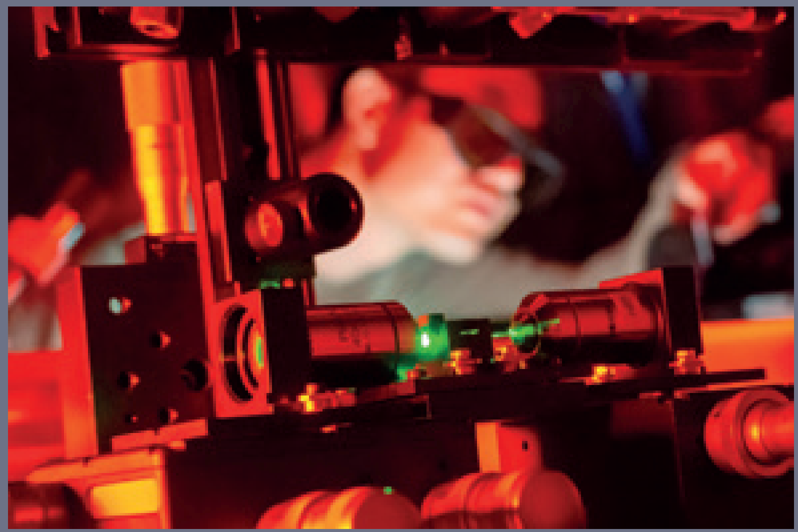
**Publication:** Jürgen Popp, Valery V. Tuchin, Valery Zakharov (Hg.): Multimodal Optical Diagnostics of Cancer. Springer, Heidelberg 2020. ISBN 978-3-030-44593-5

# Intelligent Nanomaterials for Photonics



Quyet Ngo, PhD, from the University of Jena, Germany, is studying optical fibers functionalized by 2D materials.



Jena researchers, together with Australian colleagues, have succeeded for the first time in growing 2D materials directly on optical fibers. The process significantly simplifies the previously very complex production of hybrid nanomaterials. In combination with optical fibers, 2D materials with outstanding optical properties enable new applications in the fields of sensor technology, nonlinear optics and quantum electronics.

The research team integrated a 2D material with excellent optical and photonic properties into specially designed optical fibers. The growth process was developed by a team led by graphene expert Andrey Turchanin at the Institute of Physical Chemistry at the University of Jena; the fiber was developed by Markus Schmidt, who heads the Fiber Photonics research department at Leibniz IPHT and holds an endowed professorship in fiber optics at the university. Pure quartz glass serves as the substrate for the fiber, Markus Schmidt explains. "It is heat-resistant up to 2,000 degrees Celsius and excellently withstands the high temperatures of the growth process. Its small diameter and pliability make the fiber flexible optical fibers," says Schmidt.

The system could be used for sensor technology in biotechnology or medicine, as a nonlinear light converter in spectroscopic investigations, and in quantum electronics and quantum communication.

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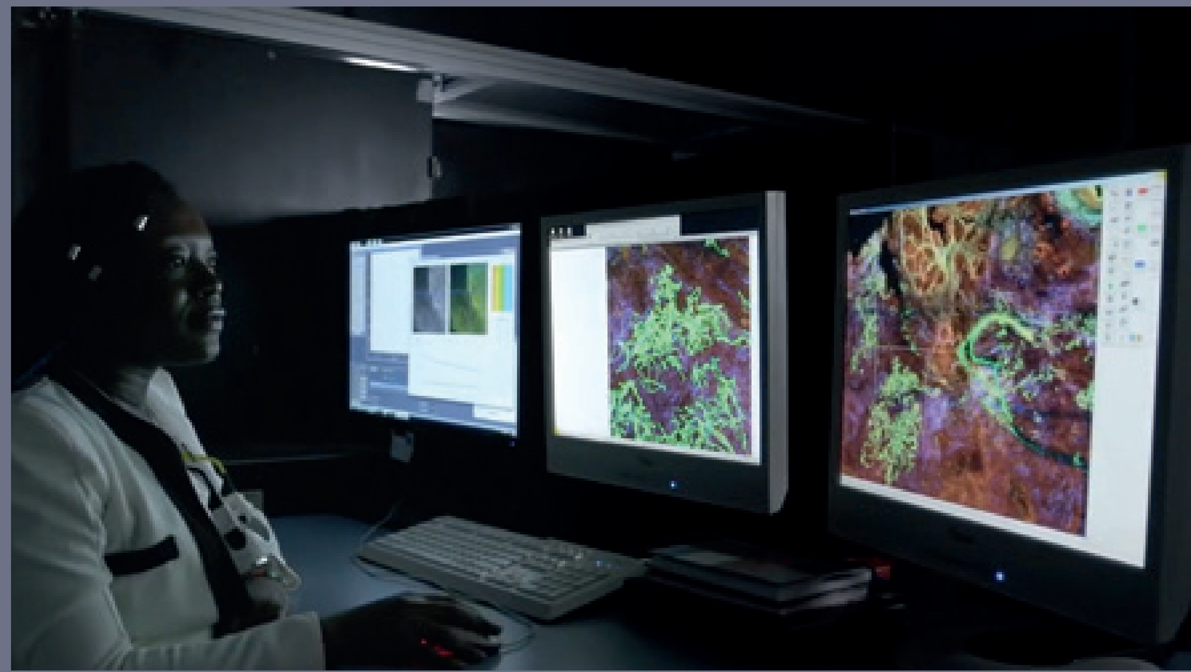
**Publication:** G. Quyet Ngo et al. (2020): Scalable functionalization of optical fibers using atomically thin semiconductors, Advanced Materials, https://doi.org/10.1002/adma.202003826

# Know-how for Cancer Research of the Future



Doctoral student Elsie Quansah acquires multimodal CARS / SHG / TPEF images from samples of of inflammatory bowel disease.



In order to enable young researchers to develop innovative light-based methods for the diagnosis and therapy of cancer, Leibniz IPHT has joined forces with other high-profile research institutions, clinics and companies from seven European countries to form a training network for doctoral students. 15 young scientists receive excellent, interdisciplinary qualification in the pioneering research field of biophotonics in the program PHAST (Photonics for Healthcare: multiscAle cancer diagnosiS and Therapy) funded by the European Commission.

The three-year PhD program focuses on the development of innovative instruments and non-invasive methods for cancer diagnostics and therapy. "Our goal is to train the next generation of researchers in the field of biophotonics in close cooperation between technology development, medicine and industry," explain Jürgen Popp and Michael Schmitt, who play a key role in training the PhD students at the Institute of Physical Chemistry at the University of Jena and the Leibniz IPHT.

"Tumors and tumor boundaries can be very difficult to detect," explains Orlando Guntinas-Lichius, head of the Department of Otolaryngology at Jena University Hospital (UKJ). Like Friedrich Schiller University and micro-optics specialist Grintech GmbH, UKJ is one of Jena's partners in the PHAST network. "Optical and especially biophotonic technologies can decisively advance our diagnostic capabilities – and with them the possibilities of effectively treating these diseases."

**www.phast-etn.eu**

# Pioneer of Photonics Innovations in Europe

View into the fiber drawing tower of the Leibniz IPHT © Sven Döring

Leibniz IPHT and the Thuringian photonics network OptoNet are partners in the new European digital center for photonics innovation. The major initiative PhotonHub Europe is funded with 19 million euros from the EU's Horizon 2020 program and is designed to help small and medium-sized enterprises become competitive digital businesses with faster and smarter adoption of light-based technologies.

This is expected to create more than 1,000 new high-tech jobs in the EU over the next five years and generate nearly € 1 billion in new revenue and venture capital. PhotonHub is scheduled to begin operations in early 2021 and will offer continuous open calls for companies wishing to apply for support.

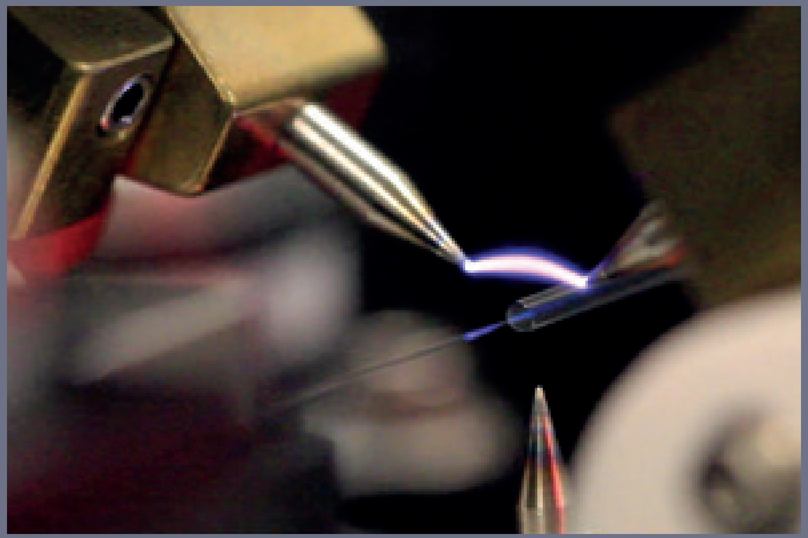
**Photonics experts support companies**

Together with other leading research and innovation institutions, Leibniz IPHT will support companies along the entire value chain, from product concept to market launch. PhotonHub follows on from the previous projects Actphast and Actphast 4.0, in which the institute has already successfully cooperated with companies such as Toptica, Sill Optics, nano4global or WZW Optic AG.

PhotonHub works closely with the European Technology Platform for Public-Private Partnerships "Photonics 21". "We mediate between the European Commission, academia and industry with a view to the strategic development of photonics in Europe," explains Jürgen Popp, chairman of the "Photonics 21" healthcare working group.

**www.photonhub.eu**

# New Competence Center for Special Fiber Optics



Splicing of special fibers for fiber optic modules © Leibniz IPHT

The Fiber Center stands for a key technology of Leibniz IPHT: Here, an experienced team of specialists manufactures optical glass fibers for various research applications. The processes involved in fiber production will be bundled in a newly founded technology center at the institute from 2021. The aim is to make internal processes even more efficient in the future.

At the Competence Center for Special Fiber Optics (CSF), all steps of the technology chain will be interlinked – from simulation to preform production, the drawing process, coating and post-treatment to functionalization. "The individual modules are available to both our research groups and our external cooperation partners,"explains Tobias Habisreuther, who heads the new center. "At CSF, we implement the ideas and results of research technologically," adds deputy Volker Reichel.

To this end, the heads of the research departments and working groups that work with fibers at Leibniz IPHT are in regular exchange. This means that all research areas in which special optical fibers are used have access to an optimal technological infrastructure - from the physics of fibers in basic research to their application in diagnostic devices such as probes and endoscopes: from Ideas to Instruments.

# Faster Together

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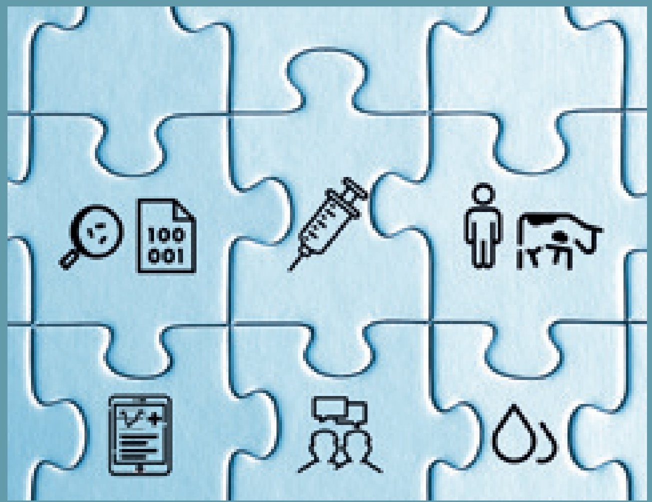
**The InfectoGnostics research campus is entering its next funding phase. The common aim of the partners from research, medicine and industry: better tests for the diagnosis of infectious agents in humans and animals**




"If the campus had not already existed, it would have had to be invented during the pandemic." This is how microbiologist Bettina Löffler from Jena University Hospital and Leibniz IPHT researcher Ralf Ehricht summed up the recipe for success of the Jena InfectoGnostics research campus in the "Thüringer Allgemeine" newspaper in February 2021. The Corona Year 2020 has impressively demonstrated what close co-operation between research, clinical practice and industry can achieve. In April 2020, the Weimar-based diagnostics company Senova, with the support of a research team from Leibniz IPHT, had already launched one of the first antibody tests for the novel virus. Currently, the partners are working, among other things, on a rapid test for the dangerous infectious disease melioidosis – also known as "pseudorotz".

Rapid test specialist Senova is one of the long-standing partners in the InfectoGnostics network; the well-established collaboration simplifies and accelerates joint developments. Since 2013, research and regional companies have been working here in public-private partnership on new ways to diagnose infections. Seven founding members have become more than 30 partners from science, medicine and industry.

After InfectoGnostics successfully completed the first funding round with a focus on pneumonia in immunosuppression, the research campus started the next phase in September 2020 with six new projects. The German government is funding the projects, in which the interdisciplinary teams aim to further advance the development of diagnostic tests, with up to 10 million euros over five years.

### Overcoming hurdles on the way to the approved test

The teams from research, medicine and industry want to develop tests for the diagnosis and resistance determination of infectious agents in humans and animals, as well as investigate the immune response to infections and vaccinations. In addition, the researchers are working with primary care physicians to find solutions for optimally integrating on-site tests into the daily routine of doctors' offices.

"We want to overcome hurdles on the way to an approved test and quickly bring good ideas from research to the market," explains Jürgen Popp, board spokesman of the InfectoGnostics Research Campus Jena. To this end, the research teams in the now launched second phase of the BMBF funding initiative "Research Campus – Public-Private Partnership for Innovation" are working primarily on the development of joint open diagnostics platforms.

**www.infectognostics.de**

InfectoGnostics Forschungscampus Jena

## Detecting Multidrug-resistant Pathogens in Humans and Animals

—

The research team is developing a cost-effective, open testing platform for screening for *Staphylococcus aureus* / MRSA in human and veterinary medicine. The system is designed to detect not only the germ, but also relevant virulence factors and resistance genes, and to enable typing of pathogens.

—

**ADA – Adaptierbare dezentrale Diagnostik für die Tier- und Humanmedizin:** BLINK AG | Leibniz IPHT | Leibniz-HKI | Friedrich-Löffler-Institut | Universitätsklinikum Jena

## Vaccination Status Record Quickly

—

The researchers are developing test formats to rapidly detect the vaccination status of humans and animals and thus contribute to the prevention of infectious diseases worldwide. An open multiparameter platform for lateral flow and microarray testing will enable rapid detection of host immunological response and determination of bacterial resistance factors.

—

**RESISTOVAC – Schnelle und ökonomische POC-Tests zur Bestimmung des Immunstatus und bakterieller Resistenzfaktoren:** fzmb GmbH | senova GmbH | -4H- JENA engineering GmbH | Leibniz IPHT

## For the Everyday Test in the Doctor's Office

—

Together with teaching and research practices in general medicine, the research team is developing a dialog between research, development and practice that mutually identifies patient benefits and clinical needs for point-of-care testing procedures in medical practices. In this way, the experiences of physicians in private practice are to be incorporated at an early stage into the development of new tests for use in local practices.

—

**POCT-ambulant – Forschungs-Entwicklungs-Praxis-Dialog zur bedarfsgerechten Entwicklung von Point-of-Care-Tests für die Primärversorgung:** Universitätsklinikum Jena | Lehr- und Forschungspraxen der Allgemeinmedizin

## Rapid Test for Pathogens and Resistance

—

The research team is building a diagnostic platform that will enable comprehensive Raman spectroscopic pathogen analysis from blood cultures for the first time. The new system builds on the Raman2Go instrument from the first main phase: It is designed to identify bacterial pathogens from positive blood cultures in just 3.5 hours and enable the generation of a resistogram for targeted therapies in the shortest possible time.

—

**InfectoXplore – Spektroskopische Plattform zur Diagnostik von Infektionen aus Blut:** Leibniz-IPHT | Ernst-Abbe-Hochschule Jena | Universitätsklinikum Jena | Biophotonics Diagnostics GmbH | MIBIC GmbH & Co. KG

## How Bacteria Knock Out Antibiotics

—

The research team is investigating how bacteria manage to override the mechanisms of action of antibiotics using machine learning techniques that identify molecular patterns. The goal is to develop an mRNA-based assay to detect phenotypic resistance to carbapenems (reserve antibiotics) in Gram-negative bacteria.

—

**PREPLEX – Phänotypische Resistenz durch Porin-Verlust und Efflux-Überexpression bei gramnegativen Bakterien:** Universitätsklinikum Jena | Curetis GmbH

## Monitoring of Infectious Agents in Wastewater

—

The analysis system to be developed is to detect pathogens in wastewater plants. This will be used to monitor infectious agents and resistance genes. To identify the pathogens, the researchers are combining four complementary detection methods in an open platform.

—

**FastAlert – Früherkennung von Erregern und Resistenzen in Abwasser und Trinkwasser:** Analytik Jena GmbH | Friedrich-Schiller-Universität Jena | fzmb GmbH | UKJ

# Accelerating Innovation in the Fight Against Infectious Diseases

**The Leibniz Center for Photonics in Infection Research has started building its unique technological infrastructure**

In June 2020, representatives of the sponsors signed the cooperation agreement for the LPI in the Senate Hall of the University of Jena. © Daniel Siegesmund

The starting signal has been given: Since March 2021, the construction of innovative light-based technologies for the new Leibniz Center for Photonics in Infection Research (LPI) in Jena has been in full swing. The novel tools are intended to help combat infectious diseases caused, for example, by corona viruses or multi-resistant germs. They lay the foundation for the technological equipment of the translational infrastructure, which is unique in the world and is intended to bring research results into medical application quickly and in a targeted manner.

In the coming years, parallel to the technological infrastructure, the management structures will now be established and the planning for the construction on the site of the University Hospital will be advanced. The German Federal Ministry of Education and Research (BMBF) is funding LPI with 124 million euros until the construction is completed. The groundbreaking ceremony is scheduled for spring 2024 – completion is planned for 2027. By then, novel spectral optical imaging technologies and chip-based methods will already be established in five related projects.

## A globally unique infrastructure

LPI will be open to users from research, industry and medicine – both from Germany and international – from 2027 and will enable them to take research results from proof of concept to certified product in a standardized process. In the process, development steps from basic research to market readiness will be precisely interlinked. The aim is to efficiently transfer solutions for the diagnosis, monitoring and treatment of infectious diseases into routine applications – so that groundbreaking findings from the laboratory quickly reach people.

"Our joint efforts against the Corona pandemic show us time and again what innovative power Germany has as a research location," emphasizes the Federal Minister of Education and Research, Anja Karliczek. "The Leibniz Center for Photonics in Infection Research will use optical methods to break new ground in the diagnosis and treatment of infectious diseases, which are urgently needed to combat them. Many patients will benefit from these important developments for Germany as a medical location," she said. "With LPI, we are also creating the framework for the globally unique interaction of excellent photonics research and innovative technology for state-of-the-art diagnostic methods and direct therapeutic application on patients."

## Therapies to reach patients more quickly

In March 2021, the LPI team will start researching and implementing novel enabling technologies for the translational infrastructure. "I am very pleased that the Jena center is now establishing innovative imaging platforms that use light as a tool for diagnosing infectious diseases in the first of five projects," emphasized the federal research minister. "We are funding these artificial intelligence-based optical technologies with around 14 million euros in this first project."

The basic technologies, together with the latest commercial technologies, form LPI's outstanding infrastructure. "We are complementing state-of-the-art technologies with new photonic processes that do not exist today," explains Jürgen Popp, LPI spokesman. "Users thus have access to the broad spectrum of unique light-based methods in combination with all commercially available technologies to implement solutions for biomedical problems," says Popp. The focus is on spectral optical methods, chip-based methods and spectroscopic imaging technologies.

“ LPI is revolutionizing the diagnosis and treatment of infectious diseases. ”

Federal Research Minister Anja Karliczek in March 2021

## Background

The BMBF is funding LPI 100 percent as part of the National Roadmap for Research Infrastructures with a total of 124 million euros until construction is completed. LPI's partners are Leibniz IPHT, Jena University Hospital, Friedrich Schiller University Jena and the Leibniz Institute for Natural Product Research and Infection Biology – Hans Knöll Institute (Leibniz HKI).

With the project, which began in March 2021, and funding of 13.7 million euros, LPI will start researching and implementing photonic enabling technologies – methods and processes that use light as a tool - for the center. These already application-oriented solutions will be adapted to medical needs. The diagnostic tools allow a fast, reliable and cultivation-free identification of pathogens, resistance as well as immune response.

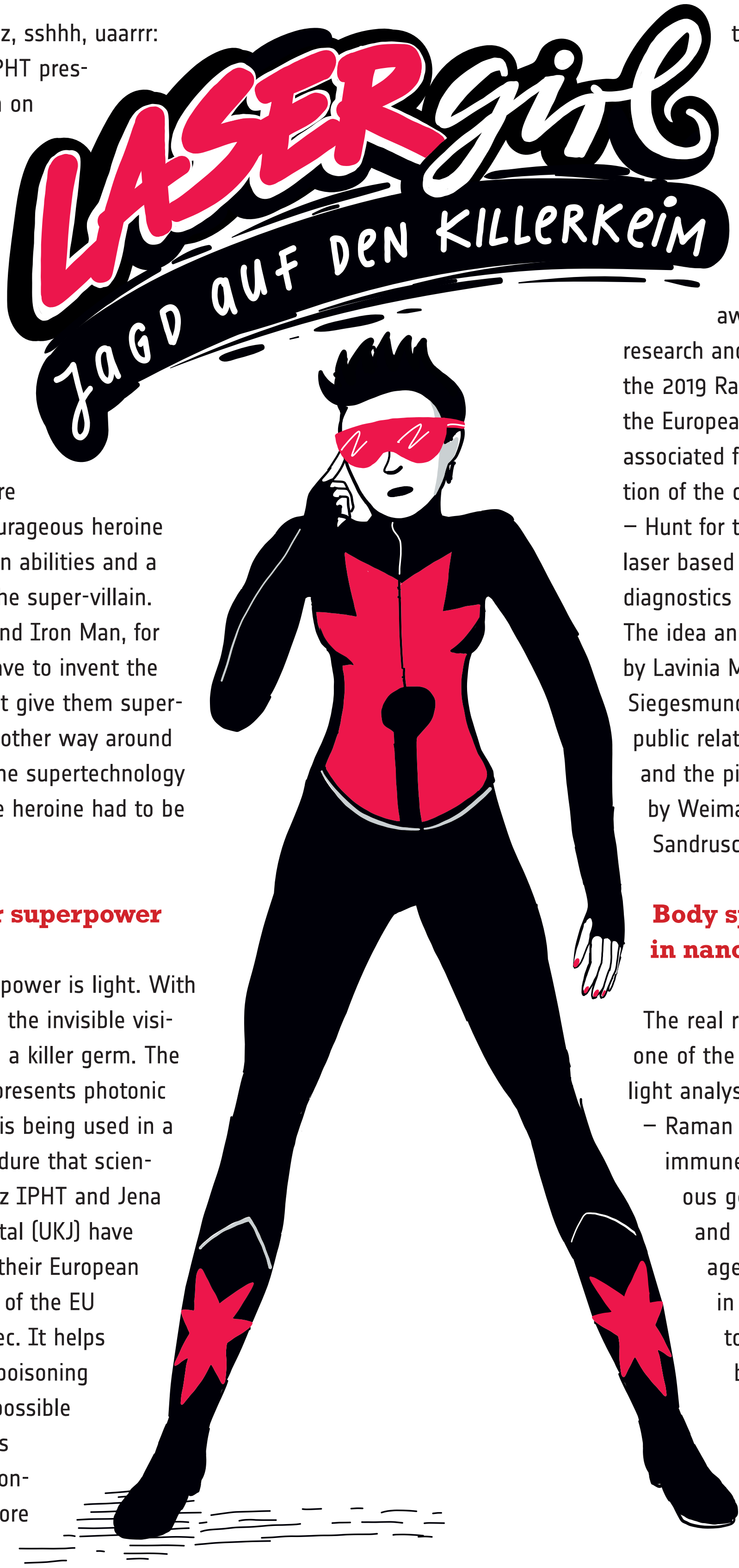
**www.lpi-jena.de**

## Rapid solutions in the fight against multi-resistant germs

As a nationally and internationally open user platform for novel photonic solutions for infection research, LPI is intended to help implement research results more efficiently and shorten development times. Diagnostic procedures and therapies should thus become available more quickly and thus reach patients earlier to fight infections. This is ensured by a holistic approach: "We are bringing excellent research, technology development and everyday clinical practice into close proximity to each other," says Jürgen Popp. In this way, LPI will also enable small and medium-sized companies to achieve standardized results more quickly. "Because not every small company has to reinvent the wheel."

# Infectious-disease Diagnostics as a Superheroine Adventure

**Lasergirl chases the killer germ: Leibniz IPHT has published a comic strip**




Wrommm, brzzzz, sshhh, uaarrr: When Leibniz IPHT presents its research on infection diagnostics, usually other vocabulary is used. Not in this case, because "Hunt for the Killer Germ" is an almost classic superheroine adventure – including a courageous heroine with superhuman abilities and a final duel with the super-villain. While Batman and Iron Man, for example, first have to invent the technologies that give them superpowers, it's the other way around with Lasergirl: the supertechnology exists – only the heroine had to be born first.

## Light is their superpower

Lasergirl's superpower is light. With it, she can make the invisible visible: for example, a killer germ. The superheroine represents photonic technology. She is being used in a diagnostic procedure that scientists from Leibniz IPHT and Jena University Hospital (UKJ) have developed with their European partners as part of the EU project HemoSpec. It helps to detect blood poisoning in the shortest possible time and enables medical professionals to provide more targeted treatments.

For this method and for the idea of telling it in comic form, the German Federal Ministry of Education and Research (BMBF) has awarded the institute's research and communications team the 2019 Ralf Dahrendorf Prize for the European Research Area. The associated funding made the realization of the comic possible. "Lasergirl – Hunt for the Killer Germ" tells the laser based procedure for infection diagnostics as an action adventure. The idea and script were written by Lavinia Meier-Ewert and Daniel Siegesmund from Leibniz IPHT's public relations department, and the pictures were drawn by Weimar-based illustrator Sandruschka.

## Body spaceship in nano mode

The real researchers unleash one of the most sophisticated light analysis methods in physics – Raman spectroscopy – on immune cells and on dangerous germs to detect sepsis and identify the infectious agent. Lasergirl travels in a spaceship shrinking to nanoscale inside the body of a sepsis patient whose life hangs by a thread, and sets out to hunt down the killer germ. In her team she has the actual protagonists: Ute Neugebauer and Anuradha Ramoji, Jürgen Popp and the intensive care physician Michael Bauer from UKJ. In real life, they are also researching the spectroscopic procedure that, for all its creative freedom (rampaging immune police), is the subject of this comic.

"Lasergirl" translates the scientific methods into an action-packed adventure. In the end, the story tells how it actually works to detect multi-resistant germs with the help of a small chip and a laser – and that this could save more than the individual patient. After all, the method could help stop the steadily growing number of multi-resistant germs that render common antibiotics ineffective – and turn harmless infections into a life-threatening danger again in the not-too-distant future.

–


**Publication:** Lasergirl: Jagd auf den Killerkeim. Herausgegeben vom Leibniz-Institut für Photonische Technologien, Jena. Story und Text: Lavinia Meier-Ewert und Daniel Siegesmund Illustration: Sandruschka. ISBN: 978-3-9822875-0-8




## Virtual Light Lab

Together with the Lasergirl comic, the BMBF awarded the Dahrendorf Prize to another idea: With a science pop-up store in a shopping mall, Leibniz IPHT wanted to inspire a broad target group with interactive experience formats for research in the fight against infectious diseases. However, as much as the Corona pandemic made the pressing relevance of this topic clear, it also threw a wrench into the planned pop-up store with public access. And so Leibniz IPHT shifted the offering from public to virtual space. In a digital light lab, the institute makes it possible for schoolchildren in particular to experience its research on infection diagnostics. Films, a digital exhibition, interactive formats and hands-on experiments illustrate how optical health technologies contribute to better diagnosis and treatment of infectious diseases.

# News

## Chairman of the University Council of the EAH Jena ...

Jürgen Popp with EAH Rector Steffen Teichert (center) and Sabine Wosche, Managing Director of the State Development Corporation of Thuringia and Deputy Chairwoman of the University Council. © Marie Koch

... is Jürgen Popp since March 2020. Among other things, the council makes recommendations on the university's profile development and is appointed by the Thuringian Ministry of Economics, Science and Digital Society for a term of four years.

Trainee Pauline Leopold
© Leibniz IPHT

## New Trainees at Leibniz IPHT ...

... is Pauline Leopold. As a future office management assistant, she is getting to know the diversity of the commercial department at a research institute.

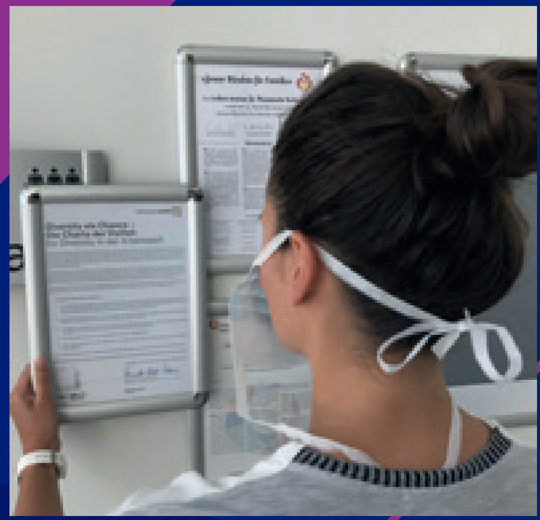


## In Front at the City Cycling

Scientist Henrik Schneidewind contributed almost 1,150 km to the institute's city cycling record. © private

Almost halfway around the world: The Leibniz IPHT team cycled 17,211 kilometers in the nationwide Stadtradeln 2020 campaign – putting it in first place among the research institutions in Jena and in fifth place in the overall local ranking. According to the organizers, the institute's employees, many of whom also commute to work by bike, saved 2,530 kilograms of $CO_2$ during the three-week campaign alone.

## Awarded for Diversity



Officially certified: Leibniz IPHT is part of the Diversity Charter. © Leibniz IPHT

The world of science is international and diverse – and so is Leibniz IPHT. 400 employees from 36 countries enrich the work at the institute. They should have the same opportunities, be able to balance work and family and receive support in difficult life situations – in an environment characterized by open-mindedness and tolerance. Leibniz IPHT is committed to this as an employer and signed the Diversity Charter in 2020.

"We are a colorful, diverse institute where we want to stand up for our employees to feel comfortable and treated equally – no matter how old they are or where they come from, what they believe in, how they live or define themselves, whether they have physical limitations or not," emphasizes Equal Opportunity Officer Sarah Meinhardt, who is a strong advocate for diversity in the workplace.

The commitment of Leibniz IPHT to intercultural openness is exemplary, according to the city of Jena, which recognized it as an intercultural institute at the iWork Business Award 2020.

# Excellent Research

© David Ausserhofer

## German Study Award 2020

to **Dr. Johanna Kirchhoff** for her dissertation on the rapid detection of infectious agents and antibiotic resistance. The Körber Foundation awards this prestigious prize to excellent dissertations of particularly high social relevance.

© private

## Best Thesis Award of the IBA Heiligenstadt

to **Dr. Brenda Doherty** for research on an optical platform for pathogen detection. She earned her doctorate in the departments of fiber photonics and nanobiophotonics.

## Albert Weller Prize

**Dr. Yusen Luo** for her outstanding dissertation in the field of dissertation in the field of photochemistry. This is the second time that the prestigious prize has gone to a researcher from Leibniz IPHT.

© private



## OSA Fellowship 2021

from the Optical Society to **Prof. Volker Deckert** in recognition of his contributions to Raman spectroscopy research.

© Sven Döring

## Ellis R. Lippincott Award

to TERS expert **Prof. Volker Deckert** for his outstanding research work in the field of vibrational spectroscopy. The award is given jointly by the Optical Society, the Coblentz Society and the Society for Applied Spectroscopy.

© Sven Döring

## OSA Senior Member

is **Prof. Jürgen Popp** since 2020. The highest membership status within the Optical Society recognizes achievements and merits in the field of optics and photonics.

## Female Role Models in Analytical Chemistry

are: **Dr. Dana Cialla-May**, **Dr. Izabella J. Jahn**, **Dr. Anna Mühlig**, **Dr. Susanne Pahlow**, **Dr. Karina Weber** and **Dr. Olga Žukovskaja**. The journal "Analytical and Bioanalytical Chemistry" selected the IPHT researchers for the special issue "Female Role Models in Analytical Chemistry".

© Sven Döring

# Publication Highlights


Impact 2019 4,352

**Differential response of liver sinusoidal endothelial cells and hepatocytes to oleic and palmitic acid revealed by Raman and CARS imaging**

–

Biochim. Biophys. Acta-Mol. Basis Dis. | 2020 (6), S. 165763-1 – 165763-9 | DOI: 10.1016/j.bbadis.2020.165763

–

Ewelina Matuszyk | Ewa Sierka | Marko Rodewald | Hyeonsoo Bae | Tobias Meyer | Edyta Kus | Stefan Chlopicki | Michael Schmitt | Jürgen Popp | Malgorzata Baranska

Impact 2019 12,121

nature communications

**A Versatile and Costumizable Low-Cost 3D-Printed Open Standard for Microscopic Imaging**

–

Nat. Commun. | 2020 (11), S. 5979-1 – 5979-9 | DOI: 10.1038/s41467-020-19447-9

–

Benedict Diederich | Swen Carlstedt | Barbora Marsikova | Haoran Wang | Xavier Uwurukundo | Alexander Mosig | Rainer Heintzmann

Eurosurveillance

Impact 2019 6,454

**An epidemic CC1-MRSA-IV clone yields false negative test results in molecular MRSA identification assays: a note of caution**

–

Eurosurveillance | 2020 (25), S. 1 – 8 | DOI: 10.2807/1560-7917.ES.2020.25.25.2000929

–

Stefan Monecke | Elisabeth König | Megan R. Earls | Eva Leitner | Elke Müller | Gabriel E. Wagner | David M. Poitz | Lutz Jatzwauk | Teodora Vremera | Olivia S. Dorneanu | Alexandra Simbeck | Alexander Ambrosch | Ines Zollner-Schwetz | Robert Krause | Werner Ruppitsch | Wulf Schneider-Brachert | David C. Coleman | Ivo Steinmetz | Ralf Ehricht


Impact 2019 14,588

**Present and Future of Surface Enhanced Raman Scattering**

–

ACS Nano | 2020 (1), S. 28 – 117 | DOI: 10.1021/acsnano.9b04224

–

Dana Cialla-May | Volker Deckert | Duncan Graham | Thomas G. Mayerhöfer | Jürgen Popp | Katherine A. Willets | Chuanlai Xu | HonXing Xu | Yikai Xu | Yuko S. Yamamoto | Bing Zhao | Luis M. Liz-Marzán et al.


Impact 2019 6,785

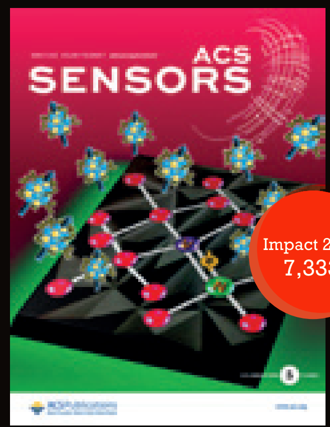
**Fiber-Enhanced Raman Gas Spectroscopy for the Study of Microbial Methanogenesis**

–

Anal. Chem. | 2020 (92), S. 12564 – 12571 | DOI: 10.1021/acs.analchem.0c02507

–

Andreas Knebl | Robert Domes | Sebastian Wolf | Christian Domes | Jürgen Popp | Torsten Frosch




Impact 2019 7,333

**Tracking and analysing the Brownian motion of nano-objects inside hollow core fibers**

–

ACS Sens. | 2020 (3), S. 879 – 886 | DOI: 10.1021/acssensors.0c00339

–

Ronny Förster | Stefan Weidlich | Mona Nissen | Torsten Wieduwilt | Jens Kobelke | Aaron M. Goldfain | Timothy K. Chiang | Rees F. Garmann | Vinothan N. Manoharan | Yoav Lahini | Markus A. Schmidt




Impact 2019 6,785

**Spatiotemporal Organization of Biofilm Matrix Revealed by Confocal Raman Mapping Integrated with Non-Negative Matrix Factorization Analysis**

–

Anal. Chem. | 2020 (92), S. 707 – 715 | DOI: 10.1021/acs.analchem.9b02593

–

Xiao-Yang Liu | Shuxia Guo | Anuradha Ramoji | Thomas W. Bocklitz | Petra Rösch | Jürgen Popp | Han-Qing Yu


Impact 2019 10,655

**Resonance-induced dispersion tuning for tailoring nonsolitonic radiation via nano-films in exposed core fibers**

–

Laser Photon. Rev. | 2020 (6), S. 1900418-1 – 1900418-9 | DOI: 10.1002/lpor.201900418

–

Tilman Lühder | Sebastian Goerke | Erik P. Schartner | Heike Ebendorff-Heidepriem | Markus A. Schmidt


Impact 2019 10,257

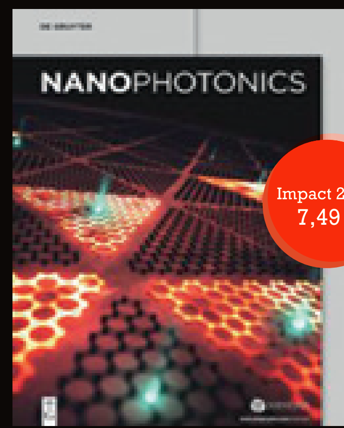
**A miRNA biosensor based on localized surface plasmon resonance enhanced by surface-bound hybridization chain reaction**

–

Biosens. Bioelectron. | 2020 (167), S. 112465-1 – 112465-6 | DOI: 10.1016/j.bios.2020.112465

–

Andrea Miti | Sophie Thamm | Philipp Müller | Andrea Csáki | Wolfgang Fritzsche | Giampaolo Zuccheri




Impact 2019 7,491

**Three-dimensional spatiotemporal tracking of nano-objects diffusing in water-filled optofluidic microstructured fiber**

–

Nanophotonics | 2020 (15), S. 4545 – 4554 | DOI: 10.1515/nanoph-2020-0330

–

Shiqi Jiang | Ronny Förster | Malte Plidschun | Jens Kobelke | Ron Fatobene Ando | Markus A. Schmidt


Impact 2019 11,459

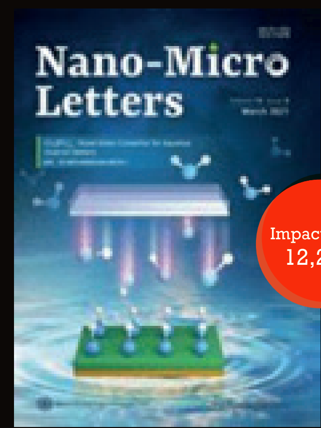
**Multimodal Characterization of Resin Embedded and Sliced Polymer Nanoparticles by Means of Tip-enhanced Raman Spectroscopy and Force Distance Curve Based Atomic Force Microscopy**

–

Small | 2020 (17), S. 1907418-1 – 1907418-11 | DOI: 10.1002/smll.201907418

–

Christiane Höppener | Felix H. Schacher | Volker Deckert




Impact 2019 12,264

**Biomimic Vein-Like Transparent Conducting Electrodes with Low Sheet Resistance and Metal Consumption**

–

Nano-Micro Lett. | 2020 (19), S. 19-1 – 19-13 | DOI: 10.1007/s40820-019-0359-9

–

Guobin Jia | Jonathan Plentz | Andrea Dellith | Christa Schmidt | Jan Dellith | Gabriele Schmidl | Gudrun Andrä

# Key Figures of 2020


**29.113.673 €**
Total budget
= 47,07 % Third-party funding

**15.410.955 €**
Institutional funding

**5.698.246 €**
National projects

**2.135.301 €**
DFG funding

**3.481.023 €**
Industrial projects

**2.388.147 €**
EU third-party funding, 341.127 € thereof from ERA-Net / ERA-NetPlus, JPI etc.

**400**
Employees 2020

**218**
Publications in peer-reviewed journals

**38 %**
Proportion of international researchers and doctoral students

**13** Doctorates,
**3** thereof earned by women

**108**
Talks | Posters
**46** thereof Invited Talks
**3** thereof Keynotes
**4** thereof Plenary Talks
**24** thereof Contributed Talks

**17** Patent applications
**10** thereof patent applications serving as priority

Employees from
**35** countries

**20** EU financed projects
**4** of which coordinated by Leibniz IPHT

**10** Trademark registrations
**6** thereof IR trademark / European Union

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

**15** Patents granted
**10** of which giving rise to priority

# Organizational Chart

**Assembly of Members**

**Board of Trustees**
**Dr. Bernd Ebersold //**
Chair

**Scientific Advisory Council**
**Prof. Dr. Christian Spielmann //**
Commissioner Chair

**Executive Committee**
**Prof. Dr. Jürgen Popp //**
Chairman and Scientific Director
**Frank Sondermann //**
Administrative Director

**Deputy Directors**
**Prof. Dr. Ute Neugebauer //**
Deputy Scientific Director
**Prof. Dr. Benjamin Dietzek //**
Deputy Scientific Director

**Administration**
**Frank Sondermann //**
Head

**Consultants to the Executive Committee**
**Susanne Hellwage //**
Personal Consultant to the Scientific Director
**Dr. Karina Weber //**
Consultant to the Executive Committee

**Employee Representation**
**Claudia Aichele //**
Employee Representative
**Sarah Meinhardt //**
Councillor for Equality
**Tino Fremberg //**
Head of PhD Council

**Staff Units**
**Dr. Ivonne Bieber //**
Project Management and Patents
**Gabriele Hamm //**
Internationalization
**Daniel Siegesmund //**
Public Relations and Research Marketing

# Scientific Advisory Council

## Chair

**Prof. Dr. Cornelia Denz //** University of Muenster, Muenster (until 30.06.2020)

**Prof. Dr. Christian Spielmann //** Friedrich Schiller University Jena, Jena (as of 01.07.2020, before Member)

## Members

**Prof. Dr. Jörg Bewersdorf //** Yale University, Yale, USA (as of 01.07.2020)

**Prof. Dr. Heike Ebendorff-Heidepriem //** University of Adelaide, Australia (until 30.06.2020)

**Eugen Ermantraut //** BLINK AG, Jena

**Prof. Dr. Heinz-Wilhelm Hübers //** Deutsches Zentrum für Luft- und Raumfahrt, Berlin

**Prof. Dr. Werner Mäntele //** Johann Wolfgang Goethe University Frankfurt, Frankfurt

**Prof. Dr. Monika Ritsch-Marte //** Medical University of Innsbruck, Innsbruck (until 30.06.2020)

**Prof. Dr. Katja Schenke-Layland //** Eberhard Karls University of Tübingen, Tübingen (as of 01.07.2020)

**Prof. Dr. Frank W. Weichold //** Food and Drug Administration, Silver Spring, USA



# Research Units

## Research Departments

**Spectroscopy / Imaging**
Prof. Dr. Jürgen Popp

**Nanobiophotonics**
apl. Prof. Dr. Wolfgang Fritzsche

**Nanoscopy**
Prof. Dr. Volker Deckert

**Microscopy**
Prof. Dr. Rainer Heintzmann

**Biophysical Imaging**
Prof. Dr. Christian Eggeling

**Clinical Spectroscopic Diagnostics**
Prof. Dr. Ute Neugebauer

**Nanooptics**
PD Dr. Jer-Shing Huang

**Optical Molecular Diagnostics and System Technology**
Prof. Dr. Ralf Ehricht

**Photonic Data Science**
PD Dr. Thomas Bocklitz

**Fiber Research and Technology**
Prof. Dr. Tomáš Čižmár

**Fiber Photonics**
Prof. Dr. Markus Schmidt

**Quantum Detection**
Prof. Dr. Heidemarie Schmidt

**Functional Interfaces**
Prof. Dr. Benjamin Dietzek

**Quantum Systems**
Dr. Ronny Stolz

## Junior Group

**Ultra Fast Fiber Lasers**
Dr. Maria Chernysheva

## Technology Groups

**Competence Center Micro- and Nanotechnologies**
Dr. Uwe Hübner

**Competence Center for Specialty Optical Fibers**
Dr. Tobias Habisreuther

**Sensor Systems and System Technology**
Dr. Walter Hauswald

# Board of Trustees

## Chair

**Dr. Bernd Ebersold //** Thuringian Ministry of Economy, Science and Digital Society, Erfurt

## Members

**Klaus Berka** // Jena

**Dr. Ludwin Monz** // Carl Zeiss Meditec AG, Jena

**Prof. Dr. Georg Pohnert //** Friedrich Schiller University Jena, Jena

**Dr. Petra Wolff** // Federal Ministry of Education and Research, Bonn

# Assembly of Members 2020

## Membership of Institutions

**Ernst-Abbe-Hochschule, Jena** // represented by the Rektor Prof. Dr. Steffen Teichert

**4H Jena Engineering GmbH, Jena** // represented by Michael Boer

**Sparkasse Jena** // represented by Michael Rabich

**CiS Institut für Mikrosensorik e. V., Erfurt** // represented by Prof. Dr. Thomas Ortlepp

**j-fiber GmbH, Jena** // represented by Dr. Ulrich Lossen

**Robert Bosch GmbH, Stuttgart** // represented by Hartmut Spennemann

**Friedrich-Schiller-Universität Jena** // represented by Dr. Jörg Neumann

**Stadt Jena** // represented by Lord Major Dr. Thomas Nitzsche

**Leibniz-Institut für Festkörper-und Werkstoffforschung e. V., Dresden** // represented by Prof. Dr. Oliver G. Schmidt

**Thüringer Ministerium für Wirtschaft, Wissenschaft und Digitale Gesellschaft, Erfurt** // represented by Jana Podßuweit

## Personal Members

**Prof. Dr. Hartmut Bartelt** // Leibniz Institute of Photonic Technology, Jena

**Prof. Dr. Hans Eckhardt Hoenig** // Erlangen

**Dr. Klaus Fischer** // Jena

**Elke Harjes-Ecker** // Thüringer Staatskanzlei, Erfurt

**Bernd Krekel** // Commerzbank AG, Gera

**Prof. Dr. Jürgen Popp** // Leibniz Institute of Photonic Technology, Jena

**Frank Sondermann** // Leibniz Institute of Photonic Technology, Jena

**Prof. Dr. Herbert Stafast** // Jena



# Budget of the Institute 2020

in T Euro

## Institutional Funding : Verwendung

| | |
|---|---|
| Free State of Thuringia, Federal | 15.411,0 |

## Third-Party Funding

| | |
|---|---|
| Third-Party Funding | 13.702,7 |
| **total** | **29.113,7** |

## Institutional Funding: Use

| | |
|---|---|
| Staff | 9.754,2 |
| Materials | 4.036,2 |
| Investments | 1.620,6 |
| **total** | **15.411,0** |

## Third-Party Funding

| | |
|---|---|
| Federal Ministries<br>of which for projects funded by Leibniz Association 607,1 T€ | 3.676,5 |
| DFG<br>Additionally IPHT-scientists at the University Jena used DFG-funds of 588,3 T€ | 2.135,3 |
| Free State of Thuringia<br>of which for restructuring in the frame of EFRE 786,4 T€ | 1.727,5 |
| EU<br>of which for EU-Initiatives such as ERA-Net / ERA-NetPlus, Joint Programming Initiatives and more: 341,1 T€ | 2.388,1 |
| Assignments from Public Institutions | 71,2 |
| Other Contributions | 294,3 |
| Subcontracting in Joint Projects | 211,8 |
| R & D Contract incl. Scientific-Technical Activities | 3.198,0 |
| **total** | **13.702,7** |

# Institute Personnel 2020

| | Full-time Equivalents | | | | |
|---|---|---|---|---|---|
| | Institutional Funding | Third-Party Funding | Professors | Total | Persons |
| **Scientists** | 49,65 | 55,02 | 8,00 | 112,67 | 125 |
| **External Funded Scientists**[1] | - | - | - | - | 16 |
| **Visiting Scientists**[2] | - | - | - | - | 20 |
| **Doctoral Students** | 13,85 | 26,80 | - | 40,65 | 70 |
| **External Funded Doctoral Students**[1] | - | - | - | - | 41 |
| **Technical Staff** | 40,67 | 33,77 | - | 74,44 | 80 |
| **External Funded Employees**[1] | - | - | - | - | 1 |
| **Administration** | 13,32 | 11,17 | - | 24,49 | 26 |
| **Scientific Coordination** | 2,50 | 5,63 | - | 8,13 | 9 |
| **PR and Research Marketing** | 2,62 | 3,88 | - | 6,50 | 7 |
| **Trainees** | 3,00 | - | - | 3,00 | 3 |
| **Executive Committee** | 1,00 | - | 0,50 | 1,50 | 2 |
| **Total Personnel** | **126,61** | **136,27** | **8,50** | **271,38** | **400** |

[1] 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)

[2] Scientists, who worked in the legal year 2020 longer than one month and who are financed by another institution. Key date regulation 31.12.2020 does not apply.

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