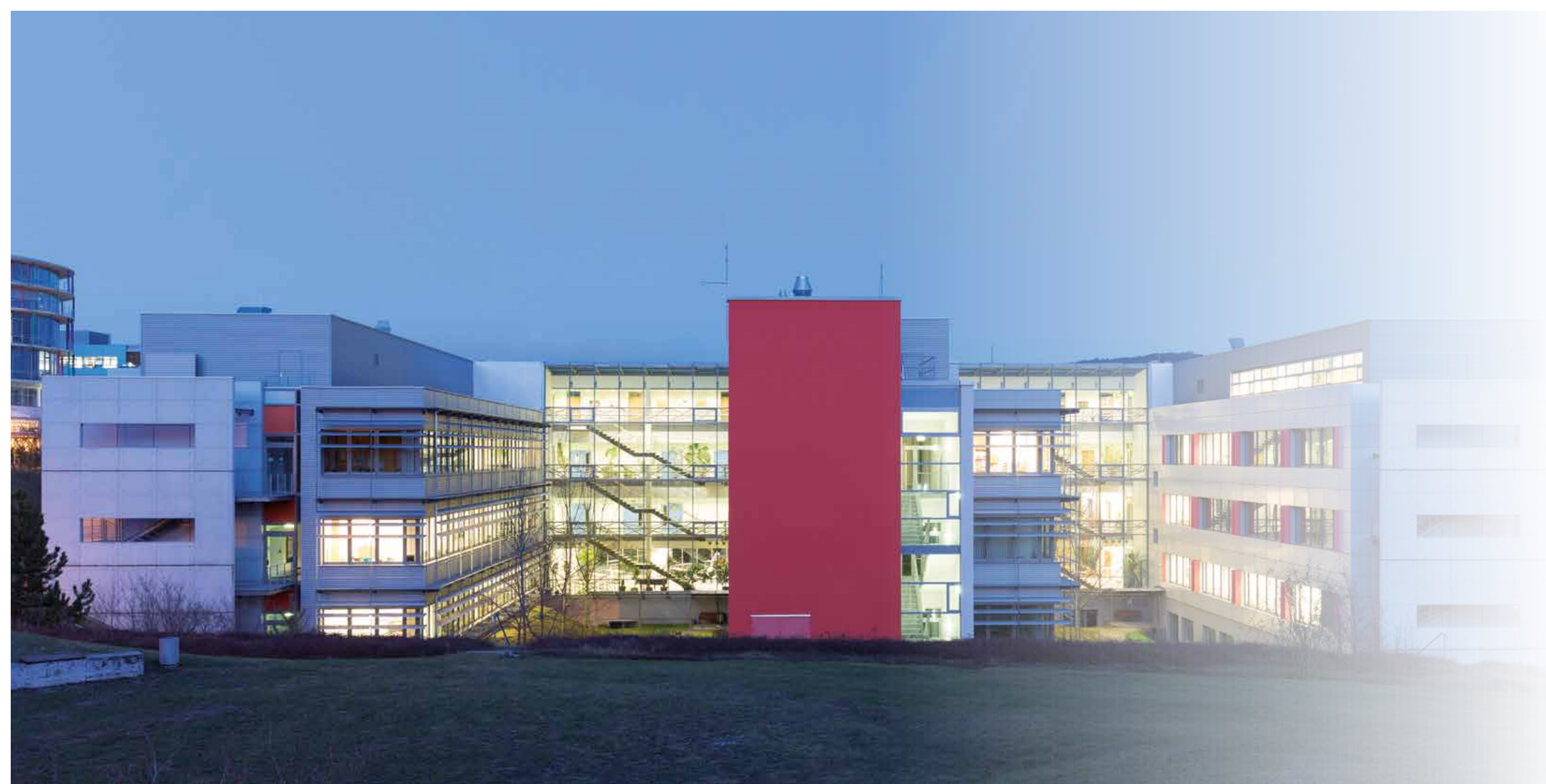




**PHOTONICS FOR LIFE**  
*from Ideas to Instruments*



# PHOTONICS FOR LIFE

*from Ideas to Instruments*



**\_PROF. DR. JÜRGEN POPP**  
Scientific Director // IPHT Jena



## FACING CHALLENGES – SHAPING THE FUTURE WITH LIGHT

*The Leibniz Institute of Photonic Technology (IPHT) performs fundamental research on photonic methods and systems of the highest sensitivity, efficiency, and resolution. This is our contribution to meeting the important challenges faced by society today and future generations equally.*

Over the course of history, challenges and technological possibilities have changed. Thanks to groundbreaking developments made by Carl Zeiss and Ernst Abbe in the field of microscopy, Robert Koch was able to detect cell-based tuberculosis pathogens for the first time in 1882. Today, at IPHT we are exploring, amongst others, optical technologies that allow medical scientists to study and understand life processes at the molecular level and to diagnose diseases earlier and better. We are also researching processes that ensure that people do not fall ill, for example, due to the consumption of contaminated food. Photonics, as one of the important key technologies of the 21st century, is the main focus of our research.

Presently, we are facing several challenges within the following fields: medicine and health care, security, energy, environmental preservation and nature conservation. The ever-changing society relies on science and research to address acute issues in these areas. How can we diagnose diseases even earlier and develop more targeted therapies? How can the threat of terrorist attacks be abated? From which sources will our energy originate in the future? How can we protect our environment from destruction? IPHT is developing innovative solutions based on optical technologies to address these issues.

The German Council of Science and Humanities concludes: "The research and infrastructural achievements of the IPHT in the field of photonic technology focused on biophotonics are more than regional significant but of nationwide of scientific, social and political interest." <sup>1</sup>

Since its founding in 1992, IPHT is performing fundamental research, converting this research into concrete applications, and aiding their transfer into industry. Since January 2014, IPHT is a member of the Leibniz Association. IPHT receives institutional funding from the federal government and the Free State of Thuringia. More than half of the annual budget at IPHT is generated by the successful acquisition of research funds, including the support of the European Union, the German Research Foundation (DFG), the Federal Government of Germany and the Free State of Thuringia.

We use light to overcome limits, develop innovative solutions, and shape the future.



Prof. Dr. Jürgen Popp  
Scientific Director // IPHT Jena

<sup>1)</sup> Report of the German Council of Science and Humanities, Drs. 3182-13, p. 17, 07/12/2013

## \_RESEARCH FOCUSES

IPHT is positioned at the interface of three research focuses.



## PHOTONICS FOR LIFE - FROM IDEAS TO INSTRUMENTS

Improving the quality of life through the use of photonic technologies is the primary goal of research at IPHT. The research focus *Biophotonics* combines all research programs at IPHT. It offers innovative photonic process solutions that are designed together with the *Fiber Optics* and *Photonic Detection* research focuses specifically for system solutions. IPHT has implemented a cross-disciplinary link between these three research focuses and generates innovative solutions and applications for pressing issues in the fields of medicine, health care, environmental preservation and nature conservation, security, and energy.

Research findings in the fields of *Micro and Nanotechnology*, *Fiber Technology*, and *Systems Technology* form the basis of these application-oriented points of focus. The existing know-how in these areas is one of our core competencies. In combination with an excellent infrastructure and technical equipment, this is a unique feature of the institute.

The process chain at IPHT includes the fundamental research of optical technologies and their implementation in custom system solutions for different areas of life: *Photonics for Life – From Ideas to Instruments*.

Through integration in efficient networks, IPHT has gained strong partners in science and industry on regional, national, and international level. These networks provide IPHT's scientists with the required freedom to break new conceptual and practical ground.

In close collaboration with the Friedrich Schiller University Jena and the University of Applied Sciences Jena, IPHT is fully invested in the advancement of young researchers. Employees at IPHT incorporate many years of research experience and their current research findings directly into their teachings. Senior research scientists work together in their roles as appointed professors at the University of Jena. Attractive opportunities for internships and dissertational work are available to students in different fields.

Research at IPHT is not science in an ivory tower. IPHT is host and co-organizer of various high-ranking seminars, workshops, and conferences at the national and international level. IPHT also keeps the general public informed of its research projects at different events and in press releases.



\_Institute building



\_TV host Ralph Caspers (WDR) at IPHT Jena

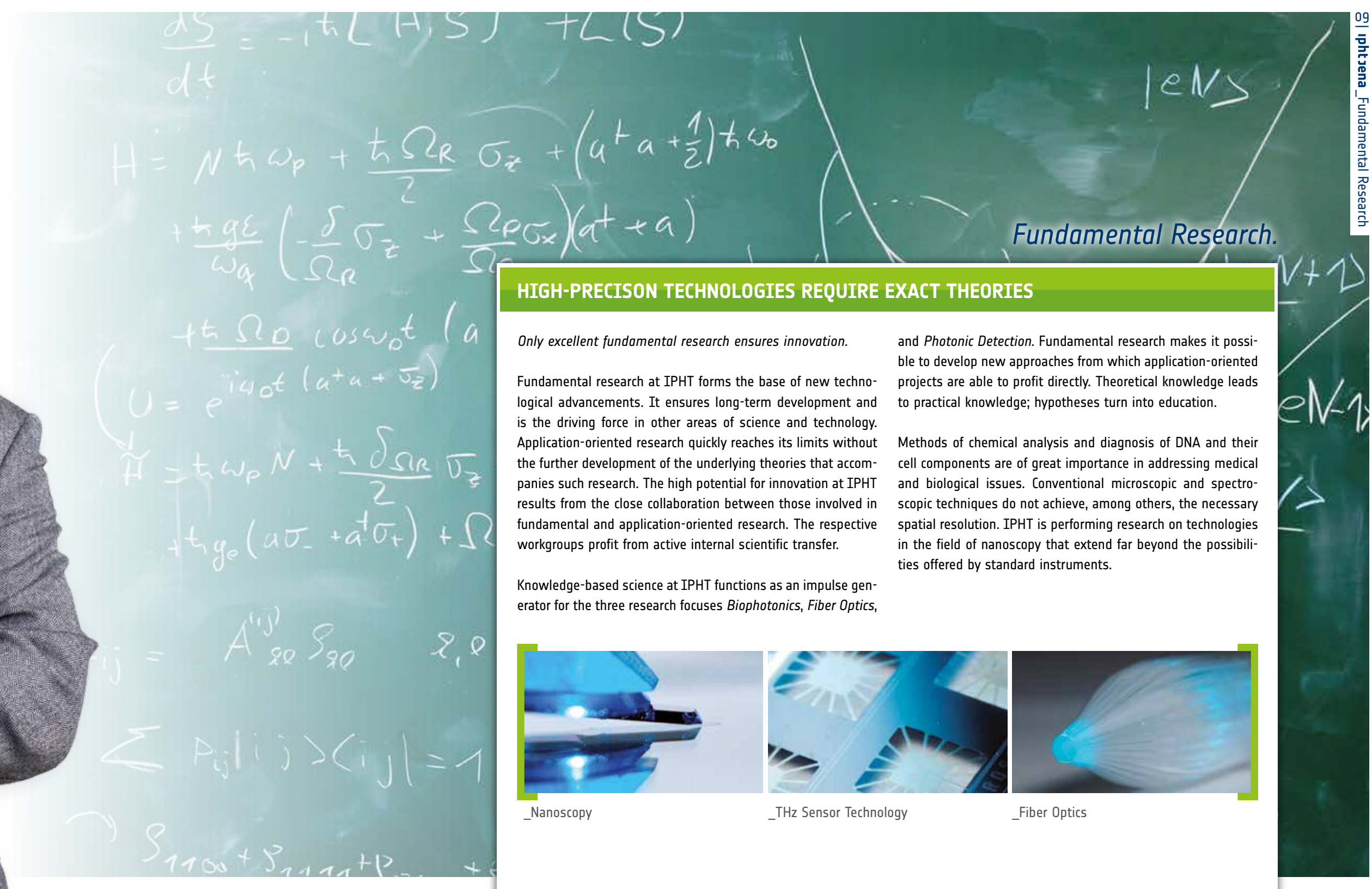


\_Interdisciplinary Summer School on Clinical Biophotonics



“For us it's not only important  
what's at the bottom line.”

**PROF. DR. EVGENI ILICHEV** // Physicist  
Workgroup Quantum Radiometry



*Fundamental Research.*

### HIGH-PRECISION TECHNOLOGIES REQUIRE EXACT THEORIES

*Only excellent fundamental research ensures innovation.*

Fundamental research at IPHT forms the base of new technological advancements. It ensures long-term development and is the driving force in other areas of science and technology. Application-oriented research quickly reaches its limits without the further development of the underlying theories that accompanies such research. The high potential for innovation at IPHT results from the close collaboration between those involved in fundamental and application-oriented research. The respective workgroups profit from active internal scientific transfer.

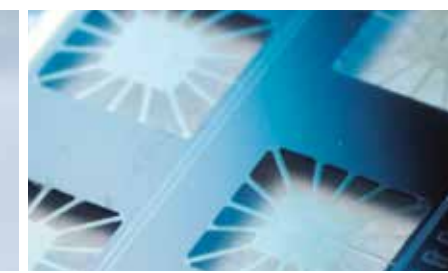
Knowledge-based science at IPHT functions as an impulse generator for the three research focuses *Biophotonics*, *Fiber Optics*,

and *Photonic Detection*. Fundamental research makes it possible to develop new approaches from which application-oriented projects are able to profit directly. Theoretical knowledge leads to practical knowledge; hypotheses turn into education.

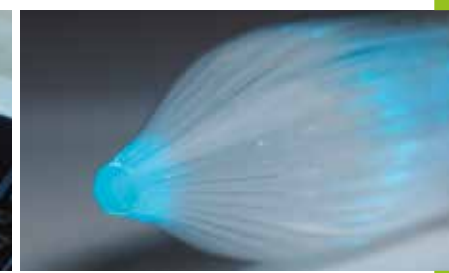
Methods of chemical analysis and diagnosis of DNA and their cell components are of great importance in addressing medical and biological issues. Conventional microscopic and spectroscopic techniques do not achieve, among others, the necessary spatial resolution. IPHT is performing research on technologies in the field of nanoscopy that extend far beyond the possibilities offered by standard instruments.



\_Nanoscopy



\_THz Sensor Technology



\_Fiber Optics



“I set traps for infectious pathogens.”

**SUSANNE PAHLOW** // Graduate Chemist  
Jena Biochip Initiative



Medicine.

## GENTLE, FAST, AND ACCURATE

*Optical technologies are used to meet medical needs.*

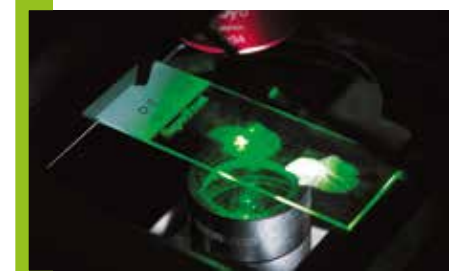
The average age of population continues to increase: the aging of society and the decreasing birth rate will have an increasing dynamic effect on society in the coming decades. Likewise, the need for accompanying medical care will increase. It is crucial today to develop innovative and gentle methods of diagnosing diseases early and to more precisely monitor the effect of different therapies and better adapt therapies to individual needs. In the future, technological solutions and commercial methods must be established to cover currently unmet medical needs by combining the triad of technology, application, and production.

At IPHT research is being performed on the use of light as a tool in the early detection and treatment of diseases. The possible fields of application in medicine are multifaceted. IPHT likewise offers a wide variety of solution approaches. State-of-the-art spectroscopic and microscopic imaging methods make it possible to gain unique insights into tissue structures, cells, and molecules. Processes that were previously hidden are made visible in this way. Germs and bacteria can be quickly

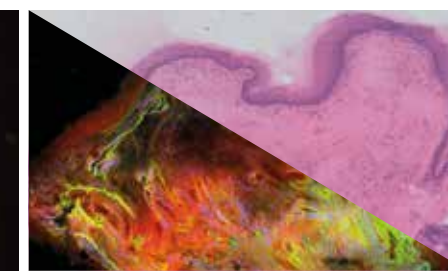
and positively identified using rapid point-of-care (POC) tests, and pharmaceuticals can be checked. Current research projects focus on spectroscopic analysis to determine infectious pathogens and tumor cells circulating in blood samples. The use of highly-sensitive fiber sensors, for example in endoscopes, leads to new methods of diagnosis.

IPHT coordinates the Leibniz research alliance “Medical Technology: Diagnosis, Monitoring, and Therapy”. As part of the Jena Research Campus “InfectoGnostics”, IPHT is researching and developing new technologies for the diagnosis of infections. The Campus – which is a regional public-private partnership supported by the Federal Research Ministry and the Free State of Thuringia – is located at the Center of Applied Research at the University of Jena.

Optical technologies contribute to the better understanding of diseases, their early detection, and their targeted and gentle treatment or prevention.



\_Examination of a tissue sample



\_multimodal imaging and  
H&E staining compared



\_Compact CARS microscope



“We research effective tools for food control. Thus, food is not only tasty but healthy.”

**\_MARTHA SCHWARZ //** Graduate Engineer  
Jena Biochip Initiative



## Health Care.

### DETECTING MICROORGANISMS AND FOOD TOXINS

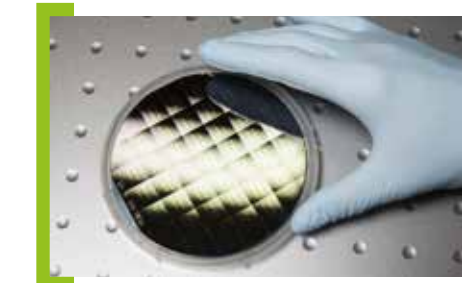
*Photonic technologies can be used to detect even the smallest concentrations of hazardous substances.*

Living healthy means, among others, eating healthy. Organic products are by now offered in most supermarkets and are in increasing demand. However, frequently food scandals cause alarm among consumers and create special challenges for inspection authorities. Salmonella in meats, legionella in drinking water, or prohibited additives in food: often, the detection of hazardous substances and microorganisms is difficult, time-consuming, and costly. Photonic technologies offer alternatives to conventional analysis methods.

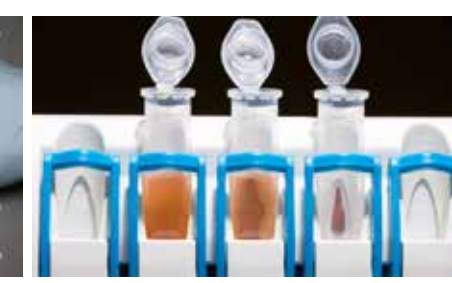
IPHT is researching convenient point-of-care (POC) and on-site diagnostic test systems that detect germs and bacteria in food using optically readable biochips, test kits, or spectroscopic measurements without time-consuming and costly sample preparation.

Together with the Friedrich Schiller University of Jena and as part of the Jena Biochip Initiative supported by the Federal Ministry of Education and Research, IPHT has implemented a method of detecting microorganisms. This system recognizes up to forty pathogens simultaneously by their DNA in a matter of minutes. Through long-standing and consistent interdisciplinary research, a robust, portable, and inexpensive system for the chip-based analysis of pathogenic organisms was developed. This makes it easy to detect microorganisms directly on site quickly and conveniently.

To detect pathogenic additives in food, such as for example different azo dyes and melamine, IPHT is developing special solutions based on surface-enhanced resonance Raman spectroscopy (SERRS). This technology makes it possible to detect even the smallest concentrations of illegal admixtures. With this tool, food manufacturers can better monitor the ingredients used and guarantee better quality for consumers.



\_Wafer with spectroscopically readable biochips



\_Sample preparation: Deposition of magnetic particles



\_Health monitoring of the future



“Passengers safety is a top priority.  
We are developing the technology for it.”

**TORSTEN MAY** // Graduate Physicist  
Head of Workgroup Radiometry



## A DISCREET LOOK UNDERNEATH ONE'S CLOTHING

*The terahertz security camera detects weapons, explosives, and drugs – reliably, safely, and discreetly.*

The threat to society due to terror attacks has become a central issue in politics in the recent years. Increased security controls at airports have become a part of daily life there. As evidenced by the public discussions about the so-called “nude scanners,” both the restrictions of ethical principles and the unknown health risks are too high a price to pay for many people in favor of more security.

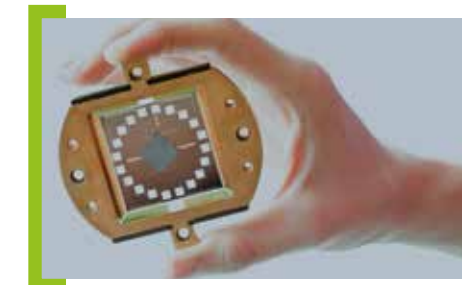
One alternative to established systems is the passive THz security camera developed at IPHT. It detects weapons and explosives reliably, it is ethically uncritical and harmless to health.

An active “illumination” of test subjects is not required because the camera simply measures the body’s own THz radiation. Potentially dangerous objects that are worn on the body, such

as weapons or explosive devices, cause a suspicious shadow on the captured radiation image. Unlike the scanning devices currently in use, the THz camera does not reveal anatomical details; thus, the images do not have to be artificially distorted. In addition, the lack of active radiation means avoidance of any potential danger to the health of the subject being scanned.

The heart of the camera is an ultrasensitive sensor designed by scientists at IPHT and manufactured in IPHT's in-house clean-room, as well as extremely low-noise and high-performance readout electronics.

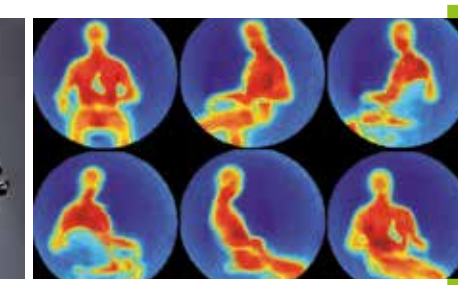
The THz security camera is a prime example of consistent collaboration between the research focuses at IPHT. Long-term experience and knowledge gained in the areas of micro/nanotechnology, systems technology, and photonic detection have made the development of this system possible.



\_THz sensor array



\_THz security camera



\_Images taken with the THz security camera



“In order for the energy revolution to succeed, I go to the limits.”

**DR. MARIA WÄCHTLER** // Chemist  
Workgroup Ultrafast Spectroscopy



## RESEARCHING INTERFACES

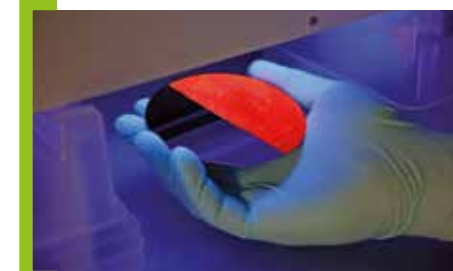
*An important contribution to the energy revolution: converting light into storable energy.*

Fossil fuels are finite. Still, approximately 86 percent of usable energy is still obtained from oil, gas, or coal. Considering the increase in the price of raw materials and the knowledge of limitation of such forms of energy, this number is still too high. To avert the threatening energy crisis, inexpensive and renewable sources of energy have to be developed and used. In addition to solar and wind power, water could be an important energy source.

IPHT is working on such solutions. One approach includes photocatalytic water splitting. This process utilizes light to split water into its hydrogen and oxygen elements. The inexpensive production of hydrogen could replace oil as the primary source of energy in the future. This is based on the research of functional interfaces between solid state bodies and molecules. This research has been a significant part of IPHT for many years.

IPHT has made the research of improving the efficiency of thin-film solar cells one of its tasks. For this purpose, solar cells made of crystalline silicon are manufactured on inexpensive glass substrates – with significantly smaller amounts of valuable silicon than conventional cells require. In another approach, research scientists use silicon rods as part of the thin-film solar cells. A carpet made of such “nanorods” is the perfect trap to catching incoming sunlight and converting this light into electrical energy.

The production of regenerative energy from wind and water power stations also contributes to the protection of natural resources. These technologies are subjected to high amounts of stress and thus require heavy maintenance. Fiber-optical sensors from IPHT are integrated into turbines and rotor blades to measure the forces affecting the material. The analyzed data helps optimize the plants and increase their efficiency.



\_Coated wafer cell



\_Analysis of dynamics in microstructured samples

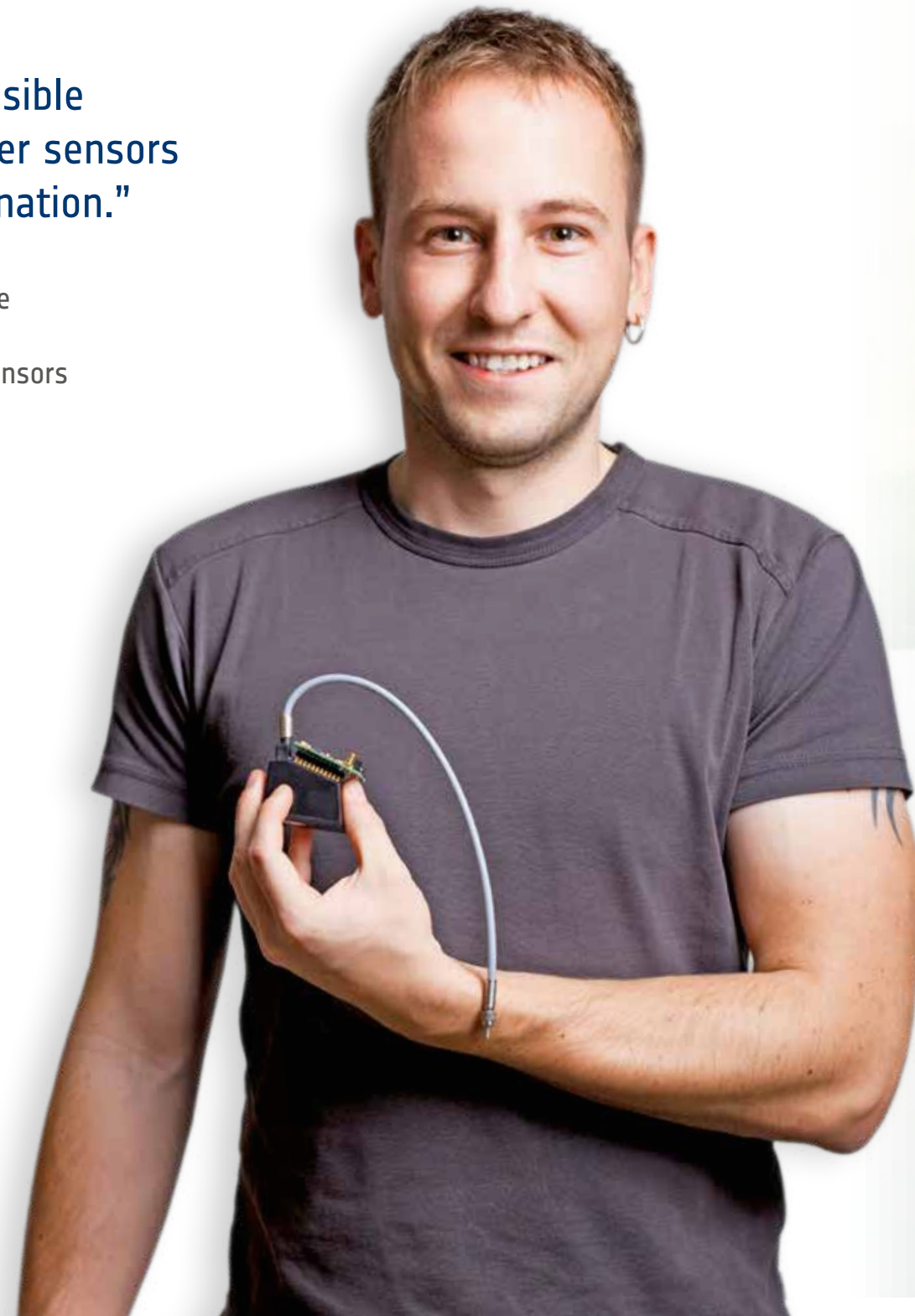


\_Fiber sensors help optimize wind power stations



“Pollution is not always visible to the naked eye. Our fiber sensors do not miss any contamination.”

**LARS KRÖCKEL** // Master of Science  
Research Group Fiber Sensors &  
Junior Group Fiber-Spectroscopic Sensors



## Environment and Nature Protection.

### SENSOR TECHNOLOGY FOR THE ANALYSIS OF SOIL, AIR, AND WATER SAMPLES

*Optical sensors detect environmental pollutants even under adverse conditions.*

Environmental pollution is an issue that can only be addressed cross generationally. The pollution of natural resources is an increasing threat to human, animal, and plant life. IPHT is researching state-of-the-art sensor technology that can be used to monitor soil, air, and water samples. Optical technology aids in the detection of environmental pollutants and maintains quality control in the recycling of wastewater.

Whether in a dam, a sewage plant, or on the open sea: modern and efficient measurement methods and sensor technologies used in monitoring the level of contaminants and nutrients in the water are gaining importance. Oceans and inland bodies of water are the largest, most significant, and most sensitive ecosystems on earth. In addition, the right to access clean water is a basic human right. IPHT is researching inexpensive

miniaturized fiber sensors for use in optical analysis methods. With these sensors and methods, it is possible to test bodies of water even under adverse conditions directly on site and in real time. Such solutions renders sample taking and transportation. Hereby the possibility of producing inaccurate measurement results were prevented. Furthermore the costs and the time exposure gets reduced.

A novel approach to the testing of the chemical and biological composition of soil samples includes the combination of fiber-optical components and spectroscopic imaging technologies. Micro-structured fiber probes detect chemicals and gases in the ground. An analytical evaluation is carried out with the help of a miniature spectrometer that identifies molecular components and makes it possible to draw conclusions about the quality of the soil and the substances contained therein. A similar analytical method is suited for monitoring fine dust particles in the air.



\_Probe for measuring water contamination



\_Wastewater treatment



\_Spectroscopic analysis of soil samples



“We are leading the light.”

**\_DR. SONJA UNGER //** Chemist  
Workgroup Fiber Technology



*Technologies.*

## BASIS FOR PHOTONIC SOLUTIONS

*Fiber Technology:* Optical fibers are the basis for efficient photonic systems in signal transmission and information technology, high-power fiber light sources, and fiber optical sensors and probes. The aim of technological research at IPHT is the development of novel fiber structures with active cores for fiber light sources, fibers with nonlinear properties, and photosensitive fiber structures in the nanometer range. With innovative material technologies and precise micro and nanostructures, fibers provide new opportunities for the targeted management of light propagation properties.

*Micro and Nanotechnology:* With state-of-the-art lithographic technology and methods of self-organization, complex functional micro and nanostructures can be developed and manufactured

for detectors, plasmonic structures, and photonic systems. The combination of thin-film technology, nanolithography, and microsystems technology is a unique feature of IPHT.

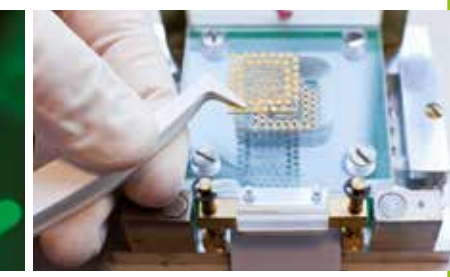
*Systems Technology:* Due to the variety of utilizable spectral ranges, the application potential offered by photonic systems is vast. The technological research performed at IPHT is concentrated on the development and system integration of sensors and detectors that directly detect photons in a wide frequency range or use them as a tool in the measurement of derived physical values. The combination of state-of-the-art micro and nanotechnology and comprehensive competency in system integration is another feature of IPHT.



\_Micro and Nanotechnology



\_Fiber Technology



\_System Technology



“From my project partners  
I expect excellence,  
reliability and innovation.”

**\_PROF. DR. MICHAEL BAUER // Physician**  
Spokesman of the Center for Sepsis Control and Care, Jena



*Research Partners.*

## REGIONALLY ROOTED – INTERNATIONALLY SOUGHT AFTER

*Achieve more through a strong network: IPHT is a competent research partner.*

Cooperation on the national and international level plays a major role in IPHT's research. In the region, IPHT collaborates closely with the University of Jena and the University of Applied Sciences Jena. IPHT takes on a joint role between photonics and the life sciences with non-academic institutes in Jena. IPHT is also active in regional networks such as "OptoNet" and "medways" and a sought-after partner in the industry.

IPHT currently participates as a research partner in more than 120 national joint research projects. In the biophotonics research focus supported by the Federal Ministry of Education

and Research, IPHT coordinates a program for the development of optical solutions to biological and medical problems.

IPHT has taken on a coordinator role in several projects, including the Leibniz research alliance for medical technology and the "InfectoGnostics Research Campus Jena," as well as the European Network of Excellence "Photonics4Life".

IPHT currently maintains collaborative efforts with partners from forty-five different countries. IPHT is a founding member of the international network Biophotonics4Life and is active in distinguished scientific organizations, such as for example the International Society for Optics and Photonics.



\_EU Commissioner Johannes Hahn visits IPHT



\_Booth at LASER – World of Photonics, Munich



\_Foundation of the „InfectoGnostics - Research Campus Jena“



**\_DR. UWE HÜBNER //** Physicist  
Head of Workgroup Micro and Nanotechnology

**\_DR. SOLVEIG ANDERS //** Physicist  
Workgroup Micro and Nanotechnology

## SPACE FOR EXCELLENT SCIENCE

*The interdisciplinary and comprehensive scientific approach of the IPHT requires modern infrastructure and technological equipment.*

With more than 7,250 square meters of floor space, the building complex at IPHT offers optimal working conditions for approximately 330 employees and visiting scientists. In addition to a cleanroom and a fiber drawing tower, IPHT also houses several CARS and femtosecond laboratories, chemical vapor deposition (CVD) facilities, and other specialized laboratories.

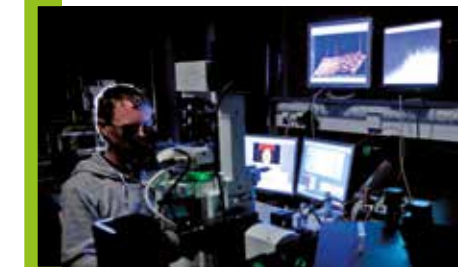
With approximately 1,000 square meters of floor space, the cleanroom is the heart of the institute. The latest processes and techniques in microfabrication are used and further developed here. Among other things, scientists are researching technologies to produce highly sensitive sensors for electromagnetic radiation and magnetic fields. These sensors are one of the integral components in the terahertz security camera. Microfluidic components and bioanalytical chips can be developed and manufactured directly at IPHT. The process chain continues on to the production of prototypes and small series. Quality

management of vital fundamental technologies has been ISO certified since 2002.

The fiber drawing towers used in the production of glass fibers with highly-complex cores are among the most advanced research facilities of fiber optics in Europe. Fibers can be drawn at speeds of up to 100 meters per minute in a broad range of parameters. Starting from different fiber preforms, complex fiber structures at sizes in the sub-micrometer range can be realized. Customized online measurement and control techniques ensure a high fiber quality and enable both the multi-coating and printed coating of optical fibers. This makes it possible to achieve a high level of technology and strengthens IPHT's position as an attractive research partner.

The German Council of Science and Humanities recognizes the technological facilities as an "outstanding, German-wide quite unique research infrastructure with a fiber drawing tower and excellent cleanroom facility and laboratory equipment, which is managed by highly qualified technical staff."<sup>2</sup>

<sup>2</sup>) Statement by the German Scientific Council and Humanities, Drs 3182-13, p. 10, 07/12/2013



\_TERS laboratory



\_Fiber drawing facility



\_Laser diagnostics laboratory



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IPHT Jena  
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Printing  
Grafisches Zentrum Cuno GmbH und Co KG, Calbe (Saale)

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