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LEIBNIZ INSTITUTE *of* PHOTONIC TECHNOLOGY // ANNUAL REPORT 2017

Leibniz ipht
LEIBNIZ INSTITUTE *of* PHOTONIC TECHNOLOGY

Leibniz Association

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Thank you very much.

We would like to thank all our employees most cordially for their hard work and high level of commitment on a daily basis. We would also like to thank the Free State of Thuringia and the Federal Government, as well as all sponsors and partners from politics, science and industry, for their many years of close and trusting cooperation. We look forward to continuing to work successfully together in the future.

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Dear Readers,

» Annual reports traditionally publish current key figures at the beginning of the year. How high is the total budget? What is the proportion of third-party funds? How many patents have been issued and how many scientific articles published? This and other key data can also be found in this current report. This data impressively shows that 2017 was a very successful year for the Leibniz IPHT. Even so, these indicators reveal only very little about the underlying motivation of our actions.

It would be wrong if we were to consider the attempts to achieve increasingly better key figures as the only driving force behind our work. But what is it then that motivates us? Is it only the increase in knowledge – the desire to understand what holds the world together at its very core? From the very beginning, basic research has been a top priority at Leibniz IPHT, however it does not describe the totality of our research profile.

What drives us on is the desire to make a contribution with our research work as a response to existing social challenges. This applies in particular to the fields of medicine, health, environment and safety. In this annual report, we would like to present you with selected photonic solutions for use in medicine and the health care sector and go into the underlying technological innovations in each case. Furthermore, we highlight certain aspects of translation: what contribution can we – together with partners from science, business, politics and clinics – make in order to transform technical solutions into marketable applications?

I hope you very much enjoy reading this report.

Jürgen Popp
Scientific Director

Frank Sondermann
Administrative Director

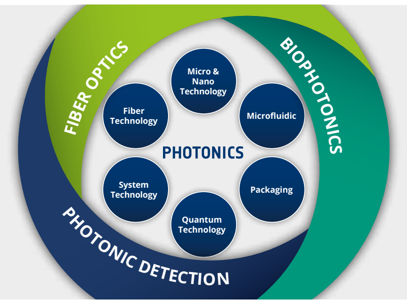
Prof. Dr. Jürgen Popp

Frank Sondermann

Contents

6
Optical Health Technologies

In correspondence to the motto "Photonics for Life", scientists at the Leibniz IPHT conduct research into photonic and biophotonic solutions for issues pertaining to the fields of medicine, health, the environment and safety.



8
Infection Diagnostics: From the Laboratory to the Clinic

How translational research can overcome structural gaps in the innovation chain

10
Tracking down Antibiotic Resistance

When combined with microfluidic lab-on-a-chip systems, light-based diagnostic technologies can detect bacterial pathogens and their antibiotic resistance in approximately three hours.

12
Bacteria, Viruses or Fungi

A nanoparticle-based optical analytical method can reliably identify several pathogens at the same time.

14
SERS as a Universal Analytical Tool

Highly sensitive spectroscopy integrated into microfluidic cartridge systems enables on-site analysis in many fields of application.

16
View Inside the Body

New technologies enable high-tech microscopes to shrink to ballpoint pen size.

20
Silicon Nanoparticles for the Medicine of the Future

The exceptional properties of silicon nanostructures are used to research into new radiation sensors and cancer theranostics.

22
Innovation through Cooperation

Diversity as a strength: Cooperation in the Leibniz Health Technologies research alliance

26
Building Bridges

System technology paves the way for innovations.

28
More than the Sum of all the Parts

International cooperations opening up synergies.

30
Promoting Young Talent

The promotion of outstanding young researchers is a cornerstone of the further scientific development of the Institute.

32
Welcome to the Team

With three new appointments, we have succeeded in attracting internationally high-ranking scientists to Jena to make their mark on and further improve the Institute's research priorities of biophotonics, fiber optics and quantum detection.

34
Outstanding Personnel

Award-winning science from the Leibniz IPHT

36
Royal Splendor

The Dutch King Willem-Alexander and Queen Māxima as guests at the Leibniz IPHT.

38
Scientific Articles in the App

40
Facts and Figures

42
Organization Chart, Research Units

43
Scientific Advisory Council, Board of Trustees

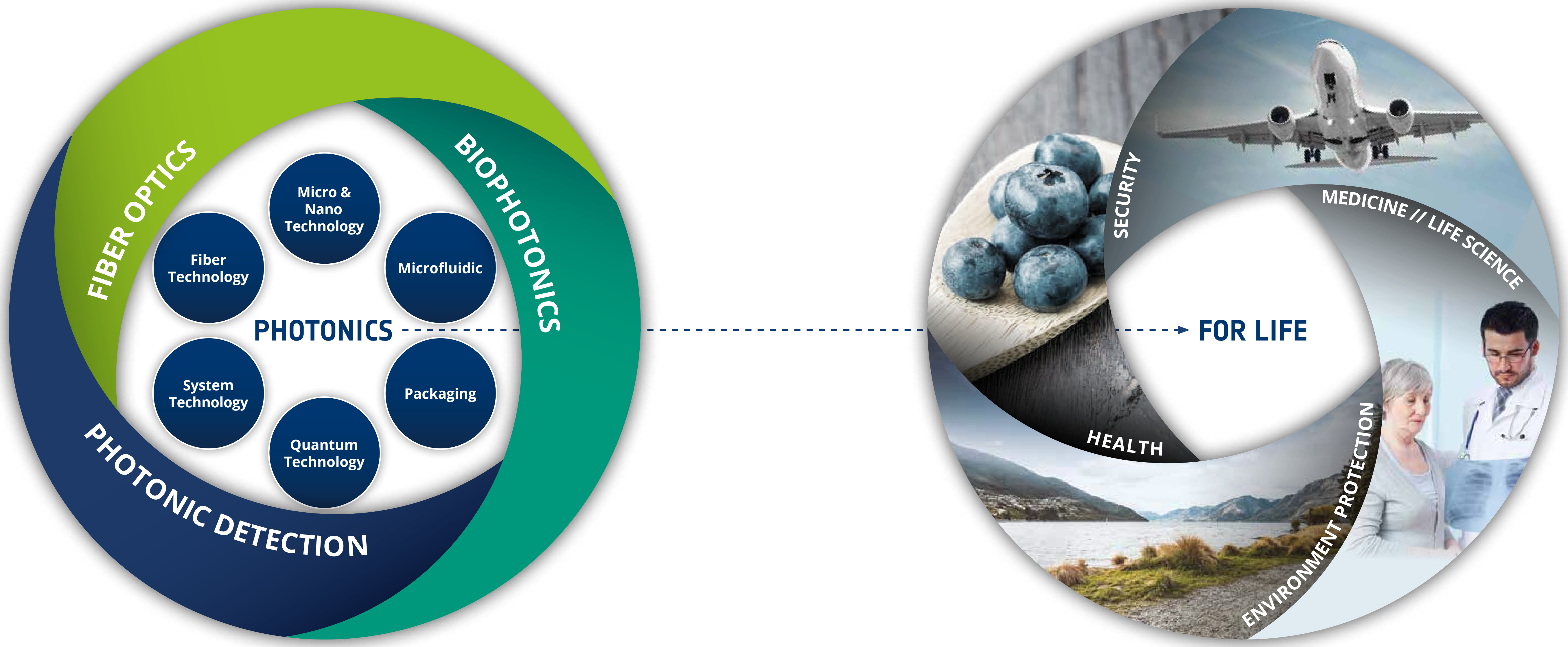
44
Assembly of Members

45
Institute Finances

46
Institute Staff

Optical Health Technologies

From Ideas to Instruments



» ***In correspondence to the motto "Photonics for Life", scientists at the Leibniz IPHT conduct research into photonic and biophotonic solutions for issues pertaining to the fields of medicine, health, the environment and safety. The findings obtained from research are translated into application-oriented processes, instrumental concepts and laboratory model setups.***

The Leibniz IPHT works at the interface of three focal points of research: fiber optics, photonic detection and biophotonics. The research activities aim to explore new dimensions in (bio)photonic solutions in terms of resolution, sensitivity, specificity, speed, accuracy and automation.

Successes in these categories form the basis for research and development of modern optical health technologies such as faster and more precise medical diagnostics. The entire process chain is mapped, including sample preparation and handling, as well as the evaluation of statistical, chemometric and image-related data in particular are mapped.

The aim is to provide not only medical, but also life and environmental science partners with new analytical, diagnostic and examination methods and establish a bridge function between optics and photonics on the one hand and life and environmental sciences and medicine on the other. Solutions from the Leibniz IPHT contribute towards making our lives safer and healthier.

The Leibniz IPHT conducts intensive basic research in the fields of micro- / nanotechnology, quantum technology, microfluidics, packaging, as well as fiber and system technology for the requisite technical implementation. The outstanding core competencies of our personnel in combination with an excellent infrastructure and exceptional technical equipment represent a unique selling point of the Leibniz IPHT. In the research of photonic health technologies, the scientists can therefore rely on a broad technological portfolio within the Institute. Furthermore, the cooperation with a large number of national and international partners results in interdisciplinary perspectives that the Institute can profitably incorporate into its own research activities.

In accordance with the motto "From Ideas to Instruments", the Leibniz IPHT maps the entire chain from basic technological research to translation into tailor-made solutions for various applications.

Infection Diagnostics: From the Laboratory to the Clinic

How Translational Research can Overcome Structural Gaps in the Innovation Chain

» The assumption that infectious diseases can be completely had to be revised in the last few years. In particular, the worldwide spread of (multi-)resistant bacteria and fungi and the emergence of previously unknown pathogens represent a massive worldwide threat today. In view of the current situation, new diagnostic and therapeutic methods need to be investigated for the fight against multi-resistant pathogens. Interdisciplinary and translational research infrastructures are required to ensure that research results benefit patients more effectively and faster than ever before.

On average, it takes 14 years to further develop an idea into a marketable product. Many concepts cannot be translated into practice as resources and development structures are not available or not open to users. As a result, the innovation potential available in Germany cannot be fully exploited. Patients only benefit from research results after a long delay. “We urgently need to change this situation”, says Prof. Jürgen Popp, Scientific Director of the Leibniz Institute for Photonic Technologies.

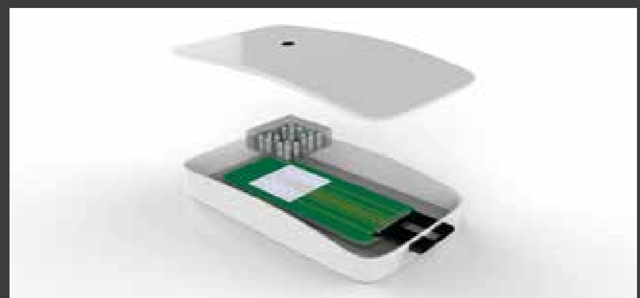
The Leibniz IPHT, together with ten scientific institutions and associations, has called on the German government to create translational research infrastructures in hospitals. Doctors, scientists and technology developers are calling for the following:

- Stronger support for the development of new diagnostic methods
- Improving research into new therapeutic approaches
- The acceleration of innovations
- Creating scope for interdisciplinary research

“With the support of politicians, various skills and experience from different fields need to be brought together in a structured manner and we jointly need to develop specific strategies for combating infections”, explains Popp. The aim is to explore new diagnostic approaches, further develop existing ones and convert them into clinical applications. Photonic technologies – processes that use light as a tool – offer one possible approach in this respect. They have the potential to revolutionize the diagnosis of infections. As they are fast and direct and do not require the prior, time-consuming cultivation of samples, it is possible to detect pathogens and their resistances within two to three hours.

At the same time, however, novel therapeutic solutions and experimental therapy approaches need to be researched and clinically tested. Among other things, these include treatment with new combinations of existing active substances, the use of nanoparticles as drug carriers, immunocell-based therapies or completely new types of therapies that prevent – or at least delay – the development of resistance on the part of such micro-organisms. This requires not only close cooperation between natural scientists, technology developers, medical experts and medical technology manufacturers, but also standardized processes and innovative concepts of research management. Questions relating to clinical validation and certification must be to the fore from the very beginning. According to Popp, “Existing gaps in the innovation chain – from basic research to market launch – should be overcome in structural terms in order to shorten the development time to just a few years.”

Prof. Jürgen Popp (Leibniz IPHT), Prof. Axel Brakhage (Leibniz-HKI) and Prof. Michael Bauer (University Hospital Jena) are developing joint strategies to combat infectious diseases.



RamanBioAssay design study: Any hurdles to further development into a marketable product have to be overcome structurally.

Design of the LPI building on the campus of University Hospital Jena

The LPI ...

... is one of eleven concepts for comprehensive research infrastructures which has been evaluated and subjected to a comparative assessment by the German Council of Science and Humanities at the request of the Federal Ministry of Education and Research (BMBF). The evaluation process is intended to serve as a basis for the BMBF's decision on its inclusion in the National Roadmap, the program for large-scale research projects of the Federal Government, in the coming legislative period. Extensive research infrastructures such as the LPI are an indispensable prerequisite for being able to deal with scientifically demanding issues and conducting top-quality research that is able to keep up internationally. The establishment of the LPI was applied for by the Leibniz Institute for Photonic Technologies Jena e.V. (Leibniz IPHT), the Leibniz Institute for Natural Products Research and Infection Biology – Hans Knöll Institute (Leibniz-HKI), University Hospital Jena and the Friedrich Schiller University in Jena under the patronage of the Leibniz Association.

Leibniz Center for Photonics in Infection Research

From 2019 on it would be possible to establish an interdisciplinary, user-open center in Jena where photonic solutions for the diagnosis, monitoring and experimental therapy of infections are researched and developed into functional solutions in cooperation with industry – the Leibniz Center for Photonics in Infection Research (LPI). By combining photonic methods with infection research, the LPI creates diagnostic approaches and targeted therapies which are directly transferred to applications and industrial products. One aim is to bring together diagnostics and therapy – so-called theranostics. In the assessment of the German Council of Science and Humanities, the LPI can therefore “revolutionize pathogen diagnostics worldwide” and offers “enormous potential for the development of new technologies, new sensors and measuring techniques, as well as new lead structures”.

“Unique, outstanding, groundbreaking and pioneering.”

German Council of Science and Humanities: “Report on the science-led evaluation of large-scale research infrastructure projects for the National Roadmap” // www.wissenschaftsrat.de

PhD student Marcel Dahms using a Raman micro-spectroscope to record the specific vibrational spectra of the bacteria fixed in the chip.

Tracking down Antibiotic Resistance

A Chip for Rapid Infection Diagnostics

» When combined with microfluidic lab-on-a-chip systems, light-based diagnostic technologies can detect bacterial pathogens and their antibiotic resistance in approximately three hours. This means that the technology is many times faster than current standard biochemical and molecular-biological diagnostic methods. At the interface of photonics, medicine, microfluidics and system integration, the Leibniz IPHT works together with the Center for Sepsis Control and Care (CSCC) at the University Hospital Jena (UKJ) on practical photonic on-site diagnostic procedures.

Bacterial pathogens are the cause of common infectious diseases such as bladder inflammation and can be the triggers of life-threatening sepsis. In order to initiate treatment with an effective antibiotic in time, medical specialists require reliable information about the resistance potential of the bacterium. The demands placed on the test procedures are high: They must be fast, simple, specific and sensitive. Furthermore, it must be possible to automate the methods for use in routine analysis. Only in this way can a large number of infectious samples be analyzed in parallel and safely, i. e. with as little contact as possible with the user. The usual microbiological diagnostic procedures are time-consuming. Even automated biochemical test methods require a full working day. Until a result is available, medical specialists often administer a broad-spectrum antibiotic in order to counteract the infection. This non-specific medication promotes the spread of resistant pathogens, the increasing number and spread of which reduces the opportunities for treating infectious diseases.

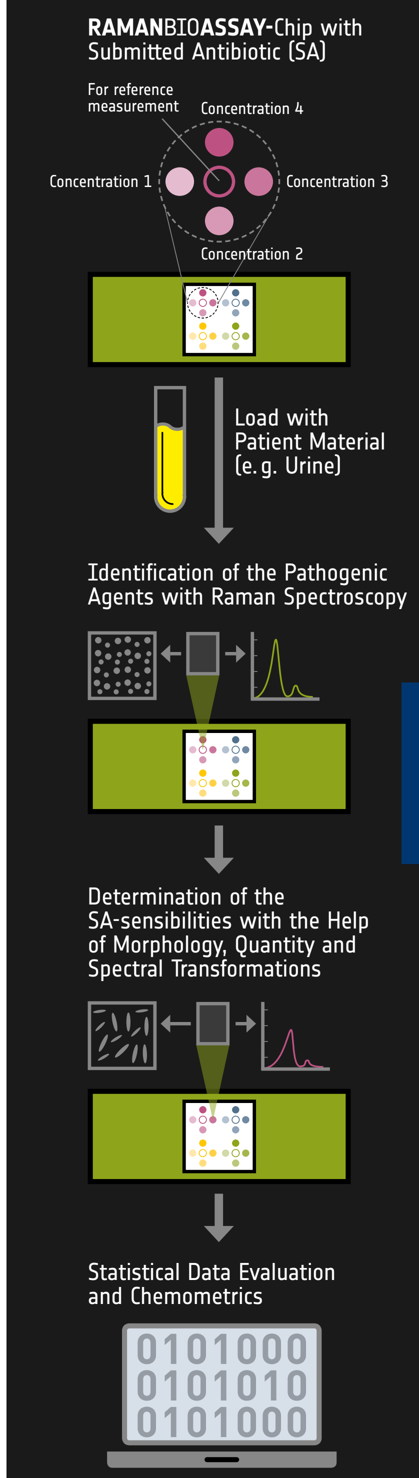
Scientists from the Leibniz IPHT, the University of Jena and the CSCC at the UKJ are conducting research into fast and cost-effective alternatives to existing pathogen diagnostics. For this purpose, the team – led by Prof. Dr. Ute Neugebauer – combines light-based diagnostic technologies with microfluidic sample processing. “With the lab-on-a-chip system, i. e. a miniaturized laboratory, we can clearly identify bacterial strains and their resistances in just three and a half hours. In addition to the qualitative result, i. e. whether the strain is resistant or sensitive, we also obtain quantitative information. This enables us to estimate the minimum concentration of the antibiotic required to inhibit bacterial growth”, is how the physicochemist explains the advantage of the method. The microfluidic lab-on-a-chip systems are produced by micro- or nano-structuring in the clean room at the Leibniz IPHT.

For the Raman spectroscopic method, just a few drops of a patient sample are sufficient. “For example, we can put the urine of a patient with bladder inflammation into the chip without using any complicated sample preparation method. The automated analytical process no longer requires contact with the potentially contagious material”, Neugebauer goes on. Electrical fields capture the bacteria from the sample in a specific region of the chip, where they are identified on the basis of their specific Raman spectrum and its comparison with databases.

In order to determine the antibiotic resistance, researchers exchange the liquid in the chip against a solution containing the antibiotic to be tested. The bacteria remain held in place by the electric fields. Within a measuring time of two hours, fine differences become apparent in the Raman spectra of the pathogens. Too fine to draw conclusions about the existence of resistance with the naked eye. The analytical algorithms that have been developed by their cooperation partner Dr. Thomas Bocklitz in his “Statistical Modeling and Image Analysis” working group at the Leibniz IPHT take over this task. “We use algorithms for data analysis which we train beforehand to recognize minimal differences in the spectra. They provide a ‘Medication Effectiveness Score’ that enables the medical expert to take a reliable decision irrespective of the device and the operator on the basis of the question: Is the bacterial strain resistant or not?” explains Bocklitz.

Current research projects with local companies aim to parallelize the methods for rapid resistance testing and therefore achieve higher sample throughput. With chips which catch the bacteria at several locations simultaneously, it is possible to test four different antibiotics of different concentrations at the same time. Another area of research is the isolation of pathogens from the sample. Here, the findings from the work with urine samples are to be transferred to more complex body fluids such as blood or sputum and further developed so that in future the test can be used for (almost) all patient samples.

Determination of the Minimum Inhibitory Concentration of Several Antibiotics



Result in **ca. 3 Hours**

Anti-biotics	Antibiotic Concentration				Result
	Conc. 1	Conc. 2	Conc. 3	Conc. 4	
SAX1	✗	✓	✓	✓	S
SAX2	✗	✗	✗	✓	R
SAX3	✓	✓	✓	✓	S
SAX4	✗	✗	✗	✗	R

Resistogram with Minimum Inhibitory Concentration (MIC)

Localized Surface Plasmon Resonance

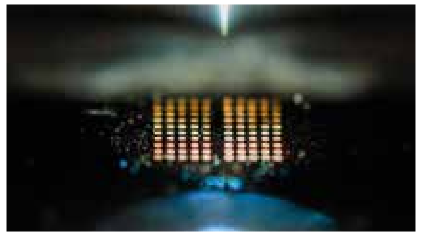
Nanoparticles made of gold or silver interact with light under certain conditions. The free electrons in the metal atoms of the particles then start to vibrate coherently, i.e. at the same frequency. The collective oscillations of the electrons parallel to the surface of the metal are called localized surface plasmons. They absorb and scatter visible light of different wavelengths depending on the size, shape and material of the nanoparticles and their environment. The latter is made use of by researchers to find answers to bioanalytical questions. If an analyte molecule binds to the recognition structures on the surface of the metal nanoparticles, the refractive index – and therefore the wavelength – of the surface plasmons on the metal surface there changes. The spectral change is recorded and evaluated.

Depending on the size, material and geometry, the suspensions of plasmonic nanoparticles are colored differently.

Bacteria, Viruses or Fungi?

Nano-sensors for Rapid Pathogen Identification

» ***It is necessary to know the pathogen or pathogens precisely in order to combat them as quickly as possible in a targeted manner. A nanoparticle-based optical analytical method can reliably identify several pathogens at the same time – within a few hours and without complex cultivation processes. As a result, the technology could be used in medicine, life sciences, biotechnology and environmental protection.***



A microarray with spots of plasmonic gold nanoparticles.

A cancer patient shows symptoms of infection after chemotherapy. High fever, chills and shortness of breath indicate sepsis. Is the infection caused by bacteria or fungi? A quick and clear answer to this question can be a matter of life and death for the patient. Only early treatment with the right therapeutic agent can stop the spread of the pathogen in the woman's body. The problem facing medical specialists becomes particularly clear in the case of sepsis caused by fungal infection. This is difficult to diagnose, as growing fungal cultures in order to accurately determine the species takes several days – even longer than is the case with bacteria. Molecular biological diagnostics, which currently promise the highest probability of success, identify each pathogen type individually. As a consequence, the amount of materials and time required is high and the search is not always successful at the first attempt. Doctors are reluctant to administer a broad-spectrum fungicide in the meantime merely on the basis of a suspected diagnosis because such treatment weakens the patient to a significant degree. Until the correct therapy can be initiated, valuable time passes, during which the patient's chances of survival diminish drastically.

Apl. Prof. Dr. Wolfgang Fritzsche, Head of the Department of Nanobiophotonics at the Leibniz IPHT, relies on optical technologies and nanoparticles for fast and reliable pathogen determination. “We use a label-free, light-based method in order to detect sepsis-relevant fungi on the basis of their DNA. The new aspect about the method is that we are able to identify five different fungus species at the same time”, says Fritzsche, referring to the result of the BMBF-funded project “ImSpec”. Up to now, such tests have been carried out one after the other using individual measurements, which mostly required complex laboratory set-ups with expensive microscopes and spectrometers. “Our aim is to create robust and inexpensive systems for point-of-care bio-analytics”, is how Dr. Andrea Csáki, head of the working group, describing the future of the technology. This is the reason why the team under the chemist is conducting research into new sensor concepts. They arrange gold nanoparticles on chips in the form of a microarray and integrate these chips into microfluidic cartridge systems, which are produced in the cleanroom of the Leibniz IPHT. Individual spots of the microarray are functionalized with molecular recognition structures of different fungal groups. The scientists pass the isolated pathogen DNA through the cartridge, where it binds to the surface of the matching gold particle spot, which is found at a specific location. The nano-sensors then change their optical properties. “We then read out the individual spots of the microarray with an imaging method”, Csáki goes on. “This enables us to determine the spectral information from all image points at the same time, so that the analysis time, which now no longer increases with the number of measurement points, is much shorter.” The process only takes a few hours from drawing of the sample to the result.

> ***“Our goal is robust and cost-effective systems for on-site bioanalytics”.***
>
> Dr. Andrea Csáki // Head of Work Group Nanobiophotonics

One Platform, Various Fields of Application

Depending on the analytical problem, the protocol can be adapted for the detection of different pathogens. In this way, the scientists are not only able to determine different sepsis-causing fungi, but also bacterial germs and their antibiotic resistance. Additionally the chip-based platform can be used to detect germs which are harmful to health and resistance genes in the environment. In surface waters in particular, researchers consider the increasing number of antibiotic-resistant bacteria to be problematic. For this reason, the Leibniz IPHT is working within the framework of the international EU joint projects “TRACE” and “WaterCHIP” on plasmonic chip-based methods that detect pathogens and resistance genes quickly and reliably in waterbodies.

Dr. Dana Cialla-May taking water samples from the Saale River and adding defined amounts of an antibiotic to them. The physicochemist uses the "spiked" samples to conduct research into powerful SERS-based analytical methods.

SERS as a Universal Analytical Tool

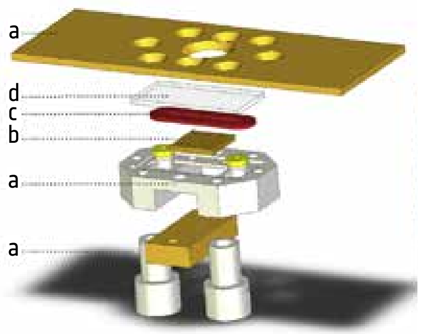
Spectroscopy Serving the Purposes of the Environment and Health

» Surface-enhanced Raman spectroscopy (SERS) is a powerful and sensitive analytical method for aspects of biological, clinical and environmental analysis. SERS combines the molecular specificity of Raman spectroscopy with high sensitivity based on the use of plasmonic nanostructures. However, it is only the combination of SERS analytics with microfluidic lab-on-a-chip systems produced in the clean room of the Leibniz IPHT which enables us to detect small concentrations of a molecule in a sample. Not only fast and easy, but also robust, cost-effective and automatable, the systems enable, for example, the quantitative determination of drug residues in surface waters.

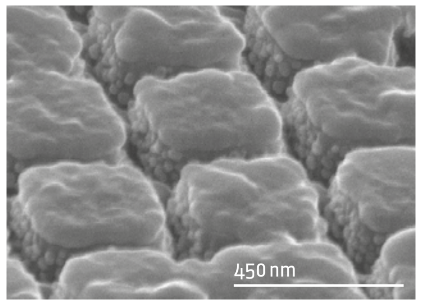
Drugs such as antibiotics and their metabolic products are found not only in body fluids of people who are ill. The residues of prescription drugs which have been administered to patients are carried by the wastewater to sewage treatment plants, where some substances are only partially removed – if at all. If such residues pass into the environment, they can cause damage not only to ecosystems, but also human beings themselves. This includes the spread of multi-resistant bacterial strains in drinking and surface water. Sulphamethoxazole, an allergenic antibiotic that is often administered to treat urinary tract infections, is detectable in surface waters all over the world. Ensuring high water quality therefore requires fast, robust and inexpensive analytical methods that also detect even the smallest impurities.

Due to their high sensitivity and specificity levels, SERS-based analytics are suitable for environmental monitoring, as well as the monitoring of food quality or drug levels in saliva or urine samples from patients. Researchers at the Leibniz IPHT have further increased the reproducibility and sensitivity of the method. They integrate nano-structured SERS-active substrates into compact, microfluidic lab-on-chip cartridge systems. For the production of the SERS substrates and microfluidic components, the scientists can make use of the established micro- and nano-technologies, as well as the technological infrastructure of the clean room at the Leibniz IPHT. Here, customized SERS-active substrates consisting of silver or gold with regular nanostructures are produced by means of electron beam lithography. The structures amplify the Raman signals of the analyte molecules, which bind to their surface, by several orders of magnitude. The reproducible substrates and the droplet-based microfluidic platform enable the detection of low-concentrated analytes (µM to nM range) in complex samples. The time required for the analysis is shorter than with conventional chromatographic methods due to the minimal sample preparation requirement, automated sample feed and the high measuring speed.

The application potential of SERS lies primarily in the field of on-site analytics. In the future it will be possible to carry out a preliminary analysis of several hundred samples for certain substances with minimal effort using the inexpensive and fast high-throughput method. After this screening, only the "hits" would then be precisely determined in the laboratory using the established chromatographic analysis methods. At present, the Leibniz IPHT scientists are working on further minimizing the sample preparation process. To this end, they are investigating substrates that have a high affinity to the analyte and are therefore able to locate the substances even more easily in complex sample matrices.



Microfluidic system for SERS-based analysis, (a) cartridge, (b) SERS substrate, (c) microfluidic silicone channel, (d) glass cover



SERS substrate consisting of a nano-structured quartz wafer coated with a 40 nm thick layer of silver

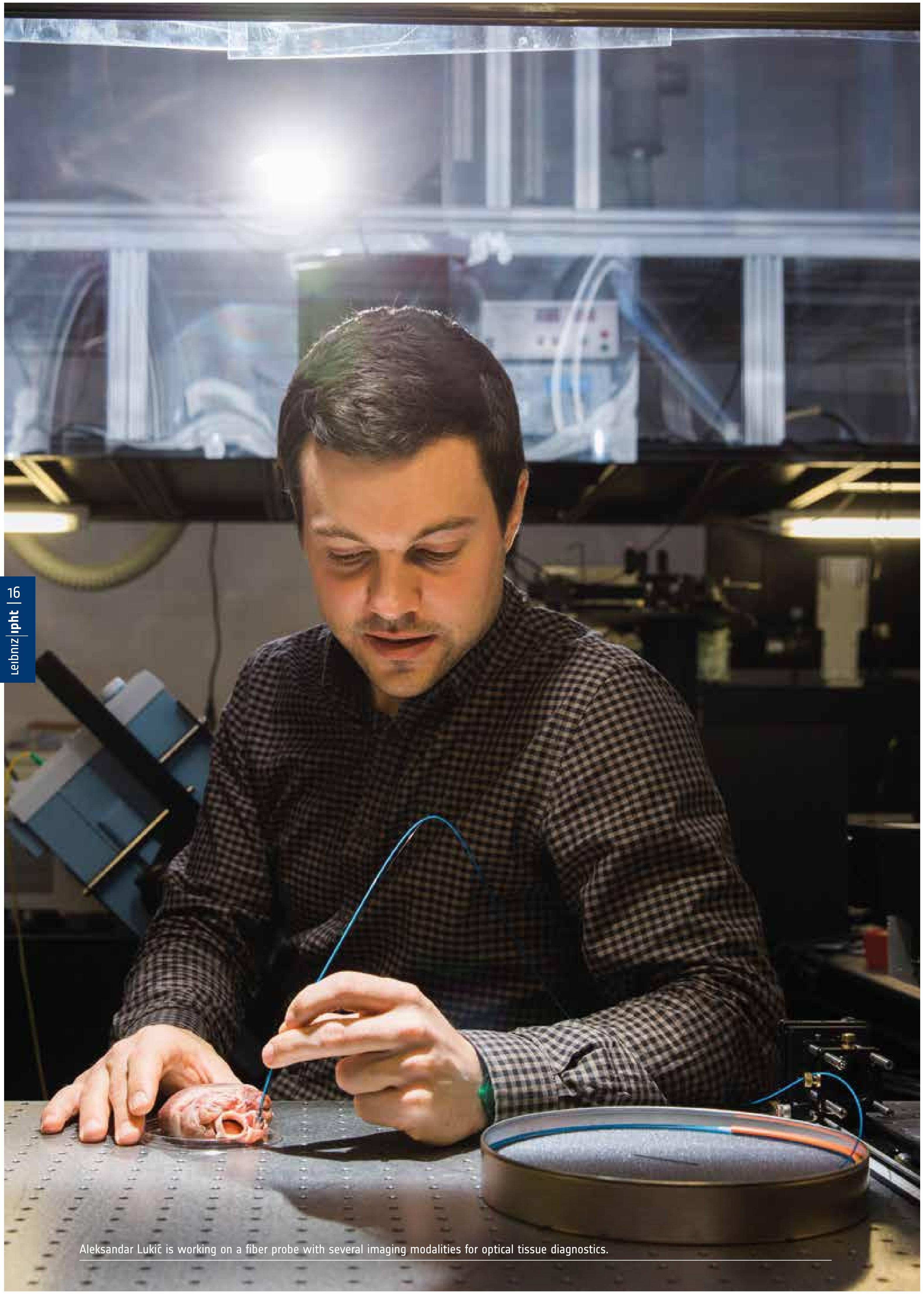
Pictures: Analytica Chimica Acta, 2017, 949, 1-7. © 2017 Elsevier

Surface-Enhanced Raman Spectroscopy (SERS)

Surface-enhanced Raman spectroscopy (SERS) is approximately 6 to 8 orders of magnitude more sensitive than conventional Raman spectroscopy. The signal amplification is based on the interaction of the incident light with metallic nanostructures. On their surface the light excites plasmons. The associated local field enhancement amplifies the Raman signal by many times.

The nano-structured SERS-active substrates consisting of silver or gold are produced in the clean room of the Leibniz IPHT by both bottom-up and top-down techniques. By means of electron beam lithography (top-down) it is possible to create uniform and well-ordered metal structures on the entire substrate surface which provide reproducible measurement signals. The disadvantages of the lithography technique, i.e. the relatively high production costs and the need for special equipment, are compensated by a simplified process with re-usable quartz templates.

For faster and easier sample preparation and the acquisition of reproducible measurement results, the SERS substrates are integrated into a microfluidic cartridge system. The sample liquid flows over the SERS substrate into tiny channels. The analyte molecules bind to the surface of the substrate and their specific fingerprint is captured by a Raman micro-spectrometer.



Aleksandar Lukič is working on a fiber probe with several imaging modalities for optical tissue diagnostics.

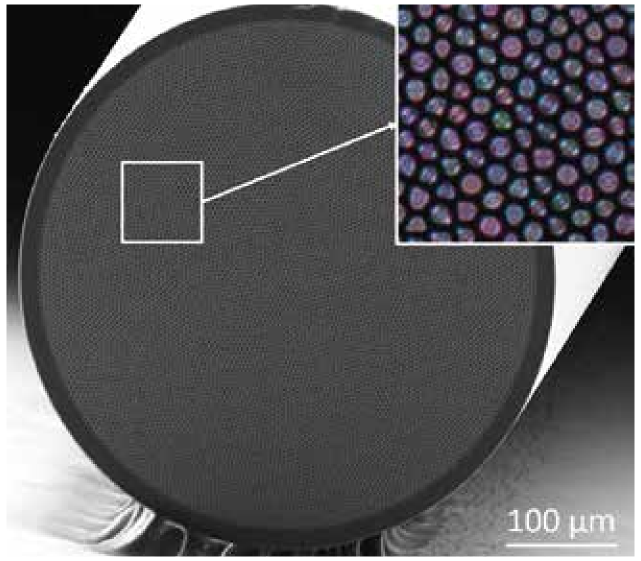
View Inside the Body

Fiber-based Probes for Endoscopic Imaging

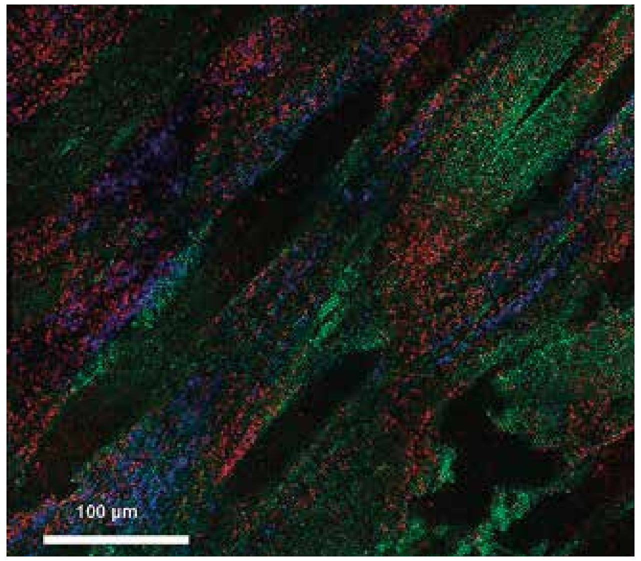
» Scientists at the Leibniz IPHT are working on a new generation of miniaturized fiber-based multi-contrast imaging methods for marker-free insights into the body, such as the digestive tract, nasopharyngeal cavity, bladder or blood vessels. The probes are the size of a ballpoint pen and offer a wide range of applications in medical diagnostics: In the future, doctors might be able to assess suspicious tissue changes in a minimally invasive manner and therefore detect tumor margins or deposits in blood vessels already during a microsurgical intervention or endoscopic examination.

The diagnosis and therapy of tumors during an operation is a challenge for physicians. First of all, they must be able to quickly and reliably distinguish between benign changes and tumor tissue. Once a tumor has been detected, it is in an ideal case completely removed during the first surgical intervention retaining as much healthy tissue as possible, which would be an advantage for the patient. This is often difficult, since tumor tissue can not always be identified by the naked eye.

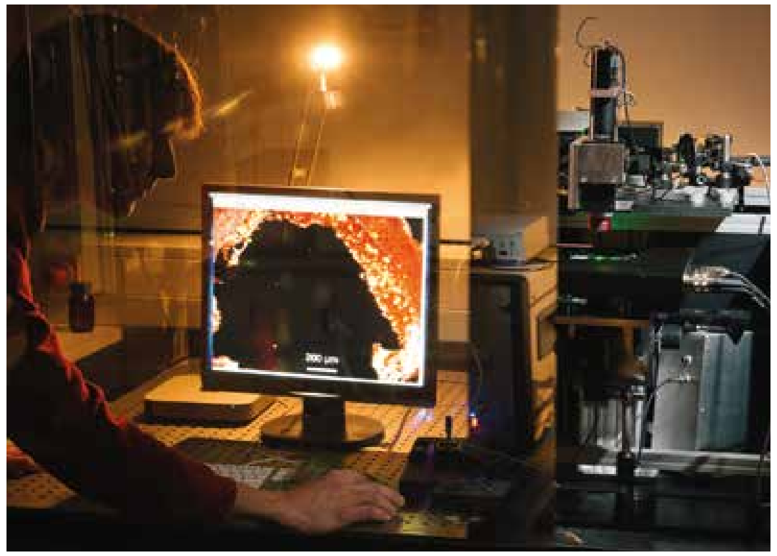
Compact micro-endoscopes that combine fast, label-free imaging techniques and automated analytical routines with fiber-based laser sources and the latest micro-optical systems have the potential to revolutionize tissue diagnostics. If integrated into a compact endoscope, doctors could detect suspicious changes in real time inside the body without taking tissue samples and distinguish tumors from healthy tissue already during surgery. This reduces to a decisive extent the risk of tumor remnants remaining in the patient's body and therefore requiring further surgery.



Cross-section of an endoscopic fiber consisting of tens of thousands of individual fibers. © BioPhotonics, 01.2017



Multi-modal image of skin tissue, red: CARS, green: TPEF, blue: SHG. © BioPhotonics, 01.2017



Tissue diagnostics using CARS microscopy.

Optical Probes for In vivo Diagnostics

In cooperation with the company Grintech, a team from the Leibniz IPHT and Friedrich-Schiller University in Jena have investigated and developed a flexible fiber-optic probe whose head is not thicker than a ballpoint pen. The fiber probe uses several non-linear imaging modalities such as CARS, SHG and TPEF (see info box) and – if integrated into an endoscope – could be used for examinations of the gastro-intestinal tract, in the head and neck area and in the field of urology. "By using multi-core fibers made of 10,000 light-conducting elements for light guidance, we are able to accommodate all moving parts and the power supply outside the probe head. As a result, the probe remains compact and enables simple and safe use within the body", is how Ph.D. student Aleksandar Lukič describes this special feature of the technology.

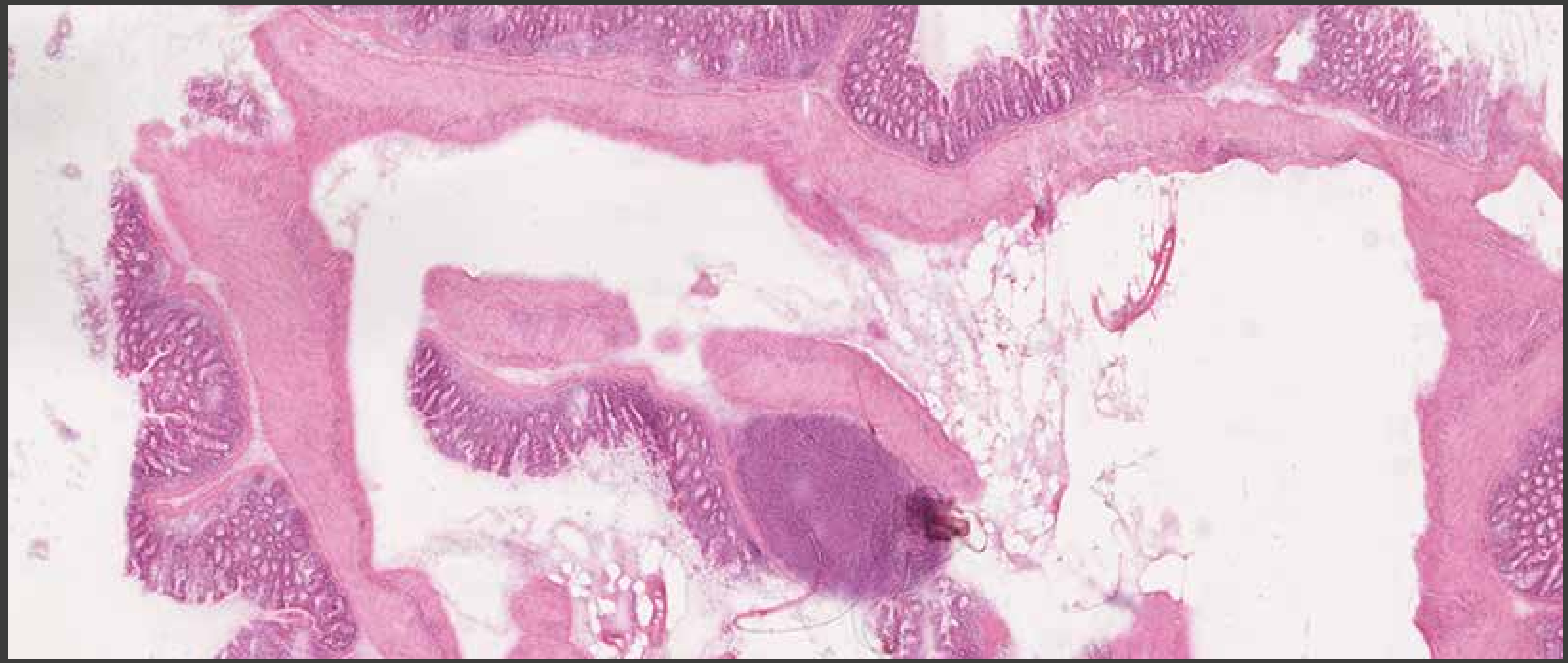
Dr. Tobias Meyer, who has been exploring non-linear imaging methods at the Leibniz IPHT for more than ten years, pursues a further technological approach. As part of the MediCARS research project he was using a compact microscope for investigating small tissue samples. In the endoCARS follow-up project, the scientist now works in cooperation with academic, clinical and industrial partners from Germany on rigid micro-endoscopic multi-contrast imaging probes that provide a direct view into the brain. "From the tissue-specific images we acquire information about its molecular composition and morphology, which neurosurgeons will be able to use in the future to detect tumors or other pathological tissue changes directly during surgery", is how Tobias Meyer explains the measurement principle. The compact and integrated design, including the laser, is intended to enable the mobile use of the endomicroscopic probes by surgeons directly in the operating theatre. The aim is to further improve the imaging technologies and evaluation algorithms and adapt the optical systems for clinical use. This includes the miniaturization of the individual components. The medical experts hope that in the future the fiber probes could be used for the selective removal of tumor tissue following micro-endoscopic detection.

Histopathological Tissue Diagnostics

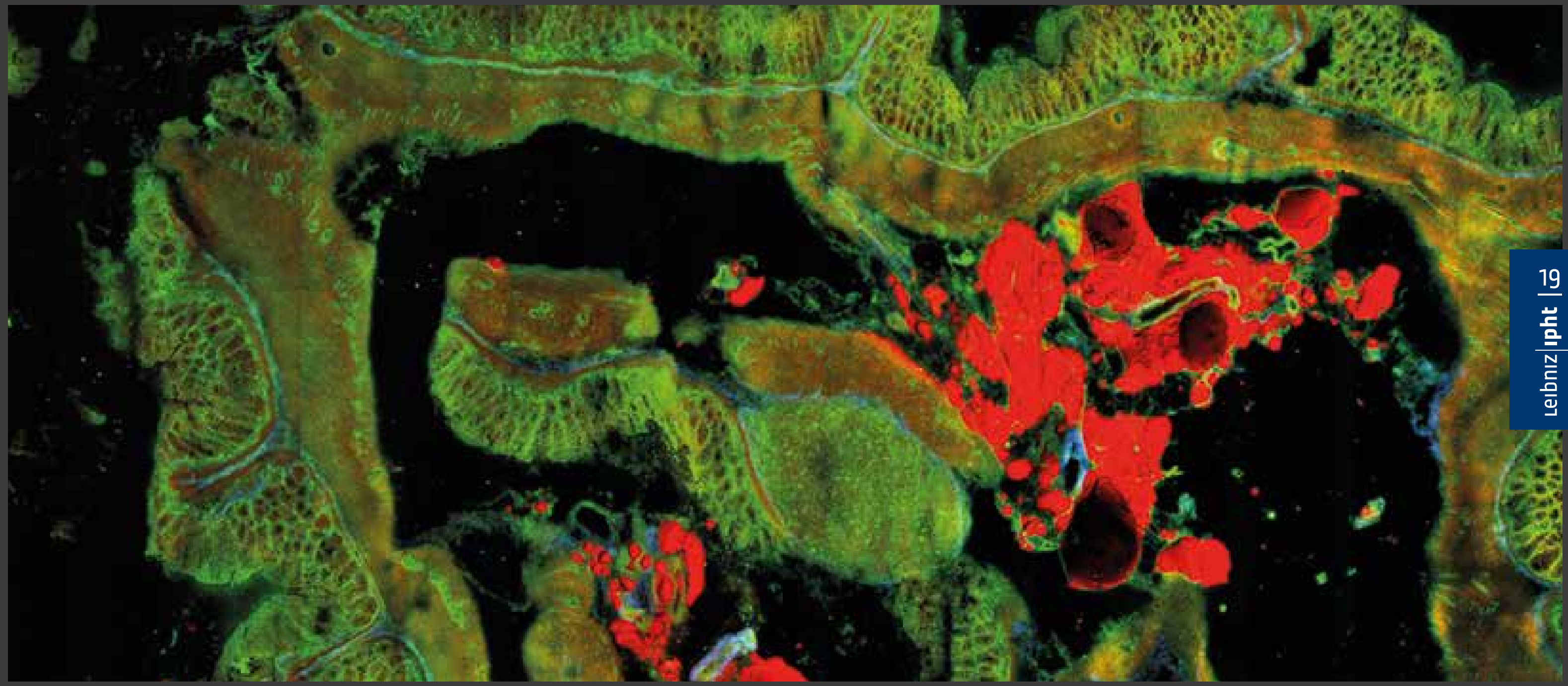
The complete removal of tumors (resection) is crucial for surgeons and for the prognosis of the patients. This is the reason why surgeons take biopsies during the operation that are stained as frozen sections and examined under a microscope for tumor cells by pathologists while the intervention is still ongoing. If there is no evidence of tumor tissue during the frozen section diagnostics, the operation is terminated. Otherwise, surgeons will have to carry out follow-up operations on the affected region, take frozen sections again and repeat the procedure. The examination of tumor margins by means of frozen sections takes 20 to 30 minutes, depending on the sample, and is subject to a not insignificant error rate. Medical experts are therefore reliant for the final assessment on the histopathological examination of embedded and stained sections of samples from the tumor and from the resection margin. This procedure is time-consuming and requires further surgery in the case of a resection margin which is not free of tumor cells. Due to the wound healing that occurs in the meantime, the resection margins are difficult to assess, which worsens the patient's prognosis and causes additional costs.

Optical Tissue Diagnostics by Means of Multi-contrast Imaging

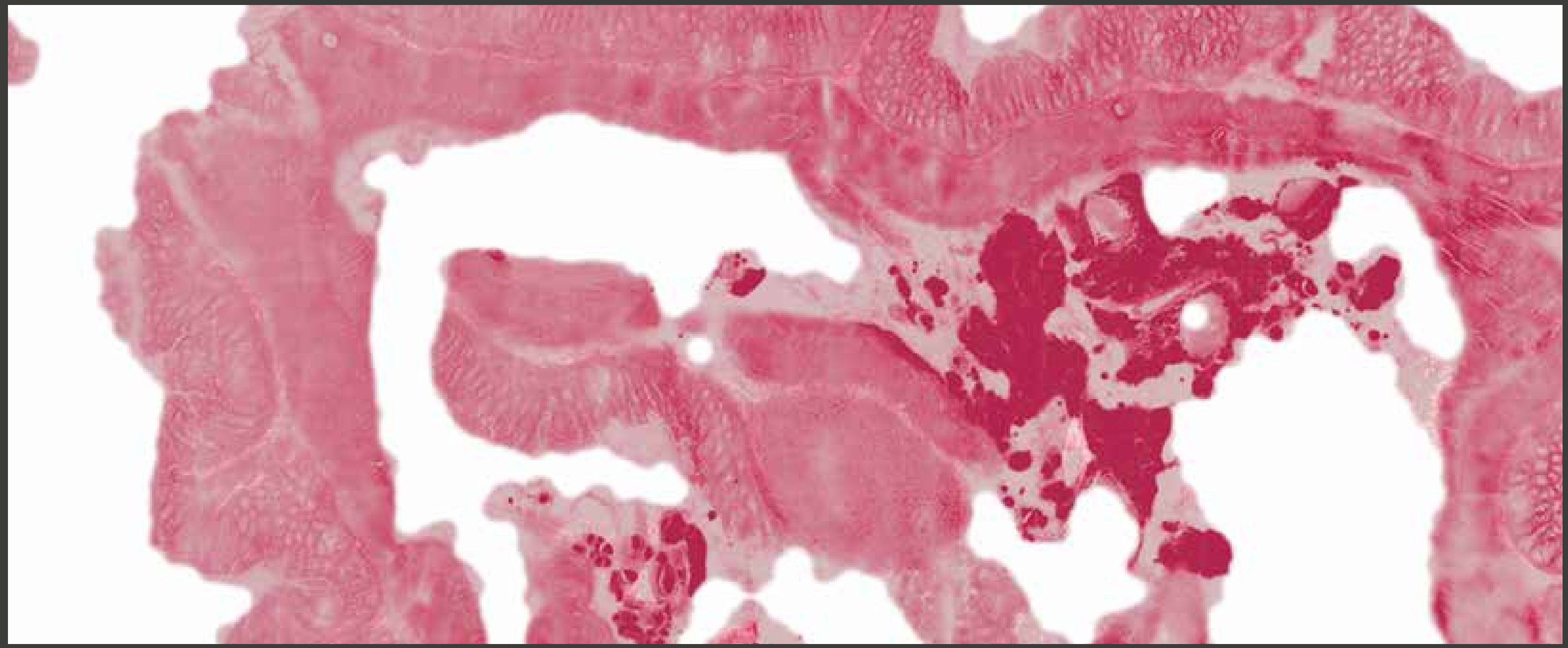
With light-based imaging methods it is possible to analyze biological samples, i.e. tissues and cells, quickly and without direct contact. The interaction of intense laser light with tissue produces tissue-specific responses that provide information on its molecular composition and morphology. Leibniz IPHT scientists are primarily conducting research in label-free methods with a focus on linear and non-linear Raman spectroscopy, i.e. Raman micro-spectroscopy, stimulated Raman scattering (SRS) and coherent Anti-Stokes Raman scattering (CARS). Other contrast mechanisms such as second harmonic generation (SHG – frequency doubling) and two-photon excited fluorescence (TPEF) or fluorescence lifetime microscopy (FLIM) are also used. All these imaging methods provide different information about the tissues being investigated. The targeted combination of several modalities into a multi-contrast imaging approach provides comprehensive image data that complement one another.



Haematoxylin-eosin staining (HE staining) of a tissue section from mouse colon.



Large scale multimodal image of the same tissue section composed of several individual images.



Pseudo-HE staining of the same tissue section derived from the multimodal image.

Irradiated with UV light, the silicon nanoparticles display red photoluminescence

A Bright Future

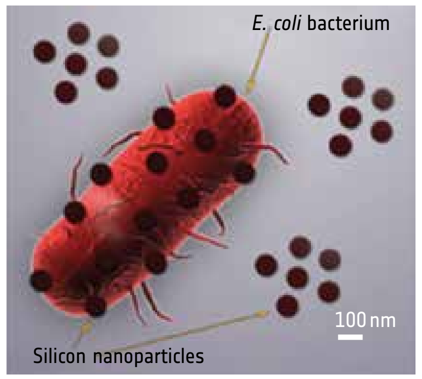
Silicon Nanoparticles for Medicine

» The Leibniz IPHT is conducting research in nanoparticles made of the semi-conductor material silicon for multimodal imaging in cells and as a carrier for the targeted release of drugs. Thanks to new inexpensive manufacturing technologies, the particles might be used in the future for biomedical diagnostics and therapy or as a new means of combating antibiotic-resistant bacteria.

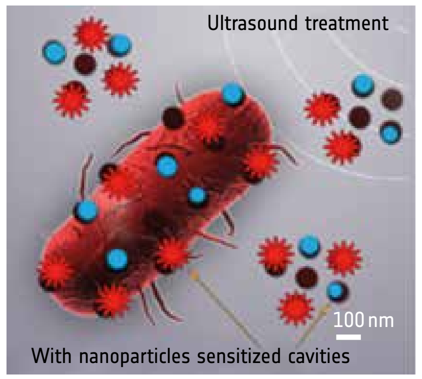
The semi-metal silicon forms the basis for a global branch of industry, the semi-conductor industry. As a component of computer chips and solar cells, we encounter the element every day. Little research has been carried out so far into the use of the element in biomedical applications. In the Semiconductor Nanostructures work group, Dr. Vladimir Sivakov is investigating the production, properties and use of porous silicon nanoparticles for diagnostics and therapy. The most striking feature of the particles is their intense photoluminescence: they light up after excitation with UV light. Due to their high porosity, the particles form nano-containers which can be loaded with active substances up to 20 times their own mass – for example with chemotherapeutic agents to combat cancer cells. Coated with bio-compatible polymers such as dextran, they penetrate easily into cells as a vehicle and exhibit low acute toxicity levels there. After some time, the nanostructures in the cells degrade into harmless substances. These properties make the silicon nano-materials interesting research objects for cancer theranostics – a portmanteau word created from therapy and diagnostics.

"Our aim is to produce theranostic nanoparticles with which we can identify tumor cells and destroy them in a targeted manner at the same time", says Sivakov. There are various methods available to do the latter, including photodynamic therapy, which is already in clinical use. In this method, cytotoxic agents that are selectively released inside the tumor or the pathological tissue changes with the help of light, destroy the cells. One disadvantage of this method is the low penetration depth of the light into the human body, which is why it is not particularly suitable for deep-seated tumors. Vladimir Sivakov is investigating alternative methods of drug release. In contrast to light, ultrasound reaches almost all regions of the human body. With the help of ultrasound waves and silicon nanoparticles, the chemist has succeeded in completely inhibiting the growth of the bacterium *Escherichia coli*. Thanks to the coating with dextran, the particles adhere to the surface of the bacteria. At these sites, the high-frequency sound waves generate very high levels of heat (hyperthermia) at certain points, which causes microscopically small cavities and destroys the cell membrane of the bacterium. "With a view to increasing antibiotic resistance, such physical methods for combating pathogens are an advantage because they also enable us to kill multi-resistant bacteria against which there is no antibiotic", explains Sivakov. Within the framework of the trans-national research network NanoPhoto, which he founded, experts from the fields of material sciences, biology and medicine want to transfer the results to cancer theranostics. In order to further promote interdisciplinary exchange, Sivakov organizes the annual "Current Trends in Cancer Theranostics" (CTCT) conference.

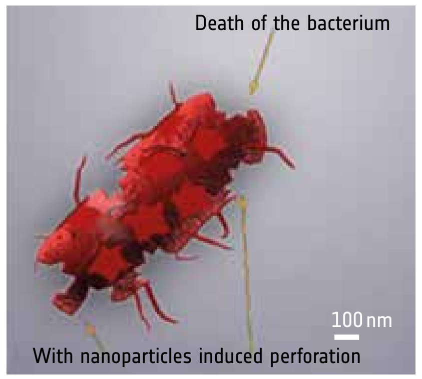
Depending on the size and surface treatment, the particles light up in suspension in green-blue or red. Silicon also displays red photoluminescence in its solid state.



Silicon nanoparticles sheathed with dextran adhere to the surface of bacterial cells.



Ultrasound creates cavities on the nanoparticles that partially destroy the cell membrane.



The holes in the cell membrane cause the bacterial cell to die.

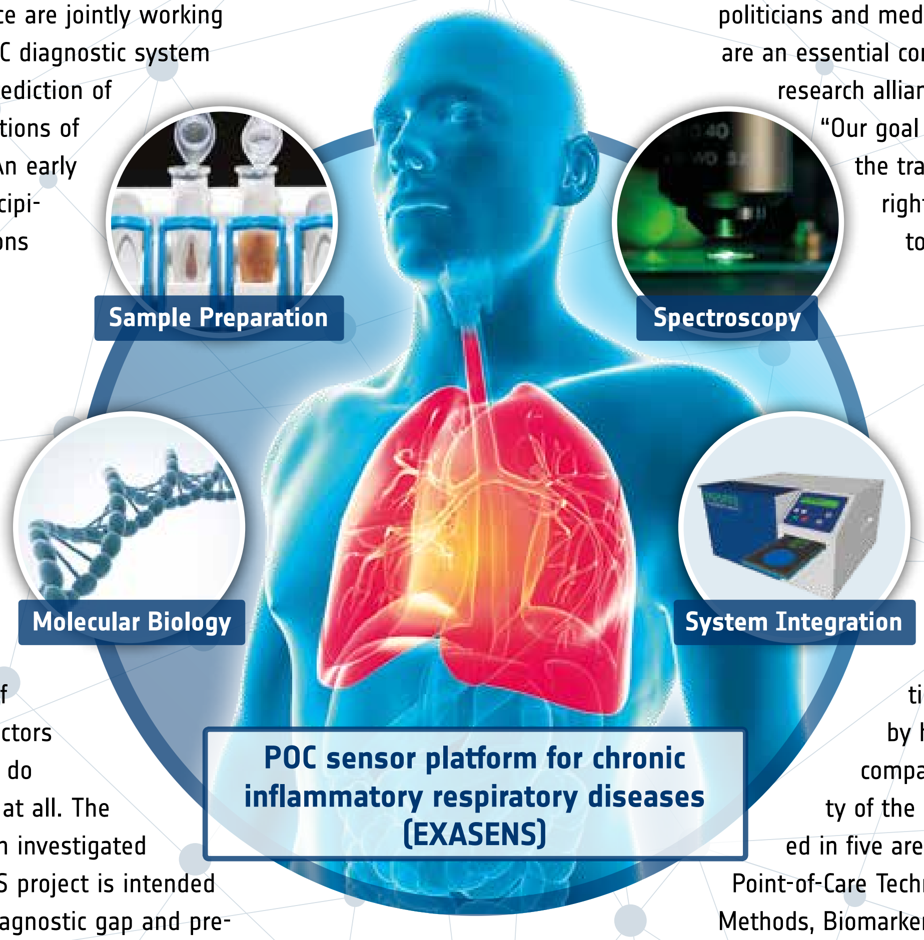
Laboratory of the "Jena Biochip Initiative" Working Group

Innovation Through Cooperation

In the EXASENS project, partners of "Leibniz Health Technologies" are researching in solutions for modular point-of-care diagnostics.

» In the EXASENS project, partners of the "Leibniz Health Technologies" research alliance carry out joint research in modular point-of-care (POC) diagnostics for the prediction and diagnosis of chronic obstructive pulmonary disease (COPD). Goal of the interdisciplinary cooperation: fast and individualized treatment for acute exacerbations of asthma and COPD and therefore a significant improvement in the quality of life. The Leibniz IPHT coordinates the project and contributes its experience in the fields of spectroscopy, POC diagnostics, micro- and nano-technology and system integration.

Ten percent of Germans suffer from the chronic respiratory diseases of asthma and COPD. Acute, seizure-like exacerbations are particularly critical for patients as they can lead to life-threatening complications. Furthermore, high additional costs are incurred by the health care system due to inappropriate admissions based on suspected exacerbations. Early intervention reduces the need for intensive care measures and improves the prognosis for patients. For this purpose, doctors are reliant on precise monitoring of the status of the disease and early diagnosis. EXASENS, Leibniz Health Technology's largest project so far, is dedicated to addressing this problem: Nine Leibniz Institutes of the research alliance are jointly working towards an POC diagnostic system for the early prediction of acute exacerbations of the diseases. An early diagnosis of incipient exacerbations would significantly improve the quality of life of patients and ensure optimum treatment. Conventional pulmonary function tests and subjective assessments of experienced doctors are not able to do this in full – if at all. The sensor platform investigated in the EXASENS project is intended to close this diagnostic gap and predict future exacerbations by means of POC diagnostic systems that can be used in a modular fashion. "The special feature of the project lies in the interdisciplinary cooperation between institutes from different sections of the Leibniz Association. This puts not only us, but also partners from industry, in a position to work on a topic along the innovation chain from basic research to marketing", adds Dr. Karina Weber, who is responsible for the scientific coordination of the project. While scientifically oriented Leibniz Institutes research into POC assays on the basis of optoelectronic and photonic technologies, the life science institutes supplement this with methods for molecular biological detection and sample preparation. The Leibniz IPHT makes use of its strengths in the areas of sample preparation, spectroscopy, micro- and nanotechnology and system integration in order to incorporate all technologies and methods into a modular, chip-based cartridge. The research approach is rounded off by an accompanying social science study of the socio-economic effects of the new POC diagnostics. The insights gained form the basis for integrated analytical systems for the performance of initial studies and application tests.



Taking Advantage of Diversity as a Strength: Interdisciplinary Research in the Network's Fields of competence

"In the field of health technologies, efficient interdisciplinary collaboration is inevitable. That's why we bring together doctors, biologists, chemists, physicists, engineers, social scientists and economists", explains Prof. Jürgen Popp, spokesman of the Leibniz Research Alliance. According to Popp, this comprehensive, collaborative concept and the cross-networking with health insurance companies, politicians and medical associations are an essential component of the research alliance's strategy: "Our goal is to speed up the translation process right the way through to the finished products and align them consistently with the requirements of users. In the case of medical solutions it is crucial that they are equally accepted by doctors and patients and paid for by health insurance companies". The diversity of the network is reflected in five areas of expertise: Point-of-Care Technologies, Imaging Methods, Biomarkers, Plasma Medicine and Bioactive Surfaces. In these fields the network brings together member institutes, which complement each other in their research profile, in a targeted manner. A key concern is to find a common language and dare to think outside the box. "It is not uncommon to find out in an intensive exchange of ideas during a thematic workshop that a colleague already has a key technology that can be integrated into an approach", explains Jürgen Popp. The Leibniz IPHT plays a key role in the two areas of competence of "Point-of-Care Technologies" and "Imaging Methods". In projects of the research alliance, the Leibniz IPHT researchers benefit, for example, from the expertise of the life scientists at the Lung Research Center in Borstel and the Hans-Knöll Institute, or use technologies of the laser experts at the Ferdinand-Braun Institute in Berlin and microelectronics developers at the Leibniz Institute of Innovations for High-Performance Microelectronics in Frankfurt an der Oder. With this successful interdisciplinary cooperation, the Leibniz IPHT plays a leading role in the investigation of innovative optical health technologies within the Leibniz Association.

Work at the interface of biology, microelectronics and spectroscopy

In the future, further projects are to be added to the research alliance that aim to achieve the rapid implementation of new solutions. In order to ensure that the applications comply with legal requirements, questions relating to approval must be included in the research process from the beginning. The Alliance therefore organizes further training courses for its members with experts on laws governing authorization.

Furthermore, the Leibniz Research Alliance will be focusing in the future more strongly on digitalization in medicine. Research institutes and clinics are accumulating larger and larger amounts of data that could help many patients. The bottleneck today is often the software for the data evaluation. Faster, more efficient and more precise algorithms are required here to bring diagnostic and therapeutic procedures to the doctor's surgery. Moreover, according to Popp, up-to-date legal regulations for the handling of patient data need to be established: "That's why we are working with the Leibniz Research Alliance on the topic of data protection and are actively seeking discussions with politicians."

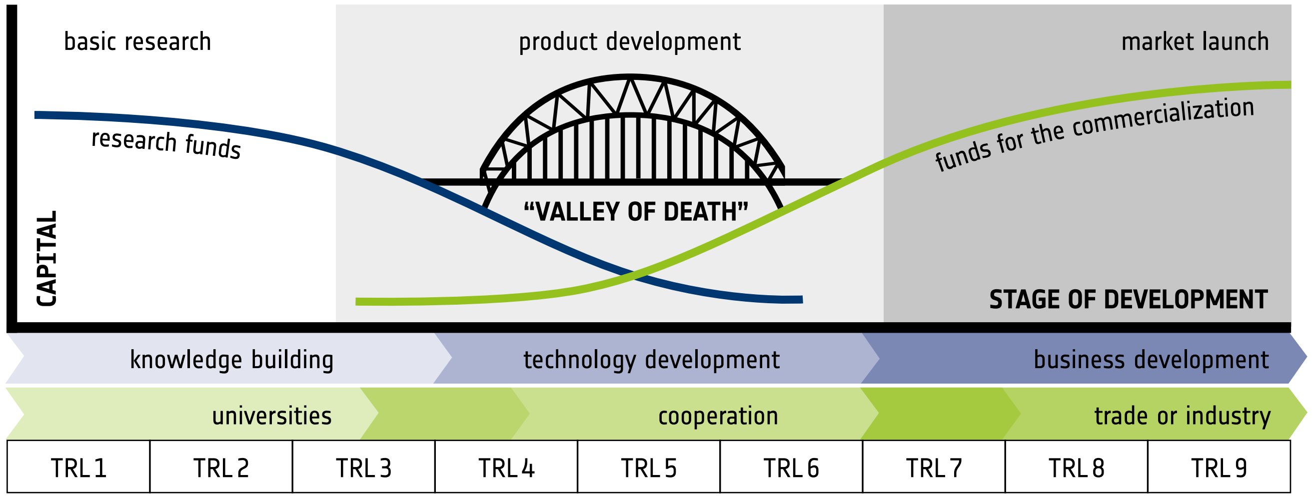
In order to accelerate the translation of research results into marketable solutions, engineers are involved in research projects at an early stage.

Building Bridges

System Technology Paving the Way for Innovations

» ***Strengthening system technology is one of the measures that have been taken by the Leibniz IPHT in order to promote innovation transfer and thereby overcome the "Valley of Death". System integration results in technologies with a high level of development which shorten the relatively long time it has taken up to now to translate research results into marketable products. At the same time, highly-developed components and processes form the technological basis for carrying out research in new approaches.***

Optical health technologies have the potential to be used to great advantage in diagnostics and therapy and thereby solve urgent medical problems. So that the photonic technologies being investigated at the Leibniz IPHT are able to find broad applications in the real world, they require a high level of technological development, i. e. a high technology readiness level (TRL). Large and complex laboratory set-ups that can only be operated by specialists would be unsuitable for use in clinical routine analysis. It is only through the expansion of existing enabling technologies with system technology that components and instruments can be produced at the Institute which demonstrate the desired function of the subsequent product. The Institute has already created and tested several integrated systems with a high TRL. For example, the thermoelectric sensors that were launched into space in 2004 with the ESA Rosetta mission. Further examples are: the terahertz camera, the Bioparticle-Explorer, PAUL (a Photonic Analytical Universal Laboratory) and MediCARS.



In order to further advance the translation of research results into marketable products, the Leibniz IPHT has firmly embedded system technology at the Institute. With the creation of the "System Integration" working group in 2016, it is not only possible to implement technological solutions as functional models on a selective basis, "but also to make expertise available to all employees which accompanies the implementation of technical solutions in functional test models from the very beginning", says Peter Horbert, who heads the working group. In a current research project, his group is developing – together with Prof. Ute Neugebauer and her team – the laboratory sample of a microfluidic chip with which it is possible to determine antibiotic resistances of bacteria within just three hours – a fraction of the time required with conventional methods. Four copies of the chip are currently going through a test phase in clinical environment. The EXASENS research network is working on a further integrated cartridge system for the prediction and diagnosis of chronic obstructive pulmonary diseases.

Furthermore, an endowed professorship in "Optical-Molecular Diagnostics and System Technology" is to be established together with the Friedrich-Schiller University in Jena under the direction of a renowned scientist with many years of industrial experience. "In this way, the Institute is consolidating its systems skills and making an important contribution towards closing the gap between knowledge-oriented basic research and specific product development", explains Professor Popp.

The endowed professorship is characterized above all by its interdisciplinary approach, which forms the basis for the research in current questions and the development of tailor-made solutions. The professorship is intended to provide optical-analytical system solutions – based on photonic approaches – for material science and life science issues, as well as environmental analyses. "With the creation of the endowed professorship, the Leibniz IPHT is increasingly translating its guiding principle of 'From Ideas to Instruments' into practice", Prof. Jürgen Popp goes on.

Technology Readiness Level

The **TRL** is a scale for assessing the development status of new technologies. The scale ranges from **TRL 1** to **TRL 9** and was originally developed by NASA in the late 1980s for the classification of space technologies.

TRL 1: Observation and description of the basic principles

TRL 2: Description of the technology concept and/or its application

TRL 3: Proof of the experimental functionality

TRL 4: Experimental validation in the laboratory

TRL 5: Experimental validation in the application environment

TRL 6: Prototype in the application environment

TRL 7: System prototype in operational environment

TRL 8: Qualified system with proof of functional efficiency in the field of application

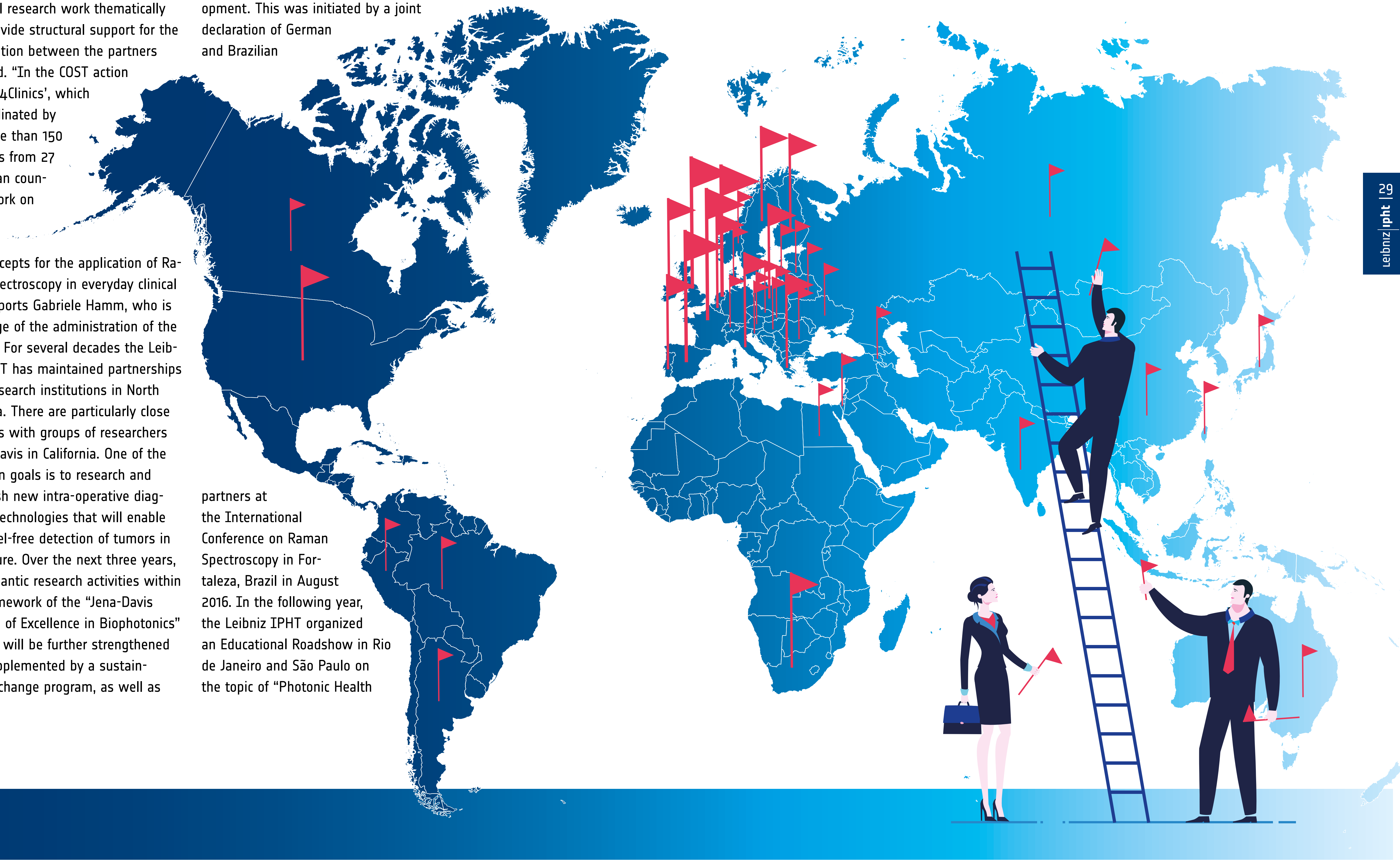
TRL 9: Qualified system with proof of successful use

More than the Sum of its Parts

International Cooperations Opening up Synergies

» *Challenges in the areas of health, medicine, the environment and safety are of global significance. Solutions require cross-national cooperation. Through strategic cooperations, the Leibniz IPHT is in a position to develop the skills of international partners. Such exchange serves the further development of the Institute‘s own program portfolio and strengthens its international visibility.*

The Leibniz IPHT cooperates with partners from 40 countries. The Institute works closely together with the Center for Nanoscale BioPhotonics in Adelaide, Melbourne and Sydney in Australia. Both institutions can look back on many years of scientific exchange in the field of biophotonics. Since March 2017 there has also been close cooperation with the Institut Teknologi Sepuluh Nopember in Surabaya, Indonesia. Teams of scientists from both institutes are working together on the development of new dye-sensitized solar cells. The contractually agreed cooperation also includes a bilateral exchange program. Foreign researchers appreciate the Leibniz IPHT as an attractive place to visit. Since 2014 more than 100 guest scientists have been using the outstanding technological infrastructure available at the Institute. Among other things, the Institute benefits from the Abbe Center of Photonics‘ guest professorship program. As part of the Dragon Gate program, more Taiwanese guests are to be given the opportunity to visit the Leibniz IPHT in the future. The Ministry of Science and Technology in Taiwan makes use of the the program to promote research stays of next-generation scientists at leading institutions all over the world. At the European level the Leibniz IPHT is participating in five COST actions. The networks, which are funded by the European Union for a period of four years, aim to cross-link national research work thematically and provide structural support for the cooperation between the partners involved. "In the COST action 'Raman4Clinics', which is coordinated by us, more than 150 partners from 27 European countries work on technological concepts for the application of Raman spectroscopy in everyday clinical life", reports Gabriele Hamm, who is in charge of the administration of the project. For several decades the Leibniz IPHT has maintained partnerships with research institutions in North America. There are particularly close contacts with groups of researchers at UC Davis in California. One of the common goals is to research and establish new intra-operative diagnostic technologies that will enable the label-free detection of tumors in the future. Over the next three years, transatlantic research activities within the framework of the "Jena-Davis Alliance of Excellence in Biophotonics" (JEDIS) will be further strengthened and supplemented by a sustainable exchange program, as well as joint summer schools and scientific colloquia. Cooperations with Brazilian partners are currently under development. This was initiated by a joint declaration of German and Brazilian partners at the International Conference on Raman Spectroscopy in Fortaleza, Brazil in August 2016. In the following year, the Leibniz IPHT organized an Educational Roadshow in Rio de Janeiro and São Paulo on the topic of "Photonic Health Technologies". The concrete objectives were to initiate an exchange program for young researchers and explore ideas for joint project applications. The global biophotonics community also continues to move closer together in virtual terms: Since the end of April 2017, international research groups have been introducing themselves on the online portal Biophotonics.World. As the operator of the platform, the Leibniz IPHT initiated, designed and implemented the website. Biophotonics.World provides access to news and articles on the latest developments in academic and industrial research. The Leibniz IPHT uses Biophotonics.World in order to present its own research topics to an international audience of experts, while at the same time systematically identifying and opening up new cooperation potentials.



Promoting Young Talent

Excellent, Independent and Interdisciplinary

» The promotion and training of the next generation of scientists is the core structural concern and central goal of the Leibniz IPHT. The main goal is to give young scientists the opportunity to conduct autonomous, independent and interdisciplinary research at an early stage. In addition to the comprehensive, structured promotion of young researchers by the Leibniz Association, the Leibniz IPHT has also established individual funding opportunities.

The central format for the IPHT's own promotion of young researchers is the funding tool for independent junior research groups, which has been in existence since 2008. These enable outstanding young scientists with a PhD to establish an independent field of work before they have been appointed to their own professorship. Upon expiration of a junior research group after a period of six years, its leader should be able to apply for professorships on a competitive basis. Alternatively, a junior research group can be established as a research or working group at the Leibniz IPHT. Two new junior research groups are to be developed next year.

The Leibniz IPHT has established a structural training system for doctoral students. An internal doctoral program pursues two objectives here: On the one hand to impart the technological skills of the Leibniz IPHT to the doctoral students, and on the other to accompany the progress of the doctorate. Furthermore, the Leibniz IPHT supports its doctoral students with their networking with the scientific community – for example through research stays, conference trips or participation in international research projects.

Cooperation with other scientific disciplines plays a particularly important role at the Institute. Thanks to the interdisciplinary research focus of the Institute and the close networking with industrial partners, doctoral students are provided with insights that go beyond their own horizons.

Early Work with Young Researchers

The Leibniz IPHT begins its commitment to helping young researchers as early as the school stage in order to engage in discussions with future young scientists and draw attention to the research fields and working opportunities of the Leibniz IPHT. Additionally, with its participation in events such as the Long Night of Science or Girls' Day, the Institute makes an important contribution towards inspiring young people for the MINT (Mathematics, Informatics, Natural Sciences and Technology) subjects of physics and chemistry. Together with the University of Jena, the Leibniz IPHT invites particularly gifted pupils from Thuringia to attend the summer school once a year.

"I'm Taken Seriously as a Young Scientist."

Interview with Dr. Marie Richard-Lacroix

After completing your doctorate, you applied in Canada for a post-doctoral fellowship. Why did you choose Jena?

My first choice was to come to Europe. Because Germany has a very good reputation in the field of spectroscopy, I looked here for suitable institutes for my research field of TERS. Jena and the Leibniz IPHT stood out in particular because Volker Deckert – an internationally recognized scientist in the field of TERS – carries out his research here.

What have you benefited from at the Leibniz IPHT so far?

I can name several things. For one, the interdisciplinary research focus and the Institute's excellent networking, which allows me to think outside the box, present my research results at conferences and network with the scientific community. Another advantage is the excellent laboratory equipment. As a young scientist, I am taken seriously and supported in achieving my goals. As a teaching assistant, I supervise PhD and other students. After all, it is not enough for a career in science to just do good research. One must have numerous other qualities.

Do you already know your way forward after your scholarship?

I'm not really sure yet, but I would definitely like to develop further and pursue an academic career. I have held lectures in Canada. I would like to do that again. My exact destination will only become apparent in the coming months.

Personal details:

Since 2016:
Postdoctoral Fellow – Leibniz IPHT and the Friedrich Schiller University of Jena

2011–2016:
PhD in Chemistry – University of Montreal / Canada

2008–2011:
Bachelor of Science in Chemistry – University of Montreal / Canada

Main focus of research:
Tip-enhanced Raman Spectroscopy

Prof. Heidemarie Schmidt, Prof. Christian Eggeling and Prof. Tomáš Čižmár are the new Heads of Research Departments.

Welcome to the Team

Competent Support for the Research Work at the Institute

» The Leibniz IPHT has recruited new and strengthened its existing staff. With three new appointments, we have succeeded in attracting internationally high-ranking scientists to Jena to make their mark on and further improve the Institute's research priorities of biophotonics, fiber optics and quantum detection. Heidemarie Schmidt succeeds Hans-Georg Meyer as Head of the Quantum Detection Department, Tomáš Čižmár has taken the place of Hartmut Bartelt as Head of the Fiber Optics Department and Christian Eggeling is developing the new Biophysical Imaging Department.

Heidemarie Schmidt

Heidemarie Schmidt is Head of the Quantum Detection Department at the Leibniz IPHT. Since September 2017 she has been Professor of Solid State Physics with the focus on quantum detection at the Friedrich Schiller University in Jena. The physicist conducts research in the fields of quantum technology, biotechnology and new material systems for nano-electronics. At the Leibniz IPHT, she investigates – with an accuracy of just a few nanometers – the displacement of electrical charges in bio-materials such as cells, tissues or proteins by irradiating the materials with light of a certain wavelength. From this charge displacement she can derive statements about the biochemical properties of the biological species. The measurements are used to elucidate fundamental biological questions and allow conclusions to be drawn about possible pathological changes to cells or tissue, for example.

***Heidemarie Schmidt** studied physics at the University of Leipzig, where she received her doctorate in 1999 on band structures in ultra-thin layers of semi-conductors. From 2003 to 2007 she was the leader of the BMBF junior research group "Nano-Spintronics" and subsequently took over a working group of the same name at the Helmholtz Center in Dresden-Rossendorf. In 2012 Schmidt was awarded a Heisenberg scholarship by the German Research Foundation and subsequently moved to the Technical University of Chemnitz. At the ENAS Fraunhofer Institute in Chemnitz she is in charge of her own working group.*

Christian Eggeling

Christian Eggeling, who had previously worked at Oxford University in England, now leads the new Department of Biophysical Imaging. Together with the Friedrich Schiller University in Jena, he was appointed Professor for High-Resolution Microscopy in December 2017. The scientist also carries out research into microscopic methods that provide unique insights into the nano-cosmos of living cells and tissue. "We combine techniques with extremely high spatial resolution based on fluorescence microscopy with methods that enable us to follow the movement of labeled molecules in real time. With this it is possible for us to examine individual molecules, which are – for example – part of cell membranes in the living cell, both in space and time. In this way, cellular mechanisms at the molecular level are brought to light that were too fast for previous analytical methods", says Eggeling, describing the advantages of the new imaging methods.

***Christian Eggeling** carried out research at the Max Planck Institute for Biophysical Chemistry in Göttingen in the field of multi-dimensional single molecule fluorescence spectroscopy. After completing his doctorate, the physicist initially moved to the commercial sphere in 2000. At the company Evotec OAI AG he worked on fluorescence techniques for high-throughput drug screening, before moving back to Göttingen. In the group led by Noble Laureate Stefan Hell he worked on high-resolution imaging methods. In 2012 he was appointed Professor of Molecular Immunology at the University of Oxford, where he headed the Wolfson Imaging Centre.*

Tomáš Čižmár

Tomáš Čižmár, who was appointed Professor of Waveguide Optics and Fiber Optics at the Friedrich Schiller University in January 2018, heads the Department of Fibre Optics at the Leibniz IPHT. His research fields comprise the optical manipulation of tiny particles, the investigation of light propagation processes in optical fibers and their application in hair-thin endoscopic fiber probes for biomedical imaging. At the Leibniz IPHT, Tomáš Čižmár conducts research in new methods for controlling light propagation in optical fibers. "By means of digital holography and computer algorithms we have succeeded for the first time in transmitting high-resolution images through a single optical fiber that is only a tenth of a millimeter thick. These miniaturized fiber probes are opening up a window to study processes in previously unattainable regions of living organisms – possibly also in humans at some time", says Tomáš Čižmár, talking about the future of technology. For his research project LIFE-GATE he received the widely acknowledged Consolidator Grant of the European Research Council (ERC) – an award for excellent scientists.

*From 2003 to 2007 the physicist **Tomáš Čižmár** worked at the Institute of Scientific Instruments at the Czech Academy of Sciences and Masaryk University in Brno, where he completed his PhD in the field of wave and particle optics in 2006. Subsequently, Čižmár carried out research in the group of Kishan Dholakia at the University of St. Andrews, Scotland, on the subject of optical manipulation and biomedical photonics. In 2010 he moved to the School of Medicine to establish innovative concepts there for holographic endoscopy. Before Čižmár came to Jena, he was a lecturer at the University of Dundee and the University of St. Andrews and headed the "Complex Photonics" research group in Dundee.*

Prof. Dr. Evgeni Il'ichev in front of a cryostat with which he cools qubits to almost -273 °C

Selected Awards in 2017

Dr. Thomas Bocklitz // Award by Beutenberg Campus e.V. as the best young scientist

Dr. Jan Dellith // 2nd Poster Prize at the Thuringia Materials Day 2017 for a new process for the production of quartz glass preforms

Vera Dugandžić // Poster Prize of the Confocal Raman Imaging Symposium for the Raman-based detection of dangerous arteriosclerotic plaques

Dr. Tino Elsmann // Green Photonics Special Prize in Thuringia of the Foundation for Technology, Innovation and Research in Thuringia (STIFT) for his outstanding work on high-temperature fiber sensors

Dr. Robert Geitner // Oral Presentation Honourable Mention and 2nd Prize of the Student Presentation Award at the International Conference for Advanced Vibrational Spectroscopy

Prof. Evgeni Il'ichev // Verkin Prize of the Ukrainian Academy of Sciences for his research work in the field of low-temperature physics

Dr. Sandra Kloß // Poster Prize of the 3rd Munich Point-of-Care Testing Symposium on the topic of the "Innovative particle and chip-based isolation of bacteria from respiratory tract samples for on-site analysis"

Robert Meyer // Analyst Poster Award of the International Conference on Advanced Vibrational Spectroscopy for his work on new experimental methods of tip-enhanced Raman spectroscopy

Dr. Tobias Meyer // Leibniz IPHT Prize 2017 – for his special commitment in the field of non-linear spectroscopy

Dr. Christian Mühlig // "Arthur Guenther Best Poster Presentation Award" of the SPIE Conference on LASER Damage for LID-Absorption Measurement Technology

Mona Nissen // Award for best Master Thesis 2017

Margitta Sossna // Leibniz IPHT Recognition 2017

Dr. Ronny Stolz // ESAS Excellence Award for Applied Superconductivity

Dr. Sonja Unger // Leibniz IPHT Recognition 2017

Outstanding Personnel

Prof. Dr. Evgeni Il'ichev

He has been researching the theoretical basis for quantum computation for several years and works on their practical realization by means of superconducting quantum bits (qubits). For his outstanding research work, the Ukrainian Academy of Sciences honored the Jena researcher with the Verkin Prize.

Margitta Sossna

She has been honored for her many years of dedication as an employee in the clean room of the Leibniz IPHT. With her enormous wealth of experience she has been involved in the further development of micro and nanotechnologies.

Dr. Sonja Unger

Dr. Unger has been honored for her life's work in the field of fiber technology. With her expertise in the manufacture and processing of quartz glass fibers, she has made a decisive contribution to the research in the Department of Fiber Optics.

Dr. Sonja Unger in the laboratory for the production of quartz glass preforms

Thuringia's Minister President Bodo Ramelow and his wife welcomed the royal couple outside the Leibniz IPHT.

Director of the Institute Jürgen Popp showed Willem-Alexander and Máxima around the Leibniz IPHT.

The main steps of the tour were the fiber-drawing tower, an exhibition and the demonstration of the terahertz camera.

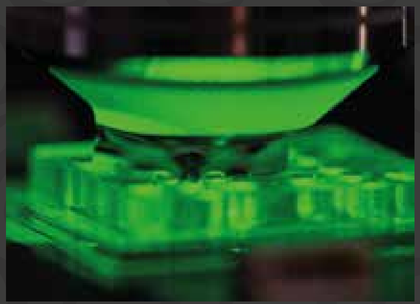
Royal Splendor

» On February 7 and 8, 2017, the Dutch King Willem-Alexander and Queen Máxima were guests in Thuringia. The royal couple accompanied a business delegation that stopped in Thuringia, Saxony and Saxony-Anhalt for four days in order to intensify trade and economic relations between Germany and the Netherlands and promote cooperation in the fields of photonics, semi-conductor technologies and chemicals.

On the second day of their stay, Willem-Alexander and Máxima visited the Leibniz IPHT together with a business delegation of approximately 70 people. During their stay at the Institute, the royal couple gained an insight into the Thuringian industrial and research landscape. Four Thuringia-based companies and research institutes from the optical and micro-electronics industry presented their latest products and research work. This included the terahertz security camera developed at the Leibniz IPHT. This camera detects weapons and explosives on the human body without actively irradiating them or depicting the anatomy of the body in detail. One highlight of the tour was a visit to the 14 meter high fiber-drawing tower. It is one of Europe's most modern research facilities for the production of optical glass fibers for special applications. At the end of their visit to the Leibniz IPHT, representatives of research institutions from Jena and the Netherlands signed a memorandum to intensify future cooperation on research in the presence of the royal couple.

Scientific Articles on the App

Biophotonics



The **research focus of Biophotonics** investigates and realizes innovative photonic methods and tools for molecular spectroscopy and hyperspectral imaging, high-resolution light microscopy as well as fiber-, chip- and nanoparticle-based analytics and diagnostics of highest specificity, sensitivity and resolution by integrating technology research in fiber optics and photonic detection.

On-chip Spectroscopic Assessment of Microbial Susceptibility to Antibiotics within 3.5 Hours
U. Neugebauer // U.-Chr. Schröder // J. Kirchhoff // U. Glaser // U. Hübner // G. Mayer // T. Henkel // W. Fritzsche // J. Popp

Innovative Bead-based Sample Preparation Strategies for the Detection of Bacteria
K. Weber // S. Pahlow // L. Lehniger // S. Hentschel // S. Kloß // D. Cialla-May // J. Popp

Endoscopic Fiber Probe for Non-linear Spectroscopic Imaging
A. Lukic // S. Dochow // H. Bae // T. Meyer // G. Matz // I. Latka // B. Messerschmidt // M.A. Schmitt // J. Popp

Surface-enhanced Raman Scattering of Cell Lysates for Improved Tumor Detection
Chr. Krafft // M. Hassoun // J. Popp

Multimodal Image Analysis for Tissue Diagnostics
T. Bocklitz // S. Guo // T. Meyer // C. Pfeifenbring // J. Popp

Untersuchungen zur Raman-Spektraldatenanalyse
T. Bocklitz // S. Guo // R. Heinke // S. Stöckel // P. Rösch // J. Popp

SERS-Application in Environmental and Medical Science
D. Cialla-May // O. Zukovskaja // S. Patze // I. Jahn // K. Weber // J. Popp

Fundamental SERS Investigation of the Interaction between Small Molecules and Silver Nanoparticles
A. Mühlig // D. Cialla-May // J. Popp

Optical and Thermal Properties of Plasmonic Nanoparticles
F. Garwe // A. Csáki // M. Thiele // W. Fritzsche

Microfluidics for Nanoparticle Synthesis and LOC Technology
M. Thiele // A. Csaki // T. Henkel // W. Fritzsche

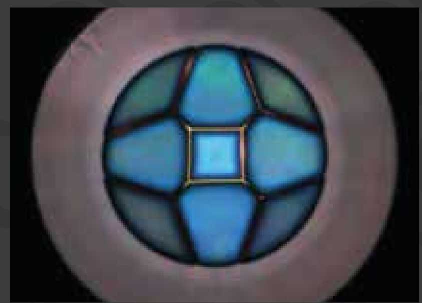
Localized Surface Plasmon-based Sensing
O. Stranik // B. Doherty // A. Csáki

Tip-Enhanced Raman Scattering on High-Energy Nanoparticles
T. Deckert-Gaudig // V. Deckert

Production of 3D Nanostructures for Innovative Biosensors
M. Ziegler // D. Cialla-May // S. Yüksel // S. Goerke // U. Hübner

Influence of the Biological Environment on the Photophysics of Photosensitizers
Chr. Reichardt // M. Wächtler // B. Dietzek

Fiber Optics



The **research focus of Fiber Optics** is dedicated to the propagation properties and the efficient and flexible control of fiber- and planar-guided light. This includes technology and basic research to understand the light propagation in fiber optic cable systems and to realize novel fiber modules and systems. The focus is on research into novel microstructured and functionalized fibers for sensory applications in biophotonics as well as nonlinear and laser-based fiber light sources.

The Viscous Behavior of Synthetic Silica Glass Tubes During Collapsing
S. Unger // J. Kirchhof

Homogenization of Doped Fused Silica via Plasma-based Processes
V. Reichel // H. Baierl // T. Trautvetter // K. Schuster

Tapered Fiber Amplifiers Prepared by Powder Sintering Technology for Peak Power Scaling and Beam Quality Improvement
M. Leich // Y. Zhu // T. Eschrich // S. Grimm // J. Kobelke // H. Bartelt // M. Jäger

Tunable All-Fiber Lasers with Single and Dual-Wavelength Emission
T. Tieß // M. Becker // M. Rothhardt // H. Bartelt // M. Jäger

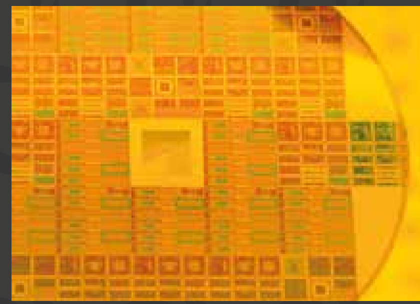
Guiding Light in Anti-Resonant Hollow-core Fibers
M. Zeisberger // M.A. Schmidt

Highly Coherent Supercontinuum Generation in Liquid-Core Fibers
M. Chemnitz // M.A. Schmidt

Excitation of Short-Range Surface-Plasmon Polaritons in a Gold Nanowire-Enhanced Step-Index Fiber
A. Tuniz // S. Weidlich // M.A. Schmidt

Multi-Octave Supercontinuum Generation in Resonance-Enhanced Anti-Resonant Hollow-Core Fibers
R. Sollapur // D. Kartashov // M. Zürch // A. Hoffmann // T. Grigorova // G. Sauer // A. Hartung // A. Schwuchow // J. Bierlich // J. Kobelke // M. Chemnitz // M.A. Schmidt // C. Spielmann

Photonic Detection



The **research focus of Photonic Detection** investigates and uses light-matter interactions to realize innovative sensor and detector concepts of highest sensitivity, precision and specificity. This includes technology research in micro- and nanotechnologies, sensor-related packaging and interconnection technologies as well as multiplex and readout circuits and the integration of the investigated molecular and solid state components into spectroscopic and imaging photonic instruments.

Blocked Energy Transfer in a Multi-excited, Multi-nuclear Transition Metal Complex
J. Kübel // M. Wächtler // B. Dietzek

Charge Separation in Functionalized CdSe@CdS Nanorods – Influence of the Size of the Metal Particle
M. Wächtler // B. Dietzek

Magnetically Induced Transparency of Superconducting Quantum Metamaterials
E. Il'ichev // U. Hübner

Single Microwave Photon Detection
G. Oelsner // E. Il'ichev // U. Hübner

Micro and Nanofabricated Targets for High-energy Physical Experiments
U. Hübner // S. Fuchs // S. Göde

Development of Superconducting Digital Circuits for New Quantum Technologies
J. Kunert // E. Il'ichev // O. Brandel // G. Oelsner // R. Stolz // H.-G. Meyer

New Magnetic Field Sensors for Deep Electromagnetic Sounding Methods
R. Stolz // M. Schiffler // M. Schmelz // A. Chwala // G. Oelsner // R. IJsselsteijn // T. Schönau // V. Zakosarenko // V. Schultze

Superconducting Imaging Magnetometry with Near Quantum-Limit Energy Resolution
M. Schmelz // V. Zakosarenko // T. Schönau // S. Anders // S. Linzen // R. Stolz // H.-G. Meyer

Optically Pumped Magnetometer in LSD Mz Mode
V. Schultze // B. Schillig // R. IJsselsteijn // R. Stolz

Enhanced Microscopic Phase-contrast Images using "smart" Algorithms Implemented on a Smartphone
B. Diederich // R. Heintzmann

Key Figures of 2017

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

6 thereof coordinated by Leibniz IPHT

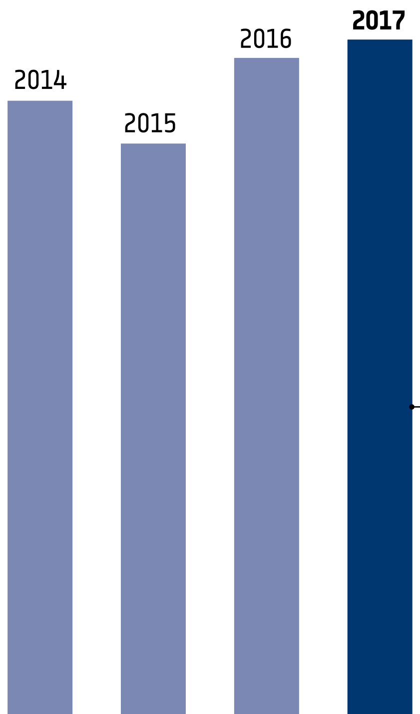
13 EU-funded projects,

4 thereof coordinated by Leibniz IPHT

6 Trademark registrations,

2 thereof union labels (EU)

195 Published articles in peer-reviewed journals



364 Employees

8 Patent applications,

4 thereof with cause for the right to priority

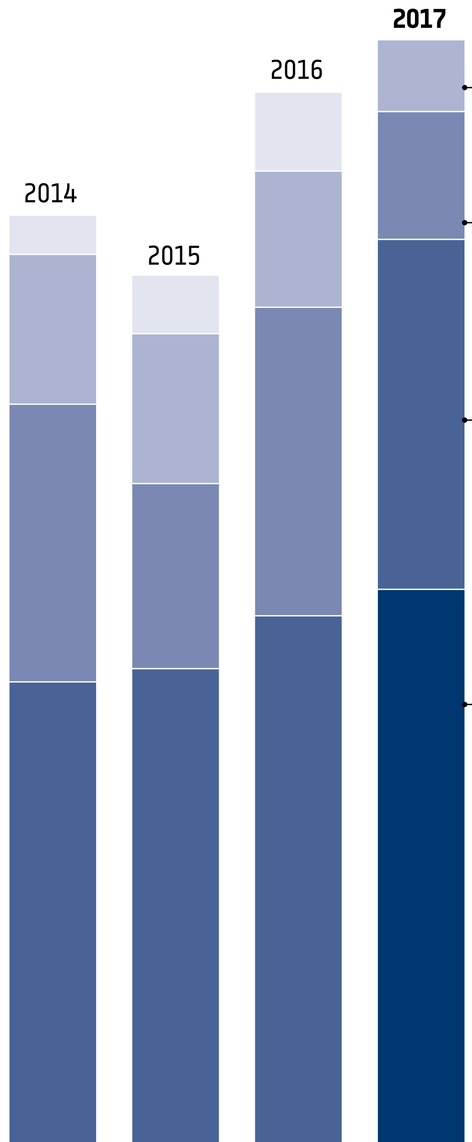
2 with patent grants

15 Doctorates,

6 thereof women

221 Talks or poster

51 Thereof invited talks / keynotes / plenary talks



1.629.871 € EU third-party funding,

818.100 € thereof from ERA-Net / ERA-NetPlus, JPI etc.

2.897.005 € Industrial projects

7.942.998 € National projects,

1.572.704 € thereof from DFG funding

12.469.874 € Institutional funding

24.054.929 € Total budget

= 51,84 % Third-party funding

Organizational Chart

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Prof. Dr. Ute Neugebauer // Deputy Scientific Director (since 01.05.17)

Prof. Dr. Benjamin Dietzek // Deputy Scientific Director (since 01.05.2017)

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Research Units

Departments

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Fiber Optics

Prof. Dr. Tomáš Čižmár

Quantum Detection

Prof. Dr. Heidemarie Schmidt

Nanobiophotonics

apl. Prof. Dr. Wolfgang Fritzsche

Nanoscopy

Prof. Dr. Volker Deckert

Functional Interfaces

Prof. Dr. Benjamin Dietzek

Bio-Spectroscopy

Prof. Dr. Christian Eggeling

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Dr. Ronny Stolz

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Clinical Spectroscopic Diagnostics

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Frank Sondermann // Leibniz Institute of Photonic Technology e. V., Jena

Prof. Dr. Herbert Stafast // Jena

Budget of the Institute 2017

	in T Euro
Institutional Funding (Freestaate of Thuringia, Federal)	11.585,1
Third-Party Funding	12.469,9
	24.055,0

Institutional Funding: Use

Staff	7.051,7
Materials	3.374,6
Investments	1.158,8
	11.585,1

Third-Party Funding

Federal Ministries of which for projects funded by Leibniz Accociation 512,0 T€	4.256,0
DFG *(Additionally IPHT-scientists at the Universtiy Jena used DFG-funds of 300,2 T€)*	1.572,7
Freestaate of Thuringia of which for restructuring in the frame of EFRE 1.034,9 T€	2.086,9
EU Of which for EU-Initiatives such as ERA-Net / ERA-NetPlus, Joint Programming Initiatives and more.: 818,1 T€	1.629,9
Assignments from Public Institutions	146,8
Other Contributions	27,4
Subcontracting in Joint Projects	115,2
R&D Contracts incl. Scientific-Technical Activities	2.635,0
	12.469,9

Institute Personnel 2017

	Full-time Equivalents				
	Institutional Funding	*Third-Party Funding*	*Professors*	*Total*	*Persons*
Scientists	36,90	61,58	7,00	105,48	115
Visiting Scientists**	-	-	-	-	16
External funded Scientists*	-	-	-	-	16
External funded Employees*	-	-	-	-	3
External funded Doctoral Students*	-	-	-	-	35
Doctoral Students	9,00	29,53	-	38,53	66
Technical Staff	35,44	39,09	-	74,53	79
Administration	12,85	4,71	-	17,56	19
Scientific Coordination	3,00	2,63	-	5,63	6
PR and Research Marketing	3,51	3,12	-	6,63	7
Executive Committee	1,00	0,00	0,50	1,50	2
Trainees	0,00	0,00	-	0,00	0
Total Personnel	**101,70**	**140,66**	**7,50**	**249,86**	**364**

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

**Scientist, who worked in the legal year 2017 longer than one month and who are financed by another institution. Key date regulation 31.12.2017 does not apply.

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from Ideas to Instruments

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